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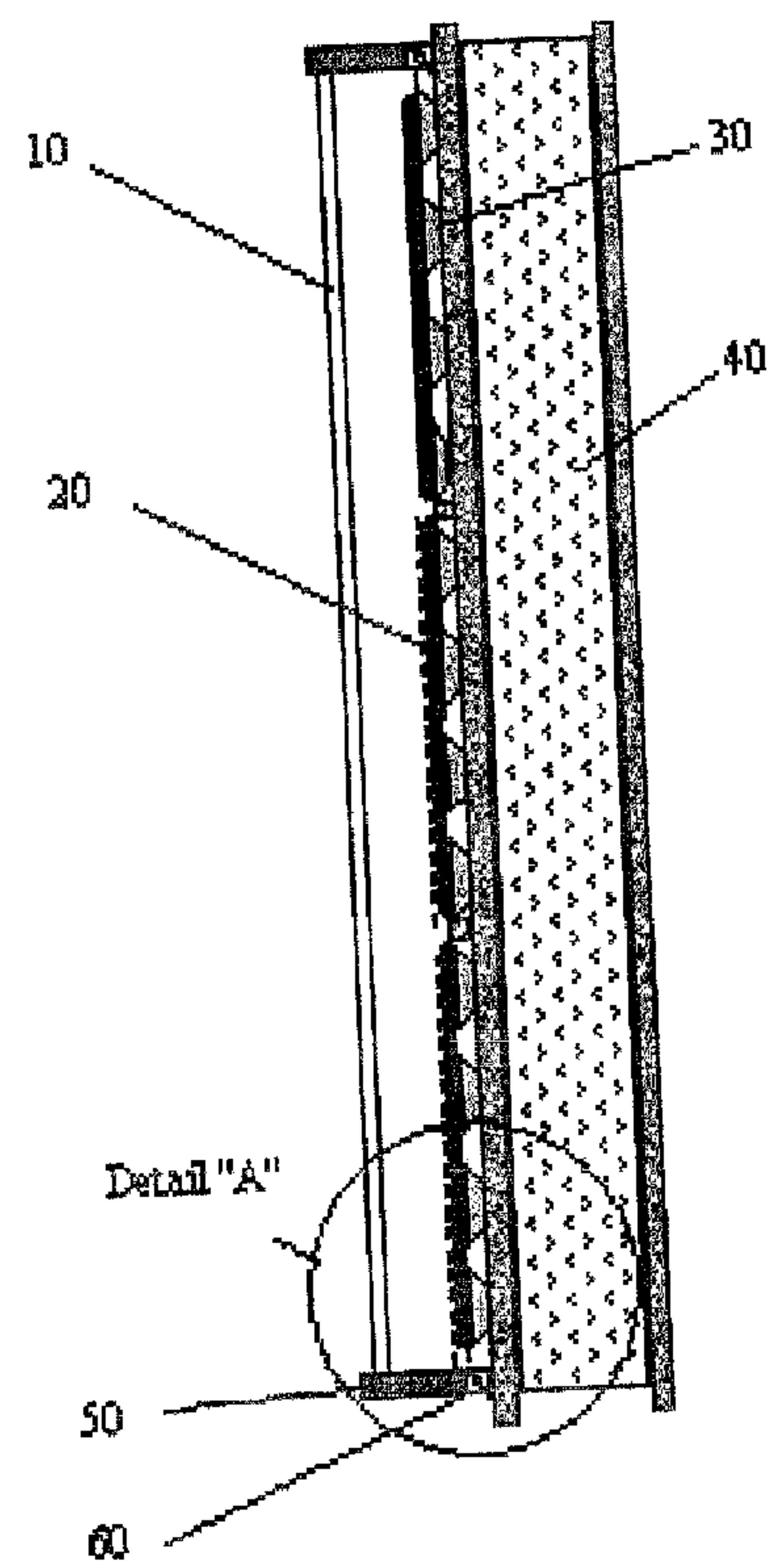
(54) Titre : CAPTEUR SOLAIRE MURAL INTEGRE AVEC CAPACITE DE STOCKAGE THERMIQUE
(54) Title: WALL INTEGRATED THERMAL SOLAR COLLECTOR WITH HEAT STORAGE CAPACITY



(57) Abrégé/Abstract:
A wall integrated thermal solar collector with heat storage capacity includes a transparent layer and a solar radiation absorption layer, that is separated by an air gap from the transparent layer. A heat storage layer of phase changing material is positioned in close contact with the solar radiation absorption layer to facilitate heat transfer. A structural panel of thermally insulating material is positioned adjacent to the heat storage layer.

ABSTRACT OF THE DISCLOSURE

A wall integrated thermal solar collector with heat storage capacity includes a transparent layer and a solar radiation absorption layer, that is separated by an air gap from the transparent layer. A heat storage layer of phase changing material is positioned in close contact with the solar radiation absorption layer to facilitate heat transfer. A structural panel of thermally insulating material is positioned adjacent to the heat storage layer.

TITLE OF THE INVENTION:

Wall Integrated Thermal Solar Collector with Heat Storage Capacity

FIELD OF THE INVENTION

The present invention relates to a thermal solar collector that is combined with building wall and, more particularly, such a building integrated thermal solar collector that is capable of heat storage.

BACKGROUND OF THE INVENTION

In cold climate regions like Canada, a predominant amount of energy expended in residential housing (`65%) is spend for space heating. Effort have been made to get portion of this space heating energy from solar radiation. Various solutions have already been proposed in the prior art for applying solar energy for house heating. Typically heat can be generated from solar radiation in different types of thermal solar collectors and systems like; vacuum tube collectors, flat plate collectors, Trombe wall or solar wall. The most efficient, in terms of heat generation, are vacuum tube collectors and flat plate collectors. These collectors are usually used for hot water generation, as they are too expensive to be used for space heating. It is known that for utilization of the solar energy for house space heating basically two types of thermal solar systems are applied - active and passive.

Active systems

A typical active system uses a glazed flat thermal collector. During a heating period (day), solar radiation is converted into heat and the generated heat is transferred with circulated liquid to a central heat storage tank (e.g. water tank). During a demand time (night), the accumulated heat is redistributed by a heating system which circulates heated fluids. Such solutions require system that consist of the solar collectors, a network of pipes, a heat storage tank, a fluid circulating pump, control valves and controllers, inside of a building. The systems are complex, and involve costly installation of the network of pipes with fluid circulating pump. The systems are prone to freezing when exposed freezing temperatures, unless expensive liquids are applied. However, such a system can be combined with well insulated walls. In some active systems, heat can be transferred with forced circulating air systems as described in US Patent 4,197,993, but because low heat capacity of air such systems are limited mostly for ventilating purposes.

The active system has a certain number of drawbacks. They are:
- relatively complex and costly system of pipes, heat storage, heat control and heat redistribution systems
- need for pumps and energy required for pumping
- operational problems with leakage and/or plugging (maintenance).

Passive systems

Passive systems are simpler and cheaper and are, therefore, becoming more and more popular. However, they have lower efficiency. In a typical passive system, solar energy is collected by a thermal energy collector combined with a wall and transferred by conduction to the house wall for storage. In such systems, a solar radiation absorption layer often is combined with a glazed enclosure and with a heat trap to reduce heat losses and improve efficiency. The simplest, and the most known solution of this kind of system is the Trombe wall. The Trombe wall solution, consists of a transparent cover, an absorption layer deposited on a heat transmitting and accumulating material like concrete, bricks or other masonry type of walls. Heat generated during exposure to solar radiation is stored in the wall and transferred through the wall to an interior of the building. A typical Trombe wall consists of a 200 to 400 mm thick masonry wall (or concrete) coated with a dark, solar radiation absorbing material and covered with a single or double layer of glass. The space between glass enclosure and masonry (collector) is from 20 to 50 mm. The solar radiation passes through the transparent glass and is absorbed by the dark surface of the absorber and is transferred slowly by conduction inward through the masonry. It take about 8 to 10 hours to transfer heat (reach the interior of the building) for a 200 mm thick Trombe wall, thus Trombe wall absorbs and stores heat for evening/night use.

In passive systems, collected heat is transferred to the wall with material that is characterized by large thermal mass (masonry, bricks, concrete) and is heat conductive. The masonry type of wall required for heat storage (as the thermal mass) typically is not a good thermal insulator. During prolonged cold nights, or cold, cloudy days, such walls experience significant heat losses. As a result, the application of such systems in cold regions (e.g. Canada) is not practical.

The prior art features several attempts to improve the ability to collect heat, reduce energy losses and increase performance. One such solution is described in US Patent 4,323,053, where a solar collector is equipped with an integral heat trap in a transparent wall. The solar radiation absorber is arranged to collect incident solar radiation passing through the front enclosure.

In another, similar solution, developed by Energiesysteme Aschauer Ltd. in Linz, Austria, a heat trap in a form of cellulose comb is positioned between the glazing and a heat-storing wall. This solution combines the thermal insulation ability with direct heat storage in the wall. However, this kind of wall still does not have sufficient thermal insulation characteristic when considering its application in cold climate regions. Thick cellulose layer blocks allow efficient heat transfer into a heat accumulating wall that on its own has limited thermal insulating value.

US Patent 4,237,865 describes a solar heating siding panel which includes double panels of clear glass secured in a housing horizontally spaced outwardly of the building. Inwardly of the housing is located a heat collector. The collector, in form of an air gap, is closed on the inside by a heat exchanger of substantially thin foil material and spaced inwardly of the glass panels. A system of temperature controlled hinged dampers at the bottom and at the top of collector passages let a flow of air from a room to be heated. Such system requires complex thermally controlled dampers and do not have any heat storage.

WO patent 99/10934 has a combined photovoltaic/thermal panel that is provided with one or more flow channels, for the purpose of delivering thermal energy during operation to a fluid flowing therein. The PV and thermal collectors have been joined to form a single assembly with the interposition of a metal-containing plastic material having bonding properties. This solution requires a structure, which is relatively complex and costly.

US patent 4,587,376 describes another combined photovoltaic/thermal solar collector in which a light - permeable superstrate (PV) and a metallic substrate (thermal) are used.

A Canadian company, Conserval Engineering Inc., has developed a "SolarWall" (Trademark) technology that is building integrated collector in form of façade or roof element. The solar energy is collected using perforated absorber plates, that are mounted in such way that cold ambient air is allowed to pass behind the perforated panels in a uniform way. Heat generated from the solar energy is transferred to the air, which is used for heating ventilation air.

An unglazed porous solar collector is sold under the Trade Mark brand name of "SolarWall"". It absorbs the sun's energy and uses it to heat the air that is pulled through the collector surface and into the air distribution path connected to the mechanical system of the building. With SolarWall, air passes through channels between a wall of a building and a solar radiation absorbing layer. However, because lack of glazing and because a very low thermal capacity of air and low thermal conductivity, such solutions are not very efficient and usually are applied for ventilating air heating. Other similar solutions, most suitable for façade type of applications are air-cooled PV panels for electrical and thermal energy generation.

In general, in prior art solutions either complex fluid circulating systems are applied in combination with well insulating walls or simpler passive solutions with direct wall (masonry) heat storage that have limited insulating value and are loosing a lot of heat when cold, thus limiting their scope of application.

SUMMARY OF THE INVENTION

What is required is a wall integrated thermal solar collector with heat storage capability.

According to the present invention there is provided a wall integrated thermal solar collector with heat storage capacity which includes a transparent layer and a solar radiation absorption layer that is separated by an air gap from the transparent layer. A heat storage layer of phase changing material is positioned in close contact with the solar radiation absorption layer to facilitate heat transfer. A structural panel of thermally insulating material is positioned adjacent to the heat storage layer.

The basic structure, as described above, is capable of being integrated into a structural panels which is thermally insulated for extreme winter conditions encountered in cold weather climates. As will hereafter be further described, by incorporating some additional features, even more beneficial results may be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings, the drawings are for the purpose of illustration only and are not intended to in any way limit the scope of the invention to the particular embodiment or embodiments shown, wherein:

FIGURE 1 is a side elevation view, in section, of a first embodiment of wall integrated thermal solar collector constructed in accordance with the teachings of the present invention.

FIGURE 2 is a front elevation view of the wall integrated thermal solar collector illustrated in **FIGURE 1.**

FIGURE 3 is a detailed side elevation view, in section, of the wall integrated thermal solar collector illustrated in **FIGURE 1.**

FIGURE 4 is a side elevation view, in section, of a second embodiment of wall integrated thermal solar collector constructed in accordance with the teachings of the present invention, with pneumatically controlled absorber membrane in an active winter mode.

FIGURE 5 is a side elevation view, in section, of the wall integrated thermal solar collector illustrated in **FIGURE 4**, with pneumatically controlled absorber membrane in a passive winter mode.

FIGURE 6 is a side elevation view, in section, of the wall integrated thermal solar collector illustrated in **FIGURE 4**, with pneumatically controlled absorber membrane in an active summer mode.

FIGURE 7 is a side elevation view, in section, of the wall integrated thermal solar collector illustrated in **FIGURE 4**, with pneumatically controlled absorber membrane in a passive summer mode.

FIGURE 8 is a side elevation view, in section, of a third embodiment of wall integrated thermal solar collector constructed in accordance with the teachings of the present invention.

FIGURE 9 is a front elevation view of the wall integrated thermal solar collector illustrated in **FIGURE 8.**

FIGURE 10 labelled as **PRIOR ART**, is a side elevation view, in section, of a house having a Trombe wall system.

FIGURE 11 labelled as **PRIOR ART**, is a side elevation view, in section, of a house having a wall integrated thermal solar collector utilizing circulating fluids.

FIGURE 12 is a side elevation view, in section, of a housing having a wall integrated thermal solar collector in accordance with the teachings of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment, a wall integrated thermal solar collector with heat storage capacity will now be described with reference to **FIGURES 1** through **12**.

Referring to FIG.1 through 3 there is shown a schematic, sectional view of a preferred embodiment of the solar thermal wall panel with heat storage that is the simplest solution according to the invention. A panel that is arranged for collecting of solar radiation and for generated heat storage includes several thermal layers and consists of; transparent outer enclosure 10 that is designed to be traversed by the solar radiation, solar absorber plate 20 for collecting solar energy that is separated from transparent outer enclosure by air gap, heat storage layer 30 with capsules of phase changing material and wall 40 that thermally insulates the house and supports house structure.

The outer enclosure is transparent for sun-light and is made preferably as a double glass or plastic cover to reduce heat losses. The transparent cover is made of material with low solar absorption coefficient and reduced reflection. It can be manufactured like a double, argon filled, low iron glass window.

The next layer, which is absorber plate 20, is a thin metal membrane that is covered with a coating 21 well absorbing solar radiation. The backside of membrane is assumed to be covered with layer 22 that is highly reflective for infrared radiation. The absorber plate is arranged in a distance of about 50 mm from the transparent cover. The backside of the absorber plate is in close contact, with sheet of capsules

30 containing phase changing material to facilitate heat transfer by conduction from heat generating absorber plate to the heat storing material in capsules. The sheet of capsules 30 that represents large thermal mass is mounted on the wall of house or building 40. During sun exposure the phase changing material melts under influence of heat. During nighttime the phase change material crystallizes and releases heat, and continues keeping temperature in the buffer zone steady until whole accumulated heat will be used, thus reducing significantly house heat losses. As long as the temperatures on both sides of wall structural insulating panel are similar there is no flow of heat through the wall.

Heat storage material with buffer zone is sandwiched between the thermal absorber 20 on one side and wall structural insulating panel 40 on the other. The temperature buffer zone 31 is formed by the multi channeled space of air between capsules and house wall. The temperature in the buffer zone is close to the temperature of the phase change. The building wall 40, which in this case is not used for heat storage (as it was in a Trombe wall case), is constructed from materials that are highly insulating (e.g. from foams).

There are many different phase changing materials available on the market, having phase change temperature in applicable range of temperatures, but the most preferable will be material changing phase in temperature of between 0 to 50°C and preferably in range of 15 to 30°C. Good example of such material is calcium chloride hexahydrate, with phase change temperature about 29°C (Cp about 200 kJ /kg K (phase change) as compared with brick 0.84 kJ/kg K)

The wall system equipped with buffer zone keeps the internal temperature of building very stable. Solution as described has advantage of more efficient solar energy collection and utilization during winter and prevention of house overheating in summer.

The heat transfer through the wall panel (forming house or building wall), depends mainly of temperature difference between both sides of the wall panel. By implementation of the heat storage/buffer zone, the temperature on the outer side of house wall is only slightly different as compared with temperature inside of the house (~22°C) and, as long as there is enough supply of stored heat, the heat transfer through the wall of house is completely blocked.
As result of thermal barrier existence that is supported by heat from heat storage system, the heat losses are blocked for many hours after the sun set.
Houses equipped with the solar wall modules greatly reduce the need from conventional heating system.

FIG. 4 and 5 show a sectional view of thermal panel that according to the invention provides a heat trap for stored heat. The panel is equipped with a pneumatically controlled absorber membrane 20 that is sealed along the perimeter with expanding seal 80. During sun operation the absorber membrane 20, as a result of slight under pressure in pneumatic line 90, is in close contact with heat storage capsules (FIG 4) facilitating heat transfer from solar radiation absorption plate/membrane to the matrix of capsules. In periods when radiation intensity is not sufficient, or during the night, the pressure in pneumatic line 90 is increased and absorber membrane is taken away from heat storage capsules (see FIG. 5), forming additional air gap (heat trap) 91 between absorber and heat storage capsules. In a result heat stored in phase changing material is lost longer and steady buffer temperature last much longer.

FIG. 6 and 7 show application of the thermal panel according to the invention, for preventing the building form overheating in summer. Referring to Fig. 6, during day time, to reduce the heat flow into building, the absorber membrane 20 is separated from layer of heat storing capsules 30 by air gap 91. The still transferred (but reduced) stream of heat that penetrates the gap is stored in heat storage system (heat sink) preventing the house wall from getting hot. Referring to Fig. 7, in night time ventilating slots 60 are open and convection induced airflow removes the stored heat to atmosphere. The effect of overheating might be only noticed when the storage capacity of the heat storage system will be exhausted.

FIG. 8 and 9 presents an option when photovoltaic cells 20A are used instead of the absorber plate 20. The advantage of such solution is that PV module operation temperature can be reduced and stabilized (at about 30 - 35 C), thus increasing PV module efficiency that, as it is known, drops with the increase of the operation temperature. In typical conditions PV modules operation temperature can be as high as 50 - 60C. The silicon PV module efficiency decreases by about 4% per each 10C temperature increase. Another advantage of such solution is reduction in absorber cost by creation of the advanced hybrid PV/thermal type of the solar collector with heat storage.

During daytime and exposure of the solar collector to sun, the collected heat is used to melt phase change material thus storing heat (in summer preventing excessive house overheating). As a result, a heat demand for house/building space heating is significantly decreased because the time when heat losses through the wall are possible is remarkably shortened. Implementation of the steady temperature buffer zone also significantly reduces impact of the outside temperature fluctuations. As a result the house interior temperature stabilize. In effect the house/building using "advanced skin technology" will hardly experience any overheating during day and will keep warm for many hours after sunset until stored heat will be exhausted. The capsule arrangement creates a network of channels that can be utilized as air channels for purpose of air ventilating system or for heat removal during summer night.

Referring to FIG. 10 through 12, there is shown a comparison of various heating models. FIG. 10 shows operation of the Trombe wall system. FIG. 11 shows the operation of a solar thermal space heating system with a circulating fluid and internal hot water storage tank for heat storage. FIG. 12 shows a wall integrated thermal solar collector with heat storage capacity in accordance with the teachings of the present invention.

The solar heating panel according to the present invention provides a novel "temperature buffer zone" concept of solar thermal collector. The solar collector is integrated with building/house wall, has ability for extensive heat storage (by implementation a big thermal mass) and has highly efficient thermal insulation. More particularly, it relates to thermal solar panel that, when integrated with building wall, forms a warm buffer zone outside of highly efficient thermal insulating wall, and as a result the offered solution is exceptionally suitable for application in buildings located in the cold region areas.
The offered solution is simple, its implementation is limited to the outer shell to the house (suitable for retrofitting), is cost effective and overcomes the above enumerated problems in either a flat panels or passive wall systems. The proposed solar thermal collector is easy to

install, is durable and very economical to manufacture. The heat storing layer according to the present invention, comprise a phase changing material that is in direct contact with the plate absorbing solar radiation and allows to accumulate heat directly in the absorption layer beneath. The heat accumulation occurs in a phase changing material that changes phase preferably at the temperature of about 10 to 30°C.
In winter the buffer zone with heat accumulation capability, extends the period of keeping the buffer zone warm far beyond sun exposure time (after sunset), thus reducing significantly heat loses from the building.
The warm buffer zone, with high heat accumulation capacity, blocks heat escape through the building wall not only during solar radiation exposure but also long time after sunset.

The wall-integrated thermal collector can be equipped with an apparatus to maximize the heat transfer and gain during collector exposure to sun and to reduce the heat losses when the system is inactive, during periods when no sufficient radiation intensity is available (very cloudy sky or during a night).
As a result of formation of the long lasting warm buffer zone on outer side of the building shell (with temperature in buffer zone similar to temperature inside of building), there heat losses through the house wall and need for building heating are significantly reduced.

The solution as described is useful not only for house winter heating but also for summer time house cooling. In summer, on hot days, the buffer zone heat accumulation ability prevents building from overheating during day. The accumulated heat is released to ambient atmosphere in night-time by intensive ventilation of the buffer zone via ventilating slots.

The thermal collector as invented has also an option where the thermal collector plate can be replaced by the photovoltaic cell. In such a case the advantage of invented solution is that by heat sink in the buffer zone (in the phase changing material) the temperature of the PV cell is kept low, thus preventing the photovoltaic cell overheating and improves PV cell efficiency. It is well known that the silicone PV cell efficiency drops with temperature growth at rate of about 4% on each 10°C temperature increase.

The present invention, therefore, provides a solar heating system having a heat storage layer integrated with wall and which forms significant thermal mass in the temperature buffer zone thus forming exceptional thermal barrier for a houses and buildings.

The functions of the integrated solar panel according to invention are:

- efficient solar energy collection,
- heat storage and temperature stabilization and
- highly effective thermal insulation

The basic invention idea is to collect, store and manage the collected heat inside of the envelope of the house shell thus avoiding pipes, holes in wall and heat management components. Such system is very simple, cheap and easy to manufacture and install. In traditional thermal solar active heating systems the heat is collected in thermal solar collectors and transferred with the circulating liquid to the storage tank to be utilized during nighttime.
The system as invented that performs the same functions, however do not require any piping, heat storage tanks, heat redistributing system or circulating pump.

It will be apparent from the above description how this invention relates to houses and buildings that utilize solar radiation for purpose of space heating. It will also be apparent that the system overcomes a number of the drawbacks inherent in other solar space heating systems. It will be apparent that the invention is characterized by very efficient solar energy utilization, simplicity, low costs, applicability for retrofitting and architectural adaptability. It will further be apparent that the invention is particularly advantageous in cold regions. The system uses solar energy as an additional source of heat and provides improved thermal insulation.

It will be understood that the principles of the present invention are applicable to both a flat plate solar thermal and photovoltaic modules with heat recovery, although the heat storage material and temperature buffer zone performs somewhat different functions in each type of solar module.

The invented solar heated insulating wall panel consists of wall panel and solar thermal collector combined together and comprise of:

- outer cover that is made of material transparent for solar radiation ,
- collector that absorbs the solar radiation and is separated from outer transparent cover by air gap
- heat storage layer containing phase changing material
- structural wall panel that is house structure element and main house thermal insulation

In this patent document, the word "comprising" is used in its non-limiting sense to mean that items following the word are included, but items not specifically mentioned are not excluded. A reference to an element by the indefinite article "a" does not exclude the possibility that more than one of the element is present, unless the context clearly requires that there be one and only one of the elements.

It will be apparent to one skilled in the art that modifications may be made to the illustrated embodiment without departing from the spirit and scope of the invention as hereinafter defined in the Claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A thermally insulated wall integrated thermal solar collector with heat storage capacity, comprising in combination:

a wall of a building, the wall having an inside surface and an outside surface;

a solar panel mounted to the outside surface of the wall, the solar panel having:

a transparent layer;

a solar radiation absorption layer, that is separated by an air gap from the transparent layer;

a heat storage layer of phase changing material sandwiched between and in close contact with the solar radiation absorption layer to facilitate heat transfer and the outside surface of the wall to facilitate heat transfer;

the heat storage layer of the solar panel collecting heat during the day to shield the outside surface of the wall from heat and thereby maintain the outside surface of the wall at a temperature which is close to a temperature of the inside surface in order to restrict thermal heat transfer through the wall and emitting heat at night to heat the outside surface of the wall and thereby maintain the outside surface of the wall at a temperature which is close to the temperature of the inside surface in order to restrict thermal heat transfer through the wall.

2. The wall integrated thermal solar collector as defined in claim 1, wherein the solar radiation absorption layer is a coated thin solar radiation absorber plate.

3. The wall integrated thermal solar collector as defined in claim 1, wherein the solar radiation absorption layer is a photovoltaic cell.

4. The wall integrated thermal solar collector as defined in claim 1, wherein means are provided to couple and uncouple the solar radiation absorption layer and the heat storage layer.

5. The wall integrated thermal solar collector as defined in claim 4, wherein the means to couple and uncouple the solar radiation absorption layer and the heat storage layer involves relative movement between the heat storage layer and the solar radiation absorption layer between an absorbing position and a buffer position, in the absorbing position the heat storage layer is in close contact with the solar radiation absorption layer for the purpose of absorbing heat and storing it in the phase changing material, and in the buffer position the heat storage layer is spaced by an insulating air gap from the solar radiation absorption layer, means being provided for relative movement between the absorbing position and the buffer position.

6. The wall integrated thermal solar collector as defined in claim 5, wherein a pneumatic system causes relative movement of the solar radiation absorption layer and the heat storage layer through the application of air pressure.

7. The wall integrated thermal solar collector as defined in claim 6, wherein the pneumatic system is controlled by a temperature sensor, to move between the absorbing position and the buffer position based upon temperature.

8. The wall integrated thermal solar collector as defined in claim 1, wherein the phase change material changes phase in the range of temperatures between −5° C. to +50° C.

9. The wall integrated thermal solar collector as defined in claim 8, wherein the phase change material changes phase in a narrower range between 15° C. to 30 °C.

10. The wall integrated thermal solar collector as defined in claim 1, wherein multiple passages are provided between the heat storage layer and the structural panel thus forming a thermal buffer zone.

11. The wall integrated thermal solar collector as defined in claim 10, wherein thermally controlled ventilating valves are provided to control flow through the thermal buffer zone, such that convection induced air flow can be selectively used to remove excess stored heat to atmosphere.

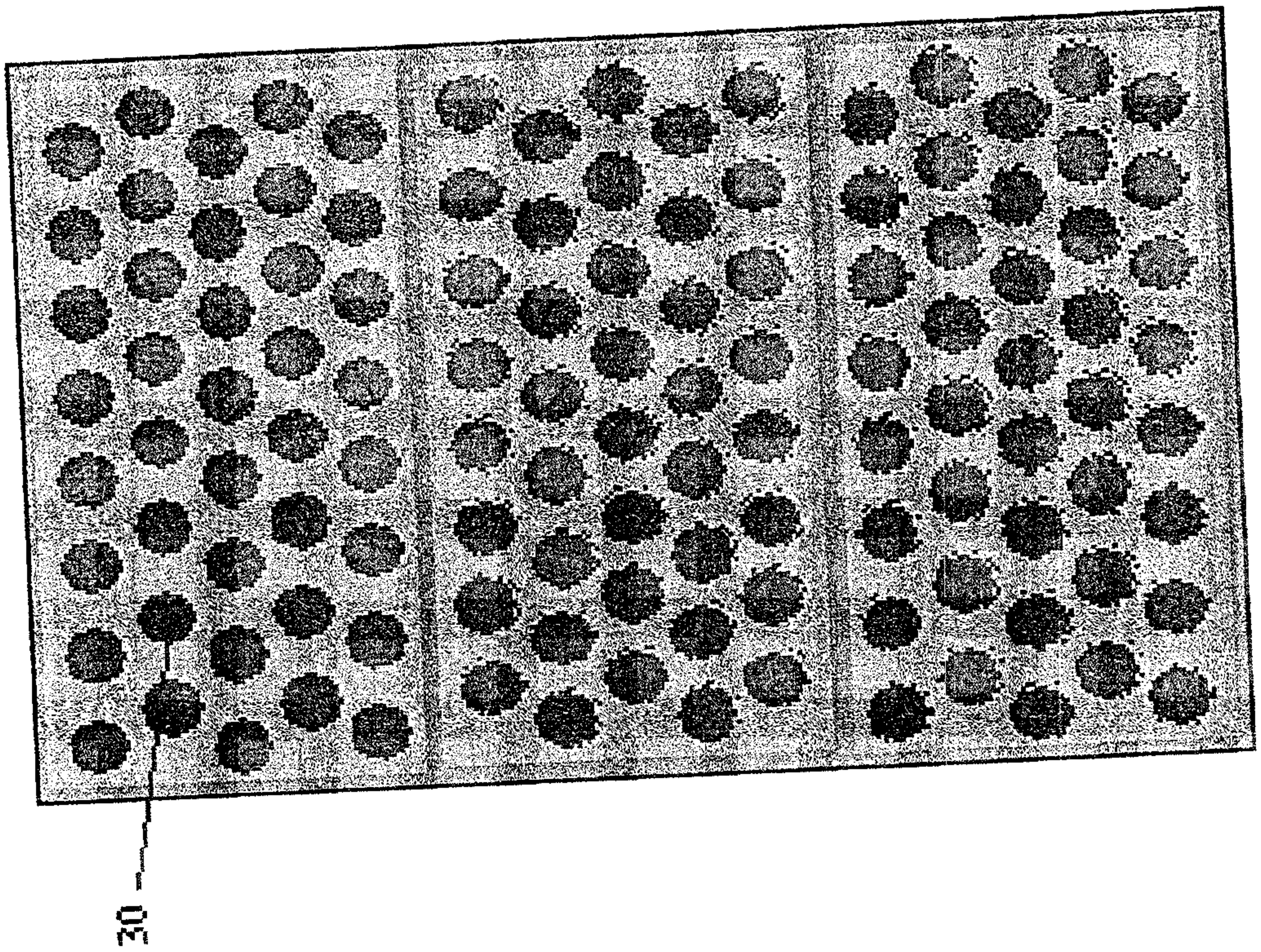


FIG. 2

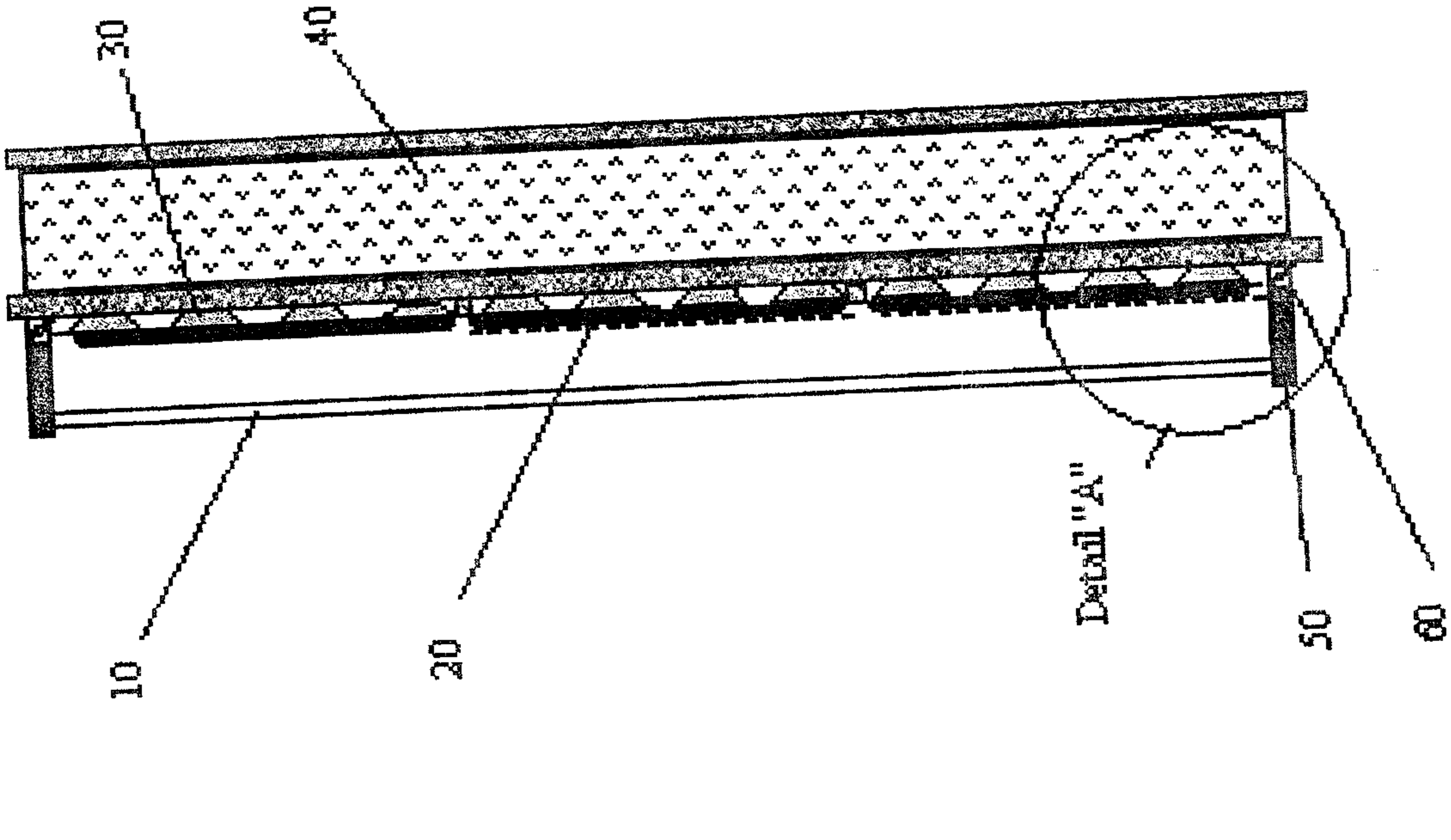
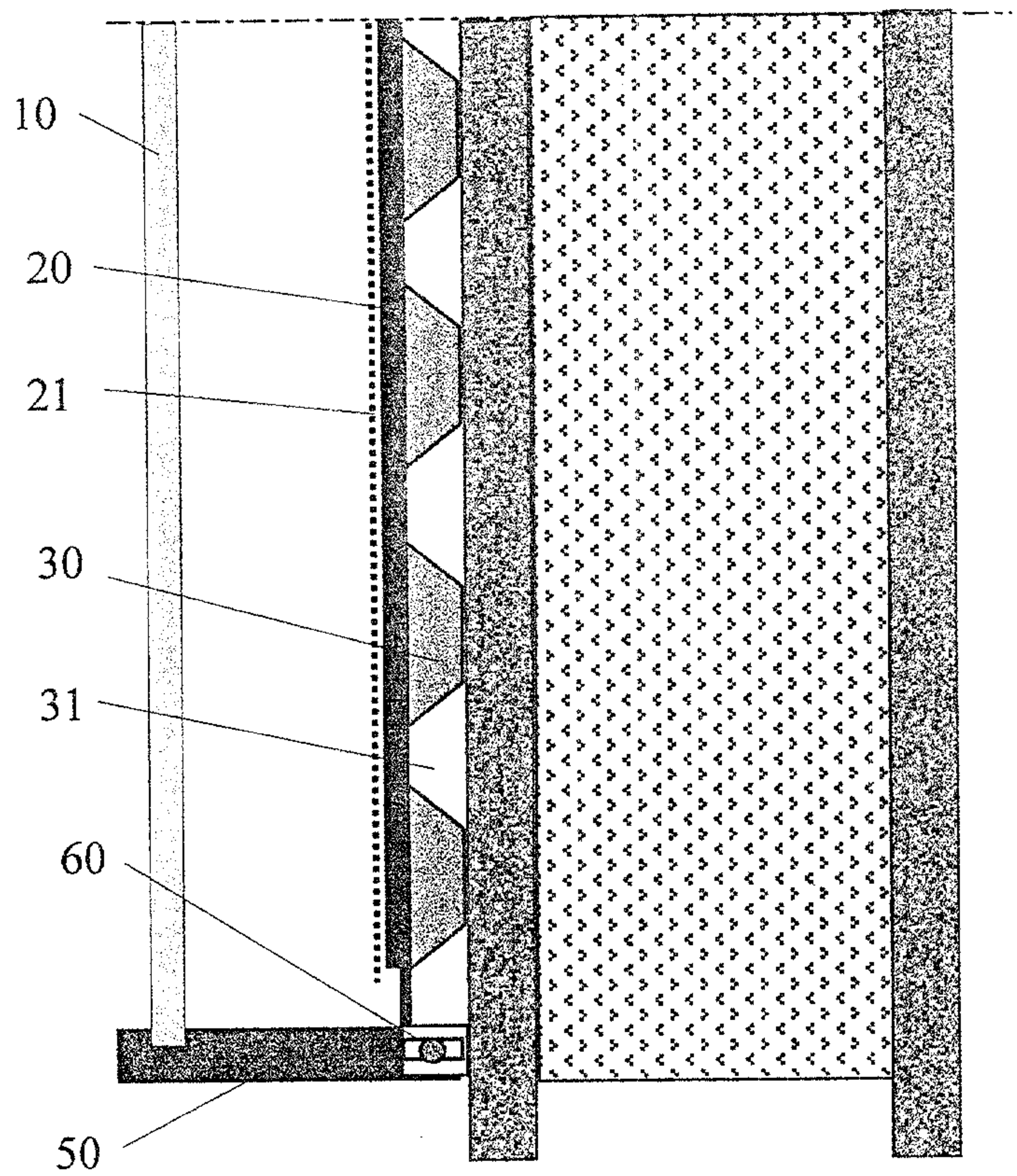


FIG. 1



Detail "A"

FIG. 3

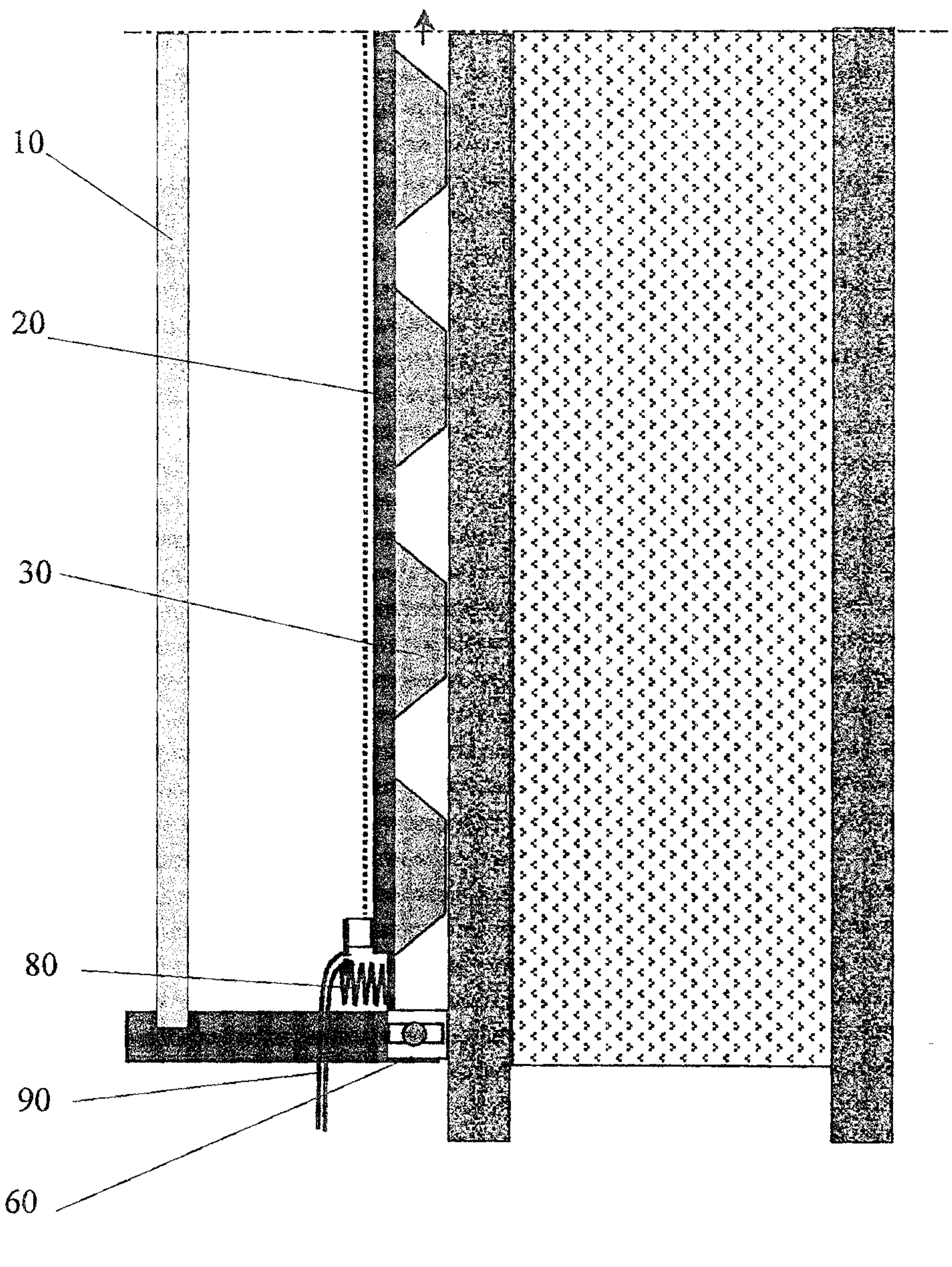


FIG. 4

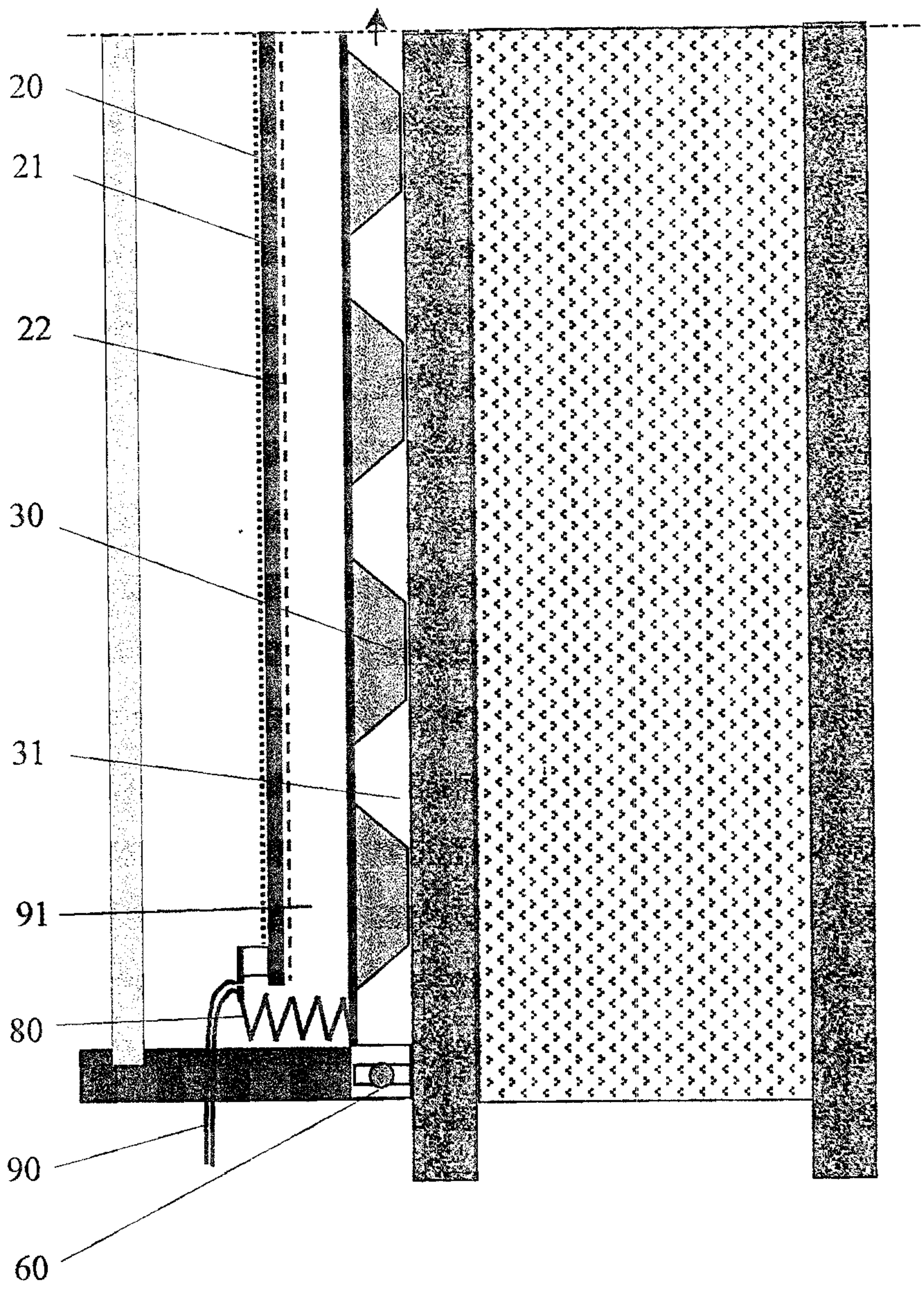


FIG. 5

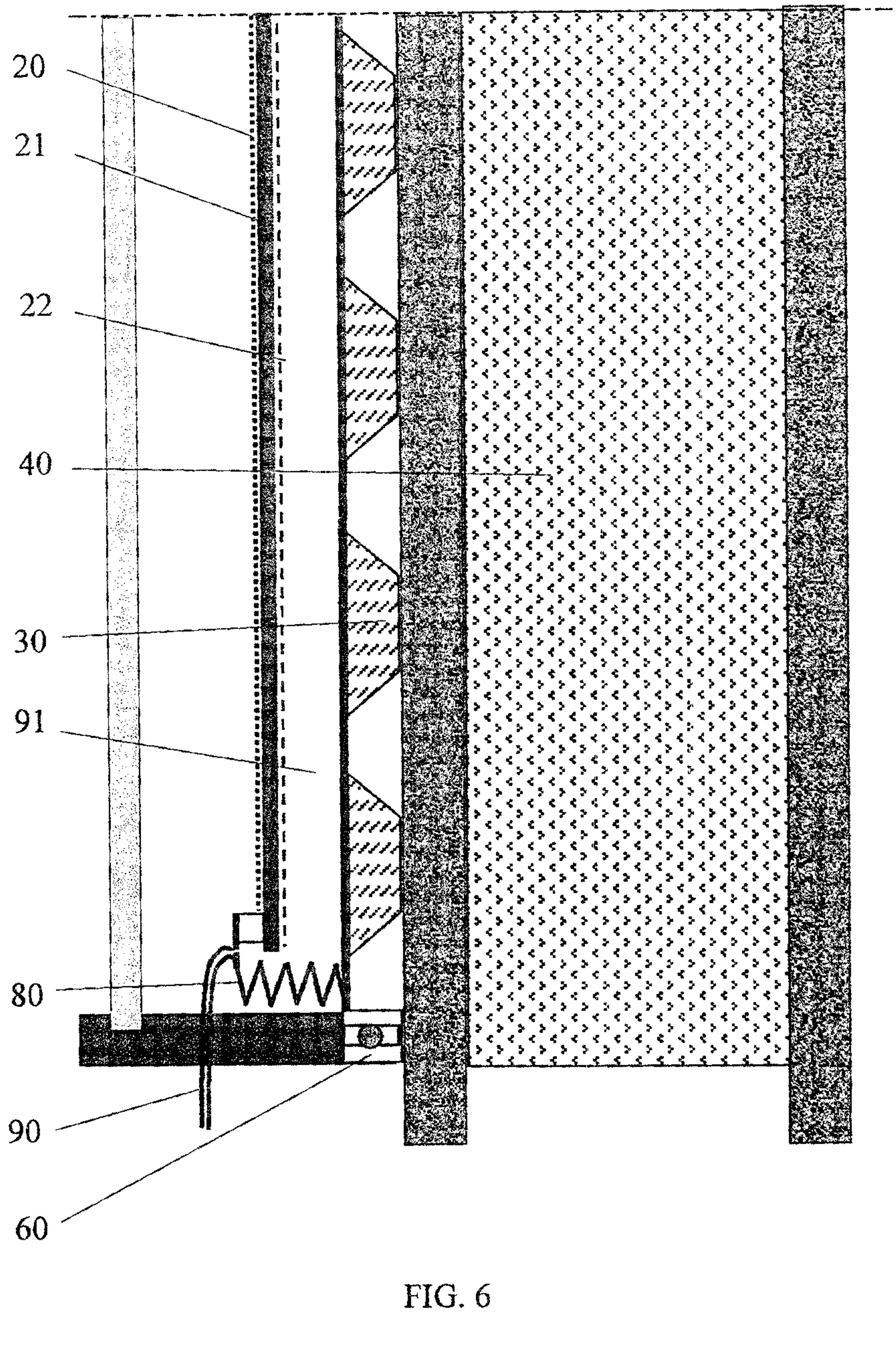


FIG. 6

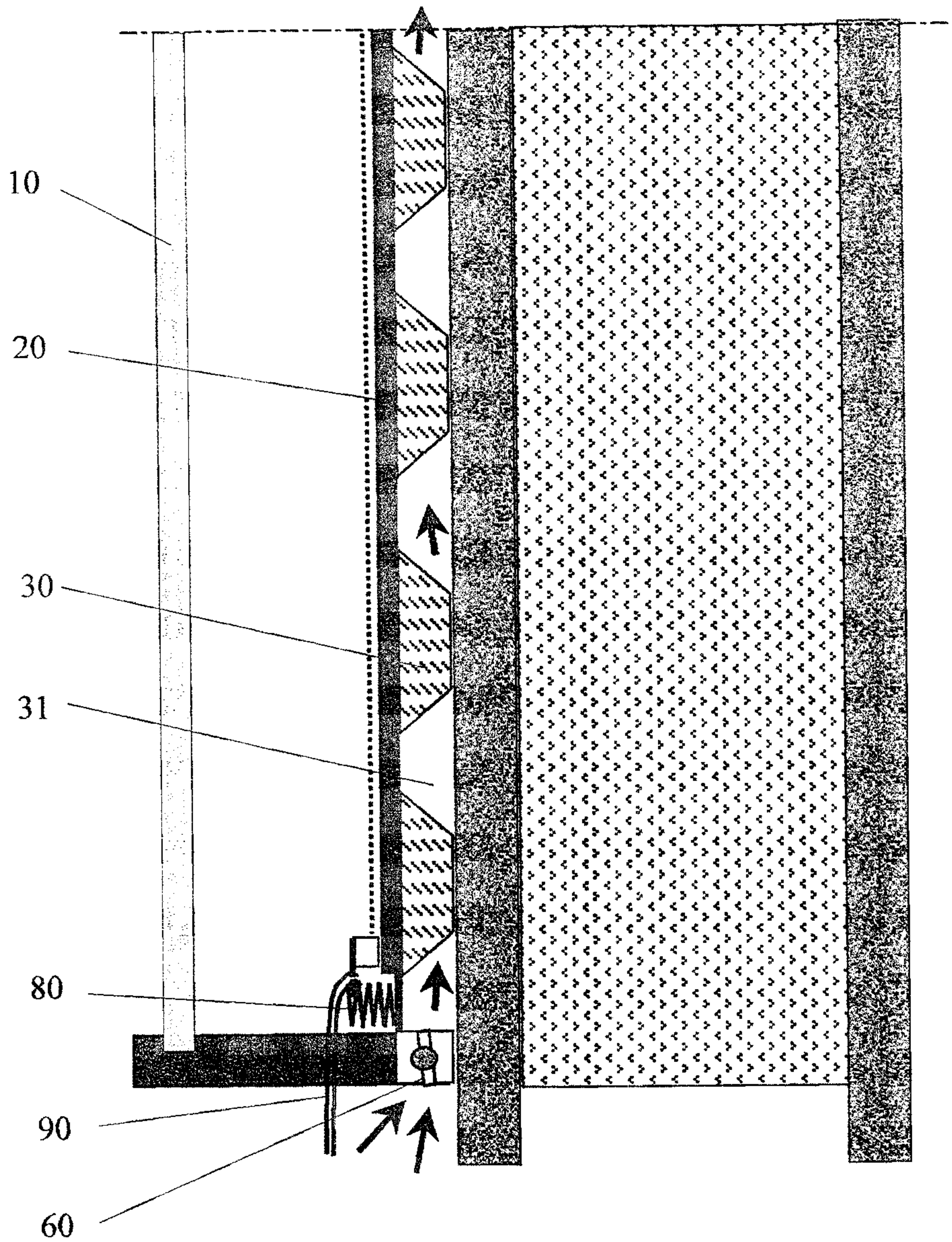


FIG. 7

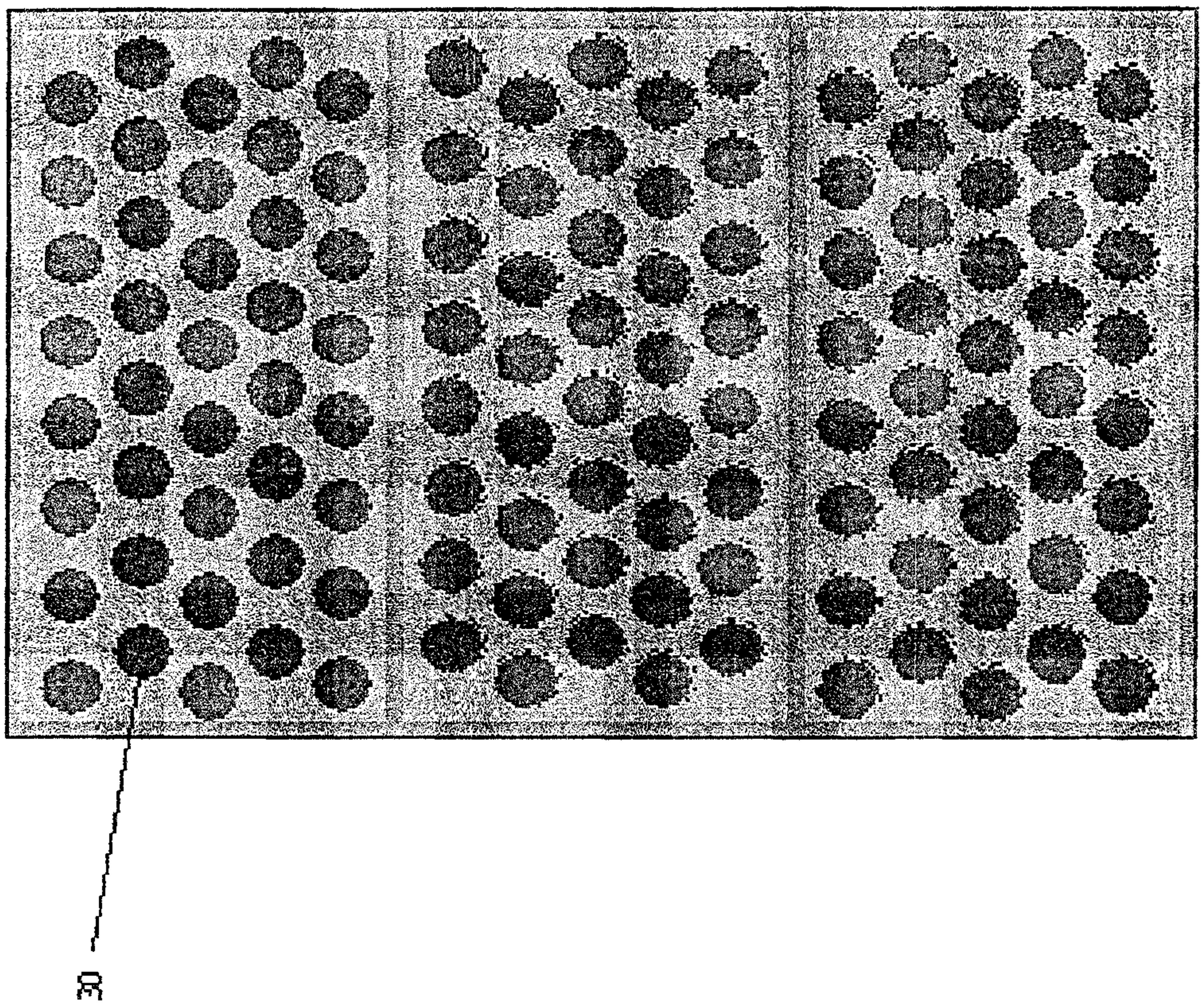


FIG. 9

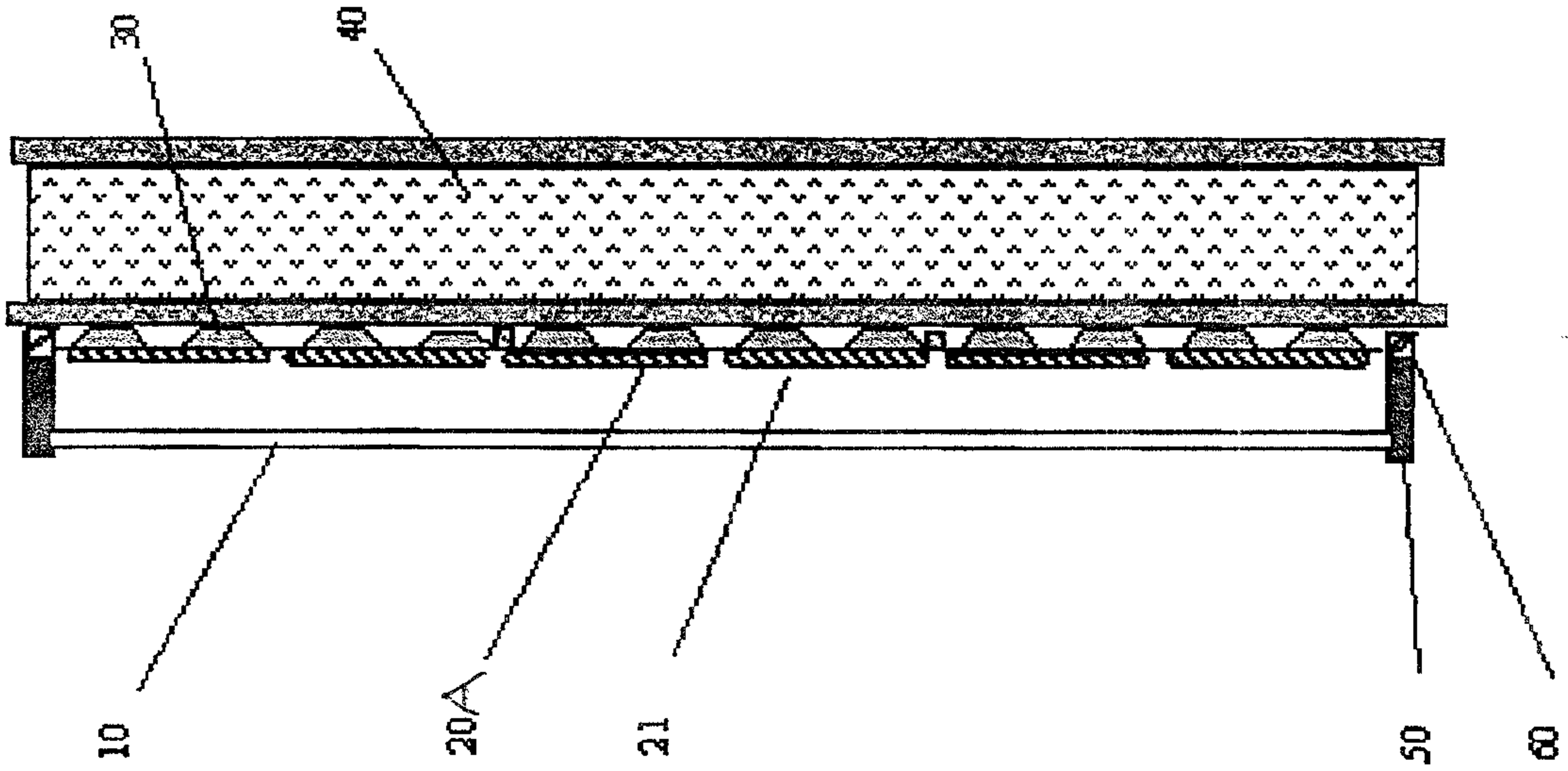


FIG. 8

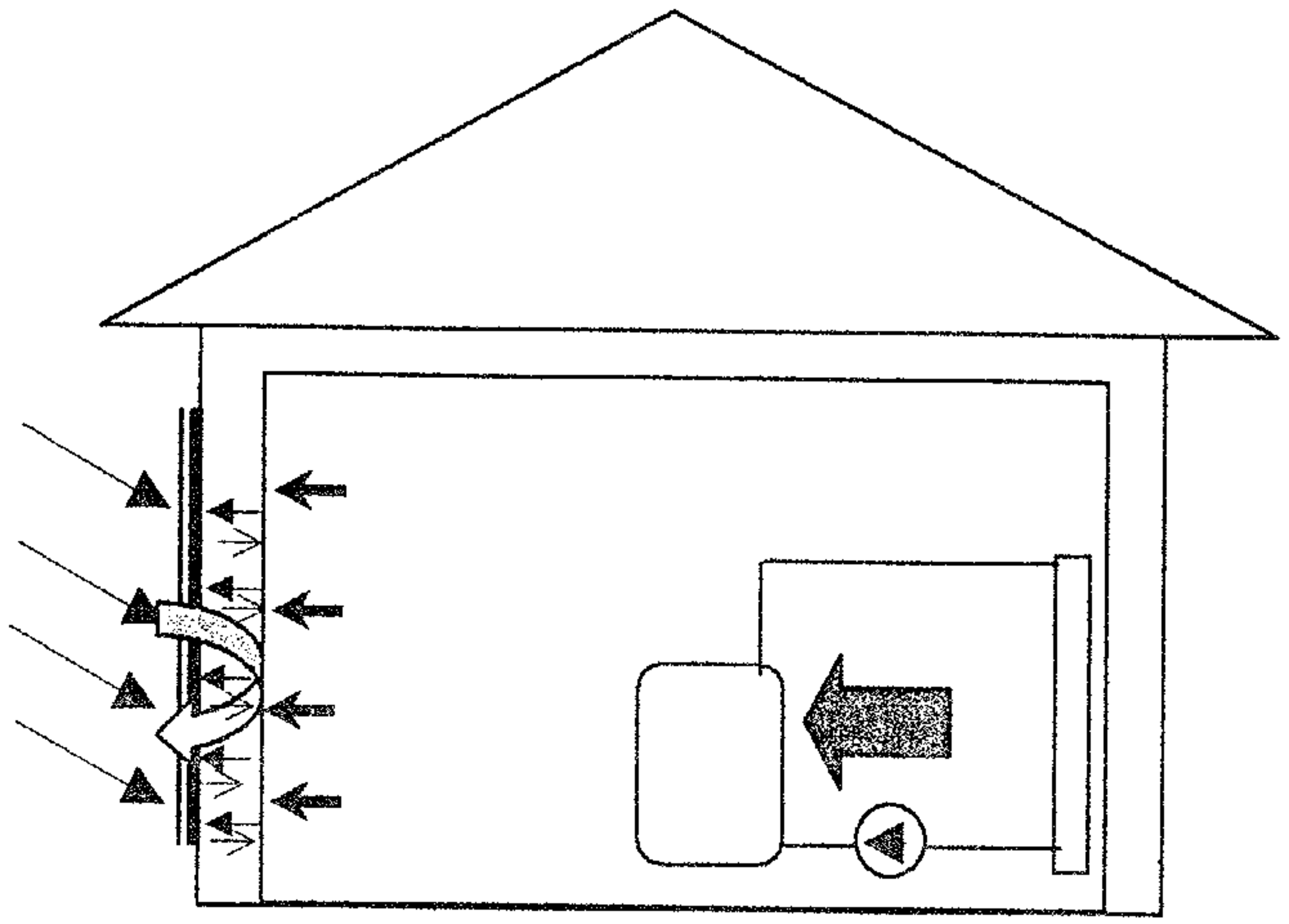


FIG 10.- PRIOR ART

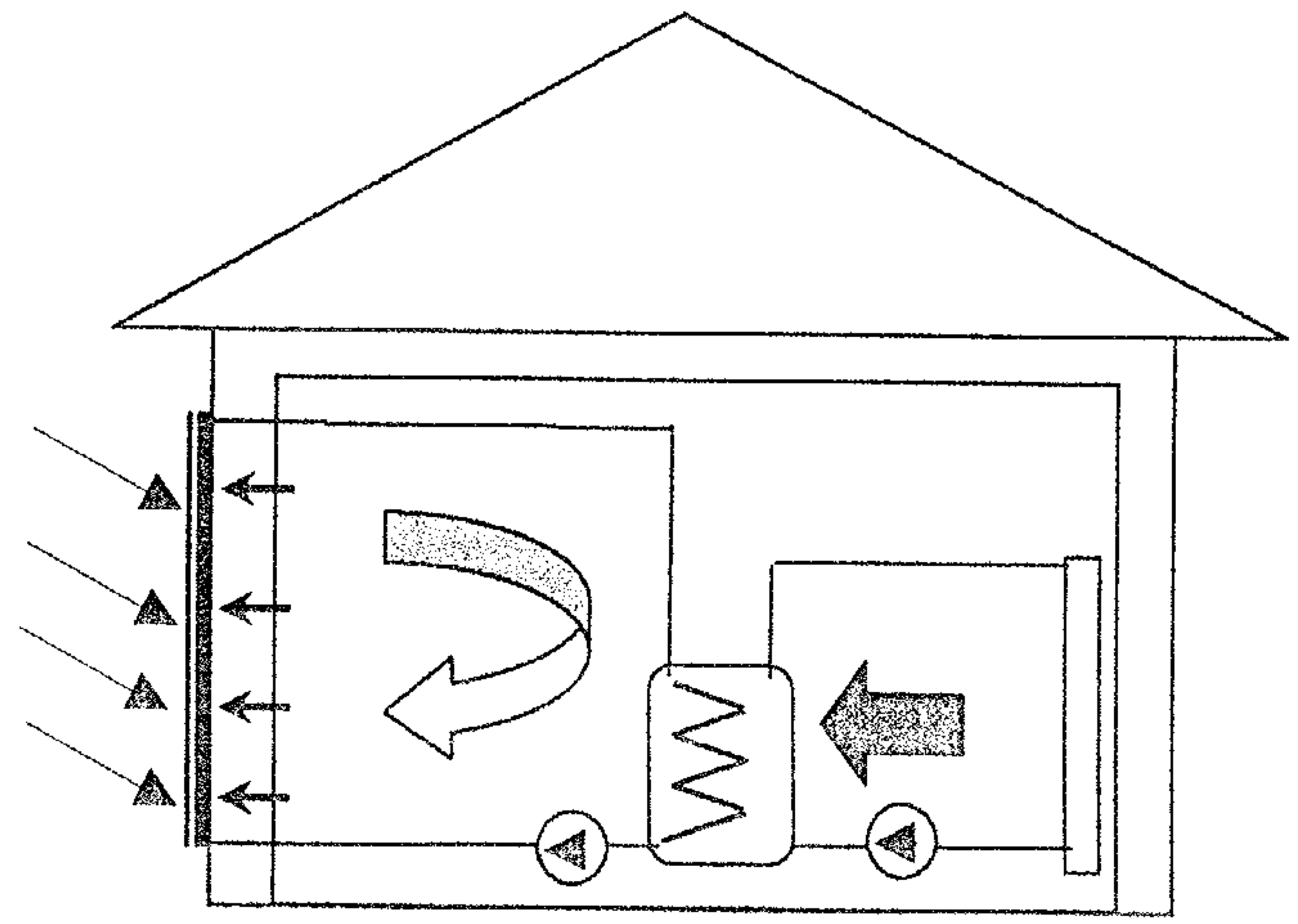


FIG 11 - PRIOR ART

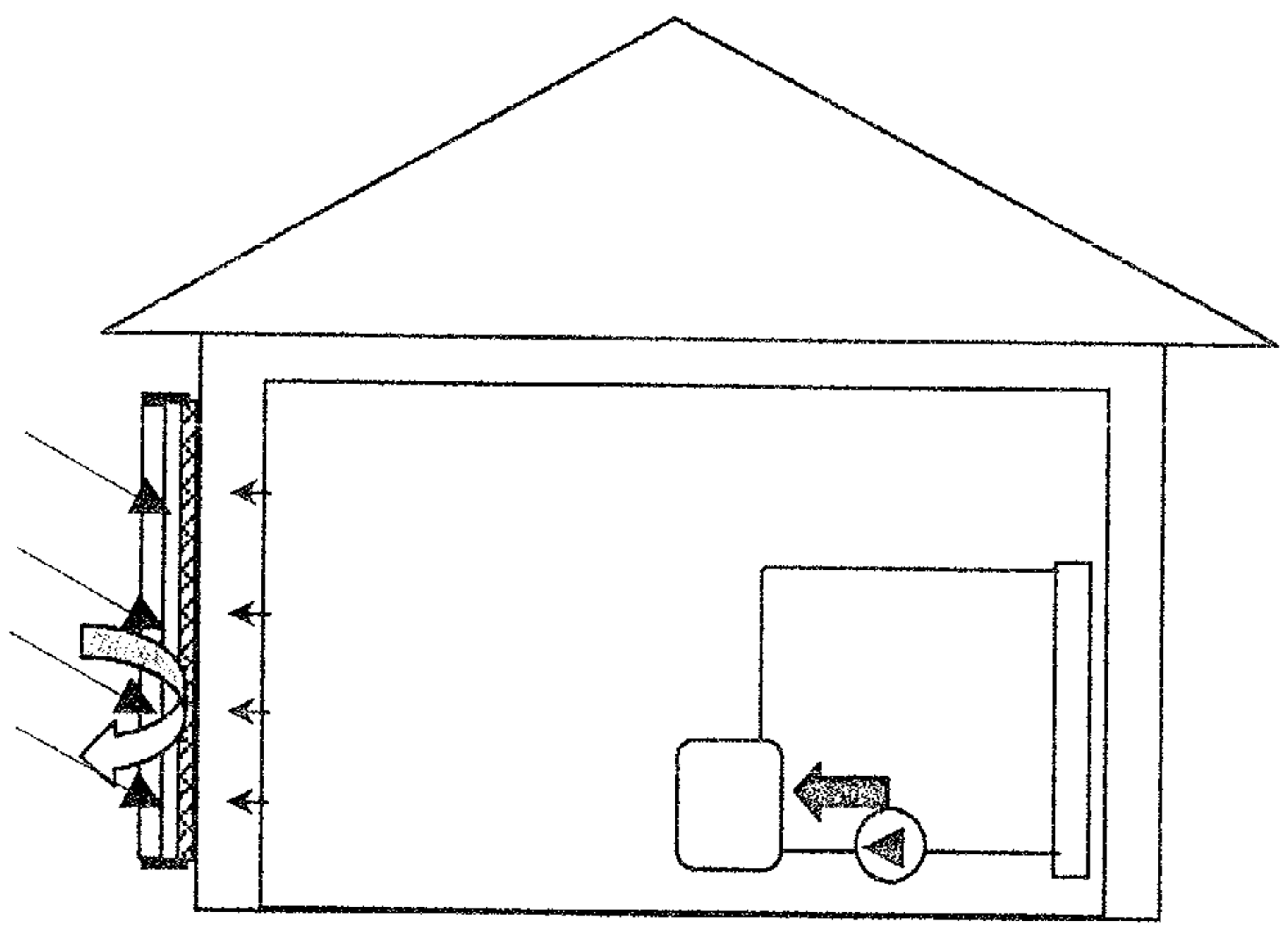
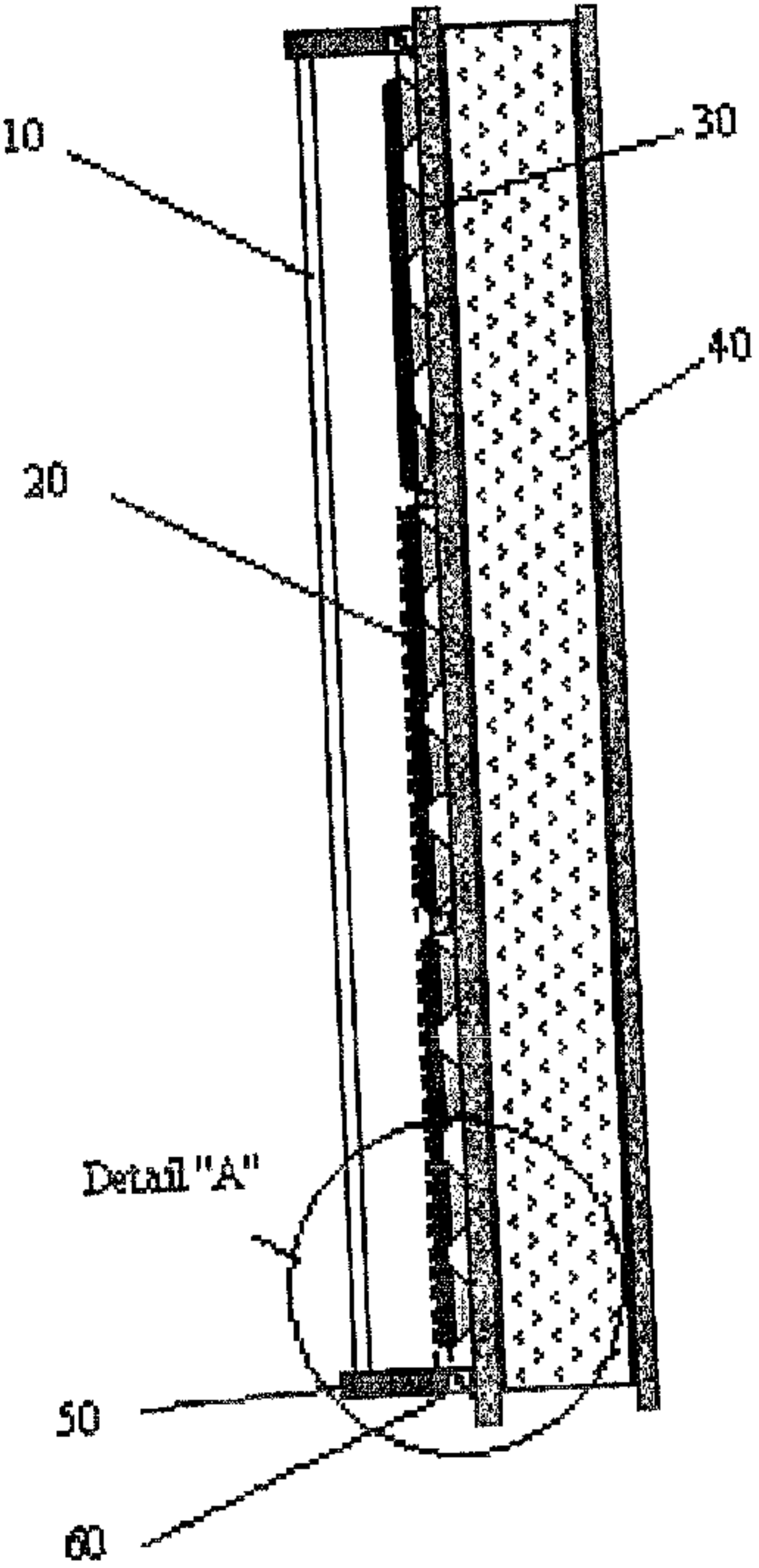


FIG 12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