Oct. 27, 1964 N. E. HAGER, JR 3,154,139

ONE-WAY HEAT FLOW PANEL

Filed June 11, 1962

Fig. 1

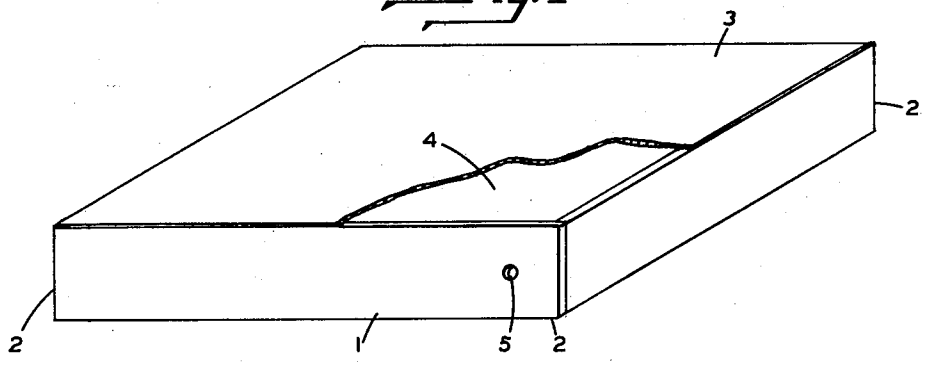


Fig. 2

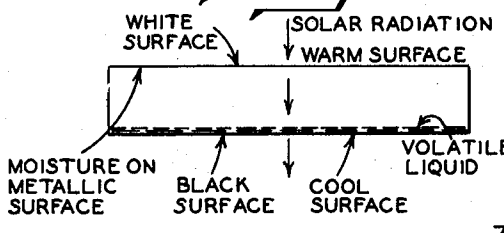


Fig. 3

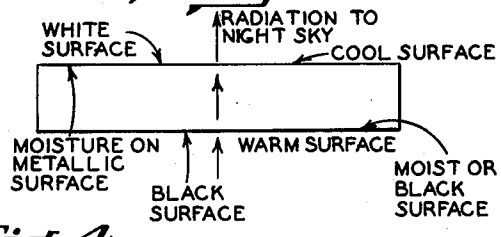
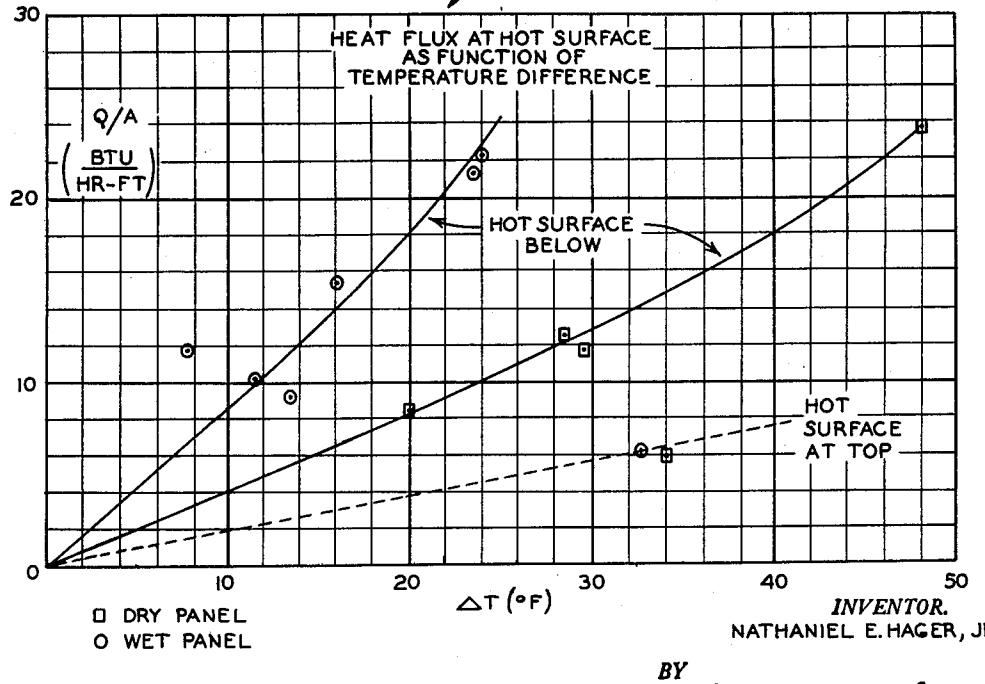


Fig. 4



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3,154,139
Patented Oct. 27, 1964

3,154,139

ONE-WAY HEAT FLOW PANEL

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Filed June 11, 1962, Ser. No. 201,458
8 Claims. (Cl. 165—105)

This invention relates generally to a one-way heat flow panel, and more particularly to a panel adapted to prevent heat from entering a room or other enclosure during the heat of the day, while allowing heat to leave the room or enclosure during the cool of the evening.

There has long been a need for a one-way heat flow panel by means of which the interior of a chamber may be maintained at a more or less constant temperature, or even cooled, by a device which limits the rate at which heat enters the chamber when the environment of the chamber is hot, and yet allows heat to leave the chamber relatively freely when the environment of the chamber is cooler. It is the primary object of the present invention to supply such a panel.

The invention contemplates a one-way heat flow panel comprising in combination a supporting edge structure and two opposing sheets mounted on the edge structure to form a sealed enclosure. The first of the sheets has a highly polished metallic inner surface and, preferably, a white outer surface. The second of the sheets preferably has a black surface on both the inner and outer surfaces of the sheet. The sealed enclosure contains a small amount of an inert liquid, such as water, which is capable of changing reversibly between the gaseous and liquid phases at ordinary ambient temperatures, the liquid boiling in the range of about 80°–120° C. The evaporation and subsequent condensation of the inert liquid on the highly polished metallic inner surface of the first opposing sheet causes a drastic increase in the emissivity of that surface. Re-evaporation from that surface as it warms re-establishes the very low emissivity of the highly polished surface.

The invention may be better understood by reference to the drawings in which

FIG. 1 is a simplified isometric view of a panel of the present invention,

FIG. 2 is a cross-sectional stylized view of the present panel in operation when the exterior environment is hot,

FIG. 3 is a cross-sectional sytlized view of a panel of the present invention in operation when the exterior environment is cool, and

FIG. 4 is a graph showing the heat flux in an operating panel of the present invention.

Referring to FIG. 1, the supporting edge structure may be made of suitable edge members 1 arranged to form the edge in the shape of a flat rectangle. These edge members 1 may be made of wood, plywood, metal sheets, plastic laminates, or the like, generally having a width in the range of about 1–6 inches. The edge members 1 should be generally impermeable to water and other vapors, as are the joints 2 where the edge members 1 meet. If wood is used, it may be foil-lined or otherwise treated to render it impermeable to the inert liquid or its vapor. Opposing sheets 3 and 4 are positioned over the opposite edges of the edge members 1 in order to form a sealed enclosure bounded by the four edge members 1 and the opposing sheets 3 and 4. These opposing sheets 3 and 4 are preferably formed of thin metal, a foil being suitable, although suitably pigmented and treated sheets of plastic may be used. The first opposing sheet 3 will preferably have an exterior surface of a white color. A white surface reflects sunlight, yet emits infra-red radiation almost as well as a black surface. The inner or under surface of the first opposing sheet 3 has a highly polished surface of metallic luster in order that the highly polished surface will have a low emissivity less than about 0.5, and preferably less than about 0.1. The second opposing sheet 4 may have a normal metallic luster or other normal color but preferably has a black-colored outer or bottom surface and also a black-colored top or interior surface. The emissivity of such black surfaces is high, generally greater than 0.9, and on the order of 0.95.

The heat panel of the present invention is completed by having a small amount of an inert liquid boiling in the range of 80°–120° C. in the interior of the sealed enclosure. By "inert liquid" is meant a liquid which does not cause deterioration of any part of the enclosure. To replenish any liquid loss, a refilling opening 5 may be provided in one of the edge members 1. The opening 5 must be equipped with a stopper or valve or other device for sealing the opening when the one-way heat flow panel is in use. The amount of liquid to be provided in the interior of the sealed enclosure will be small, less than 1% by volume of the interior, and usually less than 0.1% of the interior. Sufficient liquid is needed to form a thin layer of condensate over the polished metallic interior surface of sheet 3 when the temperature of that surface falls below the dew point existing inside the panel. Any liquid beyond this necessary amount is merely excess. Therefore it will be appreciated that only very small amounts of liquid are needed for the functioning of the one-way heat flow panel. Tests have shown that a negligible amount of heat is transferred by change-of-phase heat transfer brought about by the liquid. The liquid's sole significant function is that of changing emissivity. The emissivity of the polished metallic surface changes as the inert liquid condenses on it and then evaporates from it. It is this change in emissivity, which depends on the relative amounts of heat on each side of the panel, which renders the panel more permeable to heat flow in one direction than another.

FIG. 2 illustrates the operation of the heat panel of the present invention when the outside environment is hot on the side of the heat panel beyond the white surface, while the inside environment on the other side of the exterior of the black surface is cooler.

The panel or a series of panels may be placed in the walls, ceilings, or floors of rooms or chambers or buildings wherein it is desirable to minimize the heat flow into the chamber while optimizing heat flow out of the chamber when the exterior environment has cooled. The panel functions best, however, in a horizontal position.

Solar radiation strikes the outermost white surface and is largely reflected. Additionally, the low emissivity, polished, metallic under surface of the exterior sheet is a large contributing factor in preventing thermal radiation from penetrating the heat panel from the outside. To the extent that some heat does penetrate the one-way heat flow panel, the liquid remains at the lowermost portion of the heat panel or distributed on the black, cooler surface. Such conditions will remain in a reasonably steady state as long as the exterior environment is hotter than the interior environment separated by the heat panel. The temperature of the exterior sheet is higher than the dew point.

FIGURE 3 illustrates the operation of the heat panel when the outside environment is cooler than the inside environment. The sheet having the two blackened surfaces now becomes the warmer surface while the sheet having the outer white surface and the interior polished metallic surface becomes the cooler surface at a temperature lower than the dew point existing inside the panel. As a result, the liquid condenses and forms a light mist or film of condensate over the polished metallic surface. This condensed film of liquid changes the emissivity of the highly polished metallic surface from a value in the

neighborhood of 0.08 to one in the neighborhood of 0.90, approximately a tenfold change where water is used. This emissivity change of the highly polished metallic surface changes the characteristics of the entire heat panel and will now allow heat to flow easily from the interior of the chamber to the exterior of the chamber where the environment is cooler. The panel interior may be evacuated or pressurized as an aid in achieving dew point control.

It is apparent that the panel may be used in a reverse manner, although it does not work as efficiently. By installing the panel in a position in which the white surface faces into the interior of a chamber and the black surfaces face outwardly, the panel will tend to concentrate heat inside the chamber. Such an arrangement might be desirable in colder climates.

While the liquid to be used in the interior of the sealed enclosure inside the panel itself may be any of the inert liquids which boil in the range of 80°–120° C., it is preferred that the liquid simply be water. Benzene, near one temperature extreme, and normal butyl alcohol, at the other extreme, are representative of organic liquids. Water has the added significant advantages of being a strong infra-red absorber and a good fire extinguisher. Halogenated hydrocarbons eliminate any fire hazard, but they may raise questions of toxicity.

Example

A test panel was made wherein the edge members were fabricated from 0.25″ plywood 24″ long, and 4″ wide. The plywood frame was lined with aluminum foil to minimize water permeability. The two opposing sheets were made of aluminum foil stretched over the frame. The outer surface of one sheet was painted white, while both surfaces of the opposing sheet were painted black. The panel was tested in a horizontal position.

Resistance heaters were used to supply the heat source on both sides of the panel alternately. External insulation was applied to the sides of the panel around the edge members to minimize heat flow laterally outward through the edges. Heat flow rates were measured at hot and cold surfaces with heat meters. Thermocouples were positioned at critical points throughout the panel. All heat meters and thermocouples were electrically insulated from the metal faces of the test panel with layers of polyethylene film.

FIG. 4 gives the hot and cold surface heat flux values plotted as a function of the temperature difference across the center of the panel. The lowermost dashed curve in FIG. 4 shows that the presence of the water inside the test panel produces no significant effect when the top surface of the panel is heated. However, the two solid topmost curves in FIG. 4 show that the presence of the water in the panel makes a sizable difference when it is the bottom surface of the panel which is heated. The curves in FIG. 4 make it abundantly clear that the one-way heat flow panel functions to allow heat to flow readily in one direction through the panel, while inhibiting the flow of heat through the panel in the other direction. In the test involving downward heat flow, the heat was applied directly to the white surface; the ability of this surface to reflect sunlight was not used. Hence the observed effect was less dramatic than it would be in actual use.

I claim:

1. A one-way heat flow panel in which heat flow is controlled by a variation of the emissivity of an inner surface, said panel comprising in combination a supporting edge structure and two opposing sheets mounted on the edge structure to form a sealed enclosure, the first of said sheets having a highly-polished metallic inner surface having an emissivity lower than about 0.5, the second of said sheets having an inner surface having an emissivity higher than that of the inner surface of said first sheet, said enclosure containing a small amount less than 1% by volume of said enclosure of inert liquid boiling in the range of 80°–120° C., whereby said liquid deposits on said polished metallic inner surface when said surface is cooler than the surface on the opposing sheet, thus increasing the emissivity thereof.

2. A one-way heat flow panel according to claim 1 wherein the second of said sheets has black inner and outer surfaces.

3. A one-way heat flow panel according to claim 1 wherein said inert liquid comprises water.

4. One one-way heat flow panel according to claim 1 wherein said two opposing sheets are made of metallic foil.

5. A one-way heat flow panel according to claim 4 wherein said metallic foil comprises aluminum foil.

6. A one-way heat flow panel according to claim 1 wherein said supporting edge structure is wood and said opposing sheets are aluminum foil.

7. A one-way heat flow panel according to claim 1 wherein said highly polished metallic inner surface has an emissivity less than 0.1.

8. A one-way heat flow panel in which heat flow is controlled by a variation of the emissivity of an inner surface, said panel comprising in combination a supporting edge structure and two opposing sheets mounted on the edge structure to form a sealed enclosure, the first of said sheets having a white outer surface and a highly polished metallic inner surface having an emissivity less than about 0.5, the second of said sheets having black inner and outer surfaces, the inner surface having an emissivity greater than 0.9, said enclosure containing a small amount of water less than 1% by volume of said enclosure, whereby said water deposits on said metallic inner surface when said surface is cooler than said black surface thus increasing the emissivity thereof.

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