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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : E04C 2/54

A1

(11) International Publication Number: WO 92/16702

(43) International Publication Date: 1 October 1992 (01.10.92)

(21) International Application Number: PCT/US91/07620

(22) International Filing Date: 24 October 1991 (24.10.91)

(30) Priority data:
670,783 19 March 1991 (19.03.91) US

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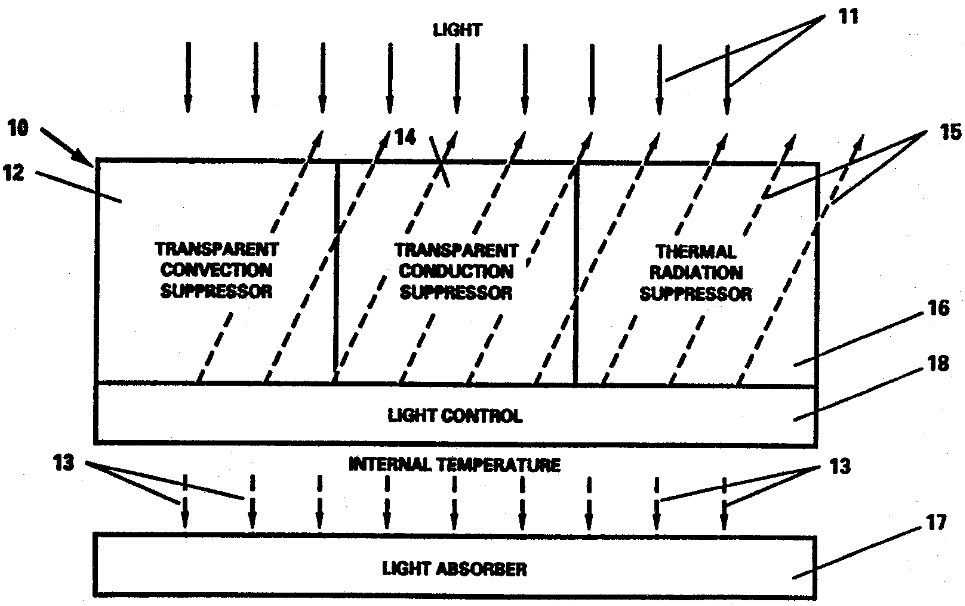
(81) Designated States: AT (European patent), AU, BE (European patent), BR, CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent), SU.

Published
With international search report.

(54) Title: LIGHT ADMITTING THERMAL INSULATING STRUCTURE



(57) Abstract

A light admitting thermal insulating structure having controllable transmissivity to visible radiation comprises a first layer generally transparent to light, a second layer generally transparent or absorptive to light and spaced from the first layer; an improved partition means separates the space between the layers into compartments; a thermal radiation suppression device for suppressing thermal radiation transmission; and a variable transparency device for controlling transmission of light. A suitable partition includes a novel convection baffle which transmits light and thermal radiation which improves the thermal resistance and/or reduces the cost of low emissivity layers.

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LIGHT ADMITTING THERMAL INSULATING STRUCTURE

BACKGROUND OF THE INVENTION

The present invention relates to an improved light admitting thermal insulating structure which prevents heat loss by thermal radiation, convection and conduction, including controllable transmission and/or reflection and/or absorption to light, and a convection baffle which transmits light and thermal radiation or "CBTLTR" to prevent convection loss.

Conventional collectors of solar heat include a dark absorber surface that turns sunlight into heat and a transparent cover for this surface to prevent the heat from escaping. The thermal collection efficiency of such a system is determined by the ratio of the resistance to the flow of heat of the transparent cover to the resistance of the rest of the system. By increasing the thermal resistance of the transparent cover without greatly reducing its light transmission, the efficiency and/or operating temperature of the solar heat collector can be greatly improved. It is estimated that two or three times the energy consumed in heating a well insulated building falls on its surface in the form of sunlight. Thus, an insulation that is transparent when the sun shines would provide most of the heating for a structure over most of the United States if it is coupled with a heat storage system for cloudy weather.

In the past the problems of heat loss through conduction, convection and thermal radiation (also called far infrared radiation) and control of sunlight have been dealt with independently. For example, convection and conduction losses are reduced using spaces filled with some fine structural material without consideration of admission of sunlight. Further, sunlight has been blocked using coatings of layers on windows to prevent room overheating but without consideration of a technique for admitting more sunlight when it is desired to increase the heat in the room. Thermal radiation loss has been of little concern since in the latter situation heat loss is desirable and in the former it is not considered.

Since the heat losses by conduction, convection and radiation are in parallel to each other and are of similar magnitudes, an insulation is ineffective unless all three are dealt with simultaneously, as heat will leave by the path of least resistance.

To best understand the invention, reference is made to the Concise Encyclopedia of Science & Technology, Second Edition, McGraw Hill (1989) for a general definition of terms. Specifically, reference is made to Solar Optical Materials, edited by H. G. Hutchins, Permagon Press (1988); Transparent Insulation Materials and Transparent Insulation T2, both edited by L. F. Jesch, Franklin Co. Consultants Ltd. for the German Solar Energy Society (1986 and 1988, respectively); Large Area Chromogenics, edited by C. M. Lampert, SPIE Optical Engineering Press (1988); Spectral Selective Surface for Heating and Cooling Applications, C. G. Granqvist, SPIE Optical Engineering Press (   ); Optical Materials Technology of Energy, Efficiency and Solar Energy Conversion, edited by C. G. Granqvist, Vol. 9 (1990), Vol. 8 (1989), Vol. 7 (1988); Material & Optics for Solar Energy Conversion and Advanced Lighting Technology, edited by C. M. Lampert, SPIE Optical Engineering Press (1986); Solar Glazing, Mid Atlantic Energy Association, Topical Conference (1979); and Thermal Shutters and Shades, W. A. Shurcliff, Brickhouse Press, Andover, Mass. (   ). These publications set forth a comprehensive overview of technology related to this invention.

A light admitting insulation may be used in conjunction with an optical shutter to regulate light transmission while preventing the flow of heat. The optical shutter may be a layer or layers covering an aperture. The shutter may be reversibly activated by: (1) its local temperature (thermochromic); (2) incident light intensity (photochromic); (3) both temperature and light (thermophotochromic); or (4) an electric current or field (electrochromic). The combination of transparent insulations with a thermochromic optical shutter is the subject of U.S. Patents 4,085,999 and 3,953,110 by the applicant herein. Thermochromic and thermophotochromic shutters, not in combination with a transparent insulation, are the subject of U.S. Patent 4,307,942 and U.S. Patent Application Serial No. 06/948,039 by the applicant herein entitled "Structure and Preparation of Automatic Light Valves," filed on December 31, 1986. See also, "Thinking Window switches Off the Sun When it is Hot", Popular Science, March, 1984, and my article "Contractor Designed Passive Heating, Cooling, and Daylighting", U. S. Passive Solar Conference (March 1990).

None of the patents or the application mentioned above provides the important advantages of addressing all forms of heat losses and heat uses for particular applications including the combination of a transparent insulation with a layer of photochromic or thermophotochromic shutter.

SUMMARY OF THE INVENTION

It is an object of this invention to provide an improved light admitting thermal insulating structure which simultaneously substantially reduces heat loss by thermal radiation, convection and conduction.

It is a further object of this invention to provide a light admitting thermal structure including a convection baffle having controllable transmissivity to light.

It is a further object of this invention to provide a simple, inexpensive light admitting insulating system for improving the efficiency of collectors for solar space cooling, water heating and reducing heat losses through windows as well as improving the efficiency of solar space heating systems.

According to the invention, a light admitting thermal insulating structure is provided having controllable transmissivity to light including a first layer generally transparent to light and a second layer transparent to or absorbing of light and spaced from the first layer. If the light admitting thermal insulating structure has a light transmitting state it is call a "transparent" or "light transmitting" thermal insulation structure. There is a partition separating the space between the layers into compartments and reducing convection losses. There is a thermal radiation suppression device for suppressing thermal radiation transmission and, in some embodiments, a variably transparent control device which controls transmission of light.

In more detail, the structure may include a convection baffle which transmits light and thermal radiation and one or more low emissivity layers, as well as an optical shutter which controls light transmission. Also, the structure may include an antireflection coating having low light and thermal radiation absorption disposed on one or more of the baffle surfaces. Further, the baffle may be constructed from a polyolefin selected from the group consisting of very high crystallinity polyethylene or very low crystallinity polyethylene thereby defining very low polyethylene.

Further, the structure of the present invention can be constructed as a thermal insulating building panel having controllable light transmission. A panel comprises a convection baffle which transmits light and thermal radiation between the inside and outside of the panel, one or more low emissivity layers near the outside surface of the building, and an optical shutter layer near the inside of the building. It is pointed out that the invention is not limited to the structure described, but is intended to broadly cover processes of converting incident light to other forms of energy by using the inventive light admitting thermal insulating structure.

As pointed out in greater detail below, this invention provides important advantages. Heat losses (by conduction, convection and radiation) are all dealt with simultaneously which prevents heat loss by the path of least resistance.

Further, the combination of a transparent insulation with a layer of photochromic or thermophotochromic optical shutters prevent the flow of heat and heat loss while regulating the flow of light.

The invention itself, together with further objects and attendant advantages, will best be understood by reference to the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing the functional components of the light admitting thermal insulating system according to the present invention;

Figure 2 shows a convection baffle which transmits light and thermal radiation suitable for suppressing convective heat transfer dividing a cavity into compartments oriented approximately parallel to the aperture it covers according to the present invention;

Figure 3 shows a CBTLTR suitable for suppressing convection heat transfer dividing a cavity into compartments oriented approximately perpendicular to the aperture it covers according to the present invention;

Figure 4 shows a CBTLTR suitable for suppressing convective heat transfer dividing a cavity into compartments using parallel sheets within a frame supporting the edges of the sheets according to the present invention;

Figure 5 is a cross section of light admitting thermal insulating structure using an illustrated modification of the CBTLTR of Figure 4 to illustrate the nature and type of each surface and layer according to the present invention;

Figure 6 is a transparent insulation which is another embodiment of the light admitting thermal insulating structure of Figure 5 according to the invention;

Figure 7 shows the dependence of light transmission on both temperature and incident light intensity for a typical thermophotochromic optical shutter according to the present invention;

Figure 8 shows in cross section a light transmitting building panel such as a window, skylight, or other solar collector, which is another embodiment of Figure 5 using an optical shutter according to the present invention;

Figure 9 is a cut away view of the panel of Figure 8.

DETAILED DESCRIPTION OF THE INVENTION

Turning now to the drawings, Figure 1 is a block diagram showing the functional components of the light admitting thermal insulating structure according to the invention. Figure 1 is a functional block diagram of a light admitting thermal insulating structure 10 having controllable transmissivity to light. The insulating structure 10 includes means for suppressing convection, conduction and thermal radiation heat losses, e.g., convection suppressor 12, conduction suppressor 14, and thermal radiation suppressor 16 which is a low emissivity layer. For illustrative purposes, each of the suppressor 12, 14, 16 of thermal transport mechanisms extend over the whole system but are shown distinctly for convenience in explanation. Actually they are superimposed.

A light control 18, such as an optical shutter, adjusts the transmissivity of the structure 10 to light in accordance with the desired illumination level or the temperature of the area whose environment is to be controlled. As shown in Figure 1, the incident light 11 may pass through the light control 18 to provide transmitted light 13 or may be reflected to become reflected light 15. If it is transmitted, it may be absorbed on light absorber 17 which may or may not be an integral part of the structure.

The conduction suppressor 14 may be provided through the use of two or more spaced layers or compartments with a gas, vacuum or other medium between them to prevent conduction.

The thermal radiation suppressor 16 may include one or more coatings or layers of material which reflect and does not emit thermal radiation to prevent its transmission.

These layers are called low emissivity layers. They may be transparent or may absorb light. The transmitted light 13 may then be absorbed in light absorber 17, where it turns into heat. If the light absorber 17 is part of the structure, then it may also be combined with the thermal radiation suppressor, herein called a "light absorbing low emissivity layer."

The convection suppressor 12 may include compartmentalizing the space between the layers or providing a vacuum therein. Another example of a thermal and convection suppressor is a finely structured, low density silica or other oxide(s) foam called "aerogel". The compartmentalizing may be accomplished by baffles or partitions which extend transversely between the layers and/or parallel to the layers, such as a CBTLTR, to restrict convective heat transport.

As illustrated in Figures 2, 3 and 4, a convection baffle which transmits light and thermal radiation ("CBTLTR") can be made from a thin sheet or film of a light and thermal radiation transparent material. Its function is to divide a gas filled cavity into compartments, and to thereby suppress convective heat transfer by the gas inside the cavity.

In Figure 1, the CBTLTR is an example of the convection suppressor 12. Figures 2, 3 and 4 show three possible configurations for CBTLTRs which all divide a cavity into compartments, and thereby suppress convective heat transfer.

Figure 2 shows a CBTLTR made from a polyolefin film 21 (for example, polyethylene) which may be heat sealed 22 together or assembled by another state of the art means. This embodiment of a CBTLTR has its compartments 23 oriented approximately parallel to the aperture it covers.

Figure 3 shows a CBTLTR 30 formed from a honeycomb whose plurality of compartments 31 are oriented approximately perpendicular to the aperture it covers. This example of a CBTLTR may also be made from polyethylene film 32.

Figure 4 shows a CBTLTR 40 formed from parallel sheets 41 with a frame 42 supporting the edges of the sheets. The sheets may be made from polyethylene film.

Figure 5 shows a light admitting thermal insulating structure where each surface and layer of the structure are labelled according to the specific function performed, e.g., such as CBTLTR 512, 513, 514 of the Figure 4; cover sheet 515, inner surface transparent cover sheet 502, etc. By changing what the surfaces and layers are, this figure will be used to illustrate most of the remaining embodiments of this invention. The scope of these embodiments are not limited to Figure 5, however, since Figures 2 or 3 or some other configuration could have been used as easily as Figure 4 as the basis for the figure illustrating the following discussion. For example, while the number of layers shown is five, this number is arbitrary, and is only for the purposes of illustration only. Further, because of the general nature of Figure 5 in illustrating numerous spatial relationships between the various layers and surfaces, other embodiments as hereinafter described may refer to the identifying numerals of the layer or surface as different elements.

The CBTLTR helps keep heat from being transmitted by not absorbing thermal radiation. If the CBTLTR were made of a thermal radiation absorbing and emitting material (that is if it had a high emissivity), then this material would transfer the heat it absorbs from convection of the gas into thermal radiation, which would then transfer the heat out.

A CBTLTR can also be used to improve the thermal resistance and/or reduce the cost of light admitting thermal insulating structures which use one low emissivity layer. It also reduces the cost and light transmission losses of light admitting thermal insulating structures using more than one low emissivity layer by reducing the number of low emissivity layers required to achieve a given resistance. One or more of these low emissivity layer or layers can be either light transmitting or absorbing.

In a light admitting thermal insulating structure which uses more than one low emissivity layer in order to increase its thermal resistance, substituting layers of CBTLTR for one or more of the low emissivity layers will reduce cost and improve light transmission with but only slightly reduced thermal resistance. Thus, it is possible to make higher light transmission and/or lower cost light admitting thermal insulating structures by using CBTLTRs.

A CBTLTR can also be used to improve the thermal resistance of transparent insulations which are used with a high emissivity layer in order to radiate heat. A CBTLTR on top of a high emissivity layer can be used to cool a building when they cover its roof. The high emissivity layer radiates thermal radiation to the upper atmosphere, which in dry climates and at night is as much as 30°F cooler than the temperature of the air at ground level. The CBTLTR forms an insulation by thermally isolating the cooled thermal radiation radiator from warm ambient air. At the same time the CBTLTR is transparent to thermal radiation, allowing the radiator to operate. For these applications, the CBTLTR should be weather resistant, inexpensive, easy to install and creep resistant.

A CBTLTR and a low emissivity layer that absorbs light can be used to absorb solar heat efficiently. In this case, in Figure 1, thermal radiation suppressor 16 and light absorber 17 are combined in one layer. This layer is called a "low emissivity layer which absorbs light" or a "selective black". The CBTLTR 512, 513, 514 of Figure 5 forms a transparent insulation by preventing convection between the transparent outer cover sheet 515 of Figure 5 and the low emissivity, sunlight absorbing inner layer 509 of Figure 5. The inner surface transparent cover sheet 502 of Figure 5 can be either low emissivity or high emissivity layer. For these applications, the CBTLTR should have high light transmission and heat resistance as well as the performance characteristics listed above.

Since chemical degradation processes generally occur as an exponential function of temperature, it is useful to have converters of light to heat, such as solar collectors, become opaque when either the absorber surface or the outside air exceeds a certain temperature. Thus, in a modified embodiment of the invention of Figure 5, a structure which converts light to heat includes a thermochromic shutter (at numeral 502), a CBTLTR (at numerals 512 through 514), and a light absorbing low emissivity layer (at numeral 515). When the outside temperature is high and solar energy is not needed, the shutter is opaque.

Alternately, for use, for example, in a greenhouse having varieties of plants, another embodiment of the invention as illustrated in Figure 5 would define the thermochromic shutter layer (at numeral 509) with a light absorbing layer behind the shutter (at numeral 510), a transparent low emissivity layer (at numeral 502), and the CBTLTR (at numeral 512 through 514). In this case, the converter of light to heat becomes reflective when its absorber surface exceeds a preset temperature.

It should be noted that the converter of light to heat may not be intended as such. Photocells are intended to be a converter of light to electricity and convert light to heat to its own detriment. In this case, a CBTLTR and a low emissivity layer would also be detrimental. The above structures are only three of many possible examples of structures which protect converters of light to other forms of energy with optical shutters.

The CBTLTR and low emissivity layers which transmit light can be used as a building or other surfaces which capture solar energy. The sunlight can be used for space heating, illumination and growing plants. In this case, the one or more transparent low emissivity layers can be on any of the CBTLTR surfaces such as shown at numerals 503 through 508 or on the inner surfaces 502, 509 of the transparent covers (or glazings) 511, 515, which face the CBTLTR. In these applications, as in the applications described above, with light absorbing low emissivity layers, the CBTLTR serves to improve the performance of the low emissivity layer or layers by suppressing convection, while not interfering with light transmission.

In another embodiment the Figure 5 representation shows an improved transparent insulation using a CBTLTR. In this case, the outermost layers 511, 515, can be either transparent, absorptive or reflective (low emissivity) of thermal radiation. It is preferred that the layers 511, 515 are opaque to thermal radiation. The inner layers 512, 513, 514 are preferably transparent to thermal radiation so that they form a CBTLTR. The transparent low emissivity layer may be on any or all of the surfaces 502 through 509.

Figure 6 shows a window 60 with a high, insulating value of about 7 square feet hour degree Fahrenheit/BTU (similar to an opaque insulated wall) and a high light transmission of about 60%. It is made using one transparent low emissivity coating and two layers of CBTLTR. For these applications, the CBTLTR should have all of the performance characteristics listed above, although heat resistance may not be as critical. Additionally, the CBTLTR should not impair viewing through the windows.

As shown in Figure 6, two light transmitting cover layers 61 can be made of glass, preferably of low iron content to prevent absorption and heating by sunlight. Alternatively they can be made of fiber reinforced polymer sheets which may be translucent or can be made from polymer films or sheets. A transparent low emissivity coating 62, two layers of CBTLTR 63, and spacers and seals 64 form the window. Alternatively, more than one transparent low emissivity layer can be used or placed on one or both layers of the CBTLTR 63. The number of layers of CBTLTR is not limited to three as shown in Figure 5 but may be any number suitable for the particular application.

A light admitting thermal insulating structure may be used in conjunction with an optical shutter to regulate light transmission while preventing the flow of heat. The optical shutter may be a layer or layers covering an aperture. The shutter may be reversibly activated by its local temperature; incident light intensity (photochromic); both temperature and light (thermophotochromic as shown in Figure 7); or an electric current or field (electrochromic).

A CBTLTR, one or more transparent low emissivity layers, and a thermochromic, photochromic, thermophotochromic or electrochromic optical shutter layer can be combined to make insulating panels which transmit and regulate light. In Figure 5, the shutter may be on any of the layers 511 through 515, but since it is not transparent to thermal radiation, it is preferably located on the outermost layers 511, 515. The transparent low emissivity layer or layers may be located on any of the inner surfaces 502 through 509. The inner layers, 512 through 514, are preferably CBTLTRs.

These panels can be used as improved collectors of solar energy which can be used, for example, for space heating, illumination or plant growth. These panels are an improvement over existing solar collectors for two reasons. They prevent the collection of solar energy when it is not wanted and are more energy efficient because the transparent insulation prevents unwanted loss or gain of sensible heat.

A thermochromic shutter is used as a light control, as shown by the light control 18 of Figure 1, when it is desired to keep the temperature on the "indoor" side of the panel constant. A photochromic shutter is used when more constant illumination is desired. A thermophotochromic shutter is used when constant temperature and illumination are both desired.

An electrochromic shutter is used when it is desirable to control the light transmission of the shutter externally, rather than by some combination of the incident light intensity and the temperature of the shutter. An electrochromic shutter can be controlled by, for example, a temperature or light sensor, a person or a computer. Unlike many thermochromic and thermophotochromic shutters, electrochromic shutters are usually specularly transmissive and imaging through them is possible. This is an advantage for window applications where a view through the window is usually desired along with the illumination it provides.

As shown in Figure 7, a thermophotochromic shutter whose reflectivity response to temperature and light is used to provide more constant illumination from, for example, a skylight which has transparent insulation, the shutter layer should be located on the indoor side of the transparent insulation. Indoor temperatures are more constant than outdoor temperatures and variations in the temperature of the shutter cause the undesired thermal response of the shutter to mask its desired photoresponse.

A light transmitting building panel, for example, a skylight using an optical shutter, can use a transparent insulation made from one or more transparent low emissivity layers and an CBTLTR. Transparent low emissivity surfaces typically absorb 10% of light. This absorption can make enough heat to mask a thermochromic or thermophotochromic shutter's response to heat or incident light intensity, respectively. Thus, the transparent low emissivity layer or layers should be located away from the thermochromic or thermophotochromic shutter near the outside of the transparent insulation. This location is preferable in some applications for another reason. It keeps the solar heat absorbed by the low emissivity layer or layers near the outside of the building where it can leave without causing unwanted summer heat loads.

Thus, the preferred structure for solar light and/or heat collecting panels using: a thermochromic or thermophotochromic shutter; one or more transparent low emissivity layers; and a CBTLTR, is: the shutter near (that is, adjacent to or forming) the indoor side, the low emissivity layer or layers near the outdoor side, and the CBTLTR inbetween.

As shown in Figure 8, a cross section of a light transmitting building panel 80 or skylight with this preferred structure is illustrated and is a special embodiment of Figure 5. The panel 80 includes light transmitting cover sheets 81, a low emissivity layer 82, a CTBLTR 83, a thermoptical or thermophotoptical shutter 84, and spacers and seals 85.

Merely by way of example, Figure 9 illustrates a cut away view of the light transmitting building panel 80 of Figure 8. It is pointed out that there can be more than one transparent low emissivity layer and the low emissivity layer(s) can be located on the CBTLTR. Also, there can be a different number of layers in the CBTLTR.

The scope of the invention is not to be limited by any of these illustrative figures, as many other configurations for CBTLTRs, building panels and skylights are desirable for different applications.

If a skylight's top surface is domed or faceted, the preferable location for the transparent low emissivity surface may be on the CBTLTR layer closest to the outside of the building because it is difficult to apply a transparent low emissivity layer to a domed surface.

The light transmission of a CBTLTR can be enhanced with antireflection layers. For example, the light transmission of the configurations in Figures 6 and 8 can be increased from about 60% to about 75%, and preferably to about 85%. However, these antireflection layers must not absorb much thermal radiation or they will reduce the CBTLTR's thermal resistance. Low refractive index materials which do not absorb much thermal radiation when their thickness is in the order of 1,000 Å (the approximate thickness of antireflection layers) include: porous and columnar aluminum or silicon oxide and other oxide layers, which may have a graded refractive index and broad band antireflection properties; magnesium fluoride or perfluoropolymer, such as polytetrafluoroethylene, quarter wave layers; fluorinated polymer to unfluorinated polymer graded index layers, etc.

These antireflection layers may be placed on any and all surfaces of the CBTLTR and its transparent cover or covers, e.g., in Figure 5, surfaces 501 to 510.

Antiabrasion antireflection coatings (AAR) coatings should have: refractive index in the range of 1.3 to 1.4, the lower, the better; thickness of one quarter wavelength of visible light, or 1,000 Å, at least for the top layer if the AAR is multilayer or has a graded refractive index; hard surface; low coefficient of friction; and for glazing applications, weather and pollution resistant.

AAR coatings on both sides of as plastic film can reduce the film's reflectivity of greater than 8% to 2%. To maintain their high light transmission during use, they are scratch resistant, repel dust and are easy to clean. Almost eliminating reflection makes the film or sheet virtually invisible, increasing packaging materials market appeal, and increasing glazing efficiency. Glazing applications for AAR coated glass and plastic sheet and film include building and car windows, skylights, greenhouses, solar cells and solar collectors.

A polymer surface can be made to have a graded index antireflection layer composed of low refraction index perfluorinated polymer on the outside which has a composition graded to unfluorinated polymer inside. For best results the polymer should be highly fluorinated (more than 70%) on the outside, and slightly fluorinated (less than 30%) on the inside.

For example, the thickness of this film graded index layer can be controlled such that transmission of visible or of photosynthetically active light, or of solar heat is maximum. Such antireflection layers have been made by exposing a polyethylene film to a gas composition of 99.9% nitrogen or argon and 0.1% elemental fluorine for a few minutes at room temperature.

Plastic bottles which are blow molded commercially may have their inside surfaces fluorinated while they are still hot in mold (for greater thickness of fluorination than is required for maximum antireflection) to impart impermeability to oil by exposure to a similar gas mixture.

An advantage of surface fluorination of polymers beyond antireflection is imparting durability to the surface of the polymer where degradation (or weathering or corrosion) of the polymer takes place first. One of the primary means of weather degradation of plastic surfaces is stress crack corrosion, where the plastic produces volatile products from weather degradation, and then shrinks and cracks. The tip of this crack is the site of more rapid corrosion due to the concentration in its small radius of stress from shrinkage and thus the crack propagates rapidly into the bulk of the polymer.

Stability is imparted to the polymer by surface fluorination by at least three mechanisms. First, the surface volume increases with fluorination which places the surface under compression, which forms a prestressed surface more scratch and abrasion resistant and which resists cracking when the surface is bent, such as in the creasing of a plastic film.
Second, fluorination prevents degradation because fluorinated polymers are the most degradation resistant. Third, fluorinated polymers have a much lower coefficient of friction than unfluorinated polymers, which imparts greater abrasion resistance. Surface fluorination may also be used with the hindered amine stabilizers described below, to thereby impart the many attendant advantages of each to the selected polymer.

While it has long been known that polyolefins, and preferably polyethylene, are the only highly thermal radiation transparent polymeric films, polyethylene has not been usable in transparent insulations such as low emissivity windows because of: (1) its haze and consequent poor light transmission; (2) its vulnerability to solar ultraviolet, oxidation and other degradation; and (3) its creep. The haze in polyethylene is caused by partial crystallization, so very low haze polyethylene films can be made by both very high and very low crystallinity. These polyolefin films can be stabilized for resistance to degradation with polymeric hindered amine, for example, Cyasorb 3346 made by American Cyanamide, at a loading from about 0.1% to about 0.5%. Such films have passed accelerated aging equivalent to 30 years of solar UV filtered through commercial glass. To prevent creep, these polyolefins films can be cross linked by the conventional methods for polyethylene: electron curtain, UV light, or heat; each with appropriate cross linking additives, such as polysaturated compounds, e.g., octadiene and methylene bis acrylamide.

Very high crystallinity polyethylene films are preferably made from highly linear, high molecular weight, narrow molecular weight distribution polyethylene resin or a linear medium or low density polyethylene resin. All of these polyethylene resins are made by a low pressure polymerization process typically using a Ziegler type catalyst. Low pressure polymerization also produces fewer degradation sites. This polyethylene film may be uniaxially oriented and calendared simultaneously to increase its crystallinity and light transmission both to greater than 90%. A suitable polyethylene film is available from Tredagar Films, Inc. under the trade name of MONOX. The linear medium and low density materials may then be transversely oriented on a tenter to produce more symmetrical biaxial heat shrink properties. Heat shrinking at predetermined temperatures may be used to easily assemble essentially wrinkle free CBTLTRs.

Very low crystallinity polyethylene is preferably made from low density or ultra low density linear, low pressure polymerized polyethylene which is quenched rapidly immediately after extrusion with a chill drum or water to prevent crystallization. While various polymers and combinations of a mixture of different types of polymers may be used, it is preferred to use primarily polyolefin, meaning a polymer composition of at least 80% polyolefin.

Variations on the embodiments described above are possible. For example, in Figure 1, the light control layer may be either a photochromic or thermophotochromic shutter while the combination of the transparent convection, conduction and thermal radiation suppressor constitutes a transparent insulation.

In another variation, a transparent insulation with a photochromic or thermophotochromic shutter can be used to regulate the transmission of solar light and/or heat into a building. A skylight can use a photochromic shutter to reduce the fluctuations in transmitted light caused by variations in incident light and thereby provide more constant illumination to minimize unwanted solar heat gains in the summer.

In yet another variation, a thermophotochromic shutter can be used to maximize the growth of plants in a greenhouse. The plants' growth inhibition from heat stress is minimized by the thermal response of the shutter while the greenhouses' cooling costs are minimized by the photoresponse of the shutter.

Both the skylight and the greenhouse applications would benefit from using a transparent insulation in conjunction with the shutter. The transparent insulation would reduce heating and cooling costs of both the greenhouse and the building with the skylight.

Of course, it should be understood that a wide range of changes and modifications can be made to the preferred embodiment described above. It is therefore intended that the foregoing detailed description be understood that it is the following claims, including all equivalents, which are intended to define the scope of this invention.

I claim:

1. A light admitting thermal structure having improved thermal resistance comprising a convection baffle which transmits light and thermal radiation and one or more low emissivity layers.

2. The invention of claim 1, wherein at least one of said low emissivity layers absorbs light whereby said structure converts light to heat.

3. The invention of claim 2, wherein said structure includes a light transmitting low emissivity layer.

4. The invention of claim 1, wherein said one or more low emissivity layers transmit light whereby said structure defines a light transmitting thermal insulating structure.

5. The invention of claim 4, wherein said one or more light transmitting low emissivity layers are integrally formed onto the convection baffle.

6. The invention of claim 4, wherein said structure includes one or more covers, and wherein said one or more light transmitting low emissivity layers are integrally formed onto at least one of said covers.

7. The invention of claim 6, wherein said structure additionally comprises an optical shutter which controls light transmission.

8. The invention of claim 7, wherein said optical shutter is thermochromic.

9. The invention of claim 7, wherein said optical shutter is photochromic.

10. The invention of claim 7, wherein said optical shutter is thermophotochromic.

11. The invention of claim 7, wherein said optical shutter is electrochromic.

12. A structure for converting light into other forms of energy which includes an optical shutter to prevent said structure from excess heating.

13. The invention of claim 12 wherein said shutter is thermoptical.

14. The invention of claim 13, wherein the energy conversion is light to heat.

15. The invention of claim 13, wherein the energy conversion is light to electricity.

16. The invention of claim 1, wherein said convection baffle includes one or more surfaces, and said structure additionally comprises an antireflection coating having low light and thermal radiation absorption disposed on one or more of said baffle surfaces.

17. The invention of claim 16, wherein said antireflection layer comprises a graded composition from a highly fluorinated polymer on the side facing incoming light to a slightly fluorinated polymer on the opposite side.

18. A polymer surface including a fluorination treatment of said surface thereby imparting resistance to degradation and abrasion.

19. The invention of claim 1, wherein said convection baffle is made of more than 80% polyolefin.

20. The invention of claim 19, wherein the polyolefin is selected from the group consisting of very high crystallinity polyethylene or very low crystallinity polyethylene thereby defining very low haze polyethylene.

21. The invention of claim 19, wherein the polyolefin incorporates hindered amine stabilizers whereby said structure defines improved stability from degradation.

22. The invention of claim 21, wherein said amine stabilizers define a loading from about 0.1% to about 0.5%.

23. The invention of claim 19, wherein the polymer is crosslinked whereby said structure defines increased creep resistance.

24. The invention of claim 19, wherein the polyolefin shrinks when heated above a predetermined temperature thereby defining an improved baffle having an essentially wrinkle free surface.

25. A thermal insulating building panel having controllable light transmission comprising a light admitting thermal insulation structure including one or more low

emissivity layers near the outside surface of the building, a thermochromic shutter layer near the inside of the building, and a convection baffle which transmits light and thermal radiation between the inside and outside of the panel.

26. A thermal insulating building panel having controllable light transmission comprising a light admitting thermal insulation structure including one or more low emissivity layers near the outside surface of the building, a thermophotochromic shutter layer near the inside of the building, and a convection baffle which transmits light and thermal radiation between the inside and outside of the panel.

27. A light admitting thermal insulating structure defining controllable light transmission comprising a transparent insulation and a photochromic shutter layer.

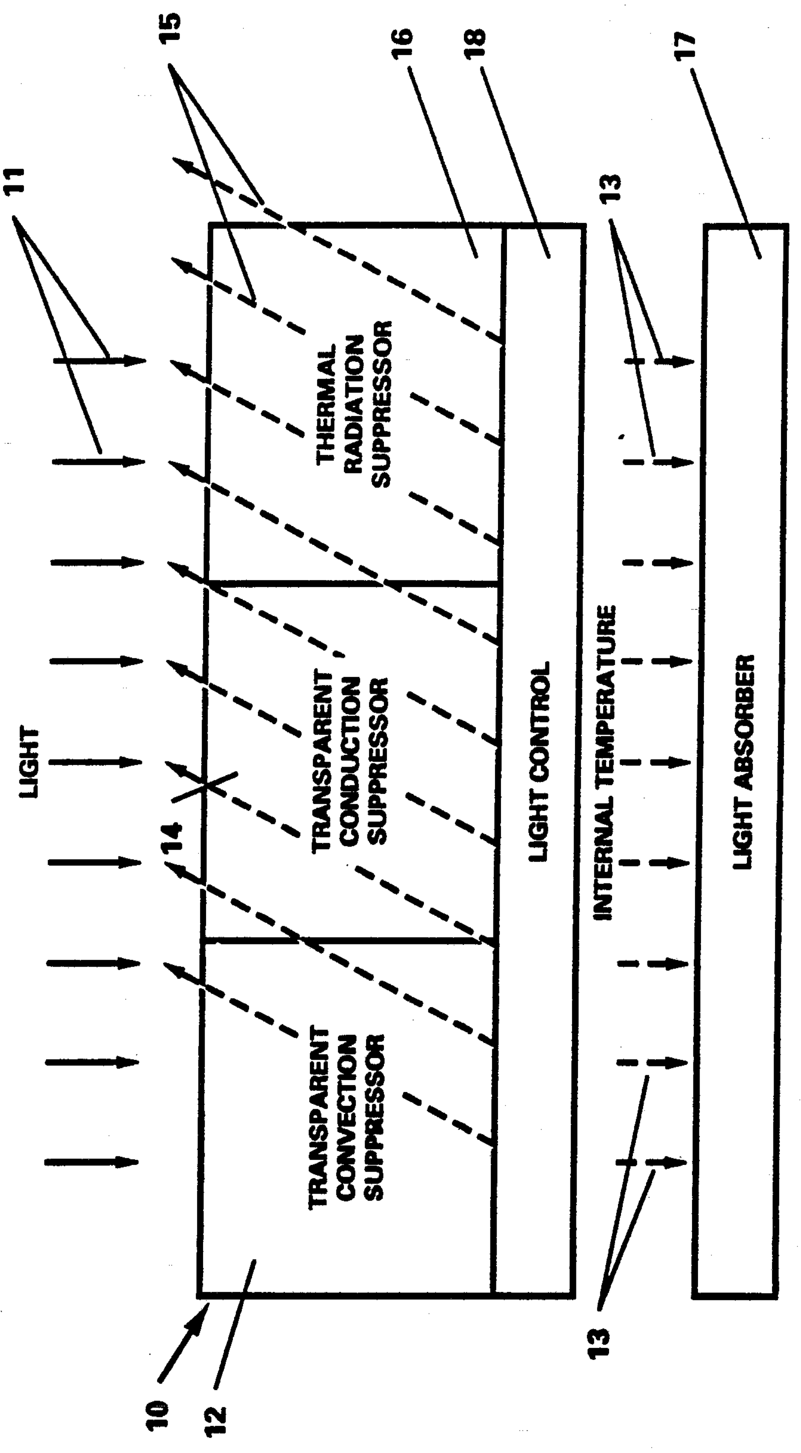
28. A light admitting thermal insulating structure defining controllable light transmission comprising a transparent insulation and a thermophotochromic shutter layer.

29. A method of converting light to other forms of energy using controllable light transmission comprising:

providing a light admitting thermal insulation structure including one or more light transmitting low emissivity layers positioned nearly adjacent to one or more covers;

providing a convection baffle which transmits the light and thermal radiation, said low emissivity layers integrally formed onto said convection baffle; and

providing an optical shutter layer which controls light transmission.


LIGHT
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10
12
TRANSPARENT CONVECTION SUPPRESSOR
TRANSPARENT CONDUCTION SUPPRESSOR
THERMAL RADIATION SUPPRESSOR
LIGHT CONTROL
INTERNAL TEMPERATURE
LIGHT ABSORBER

FIG. 1

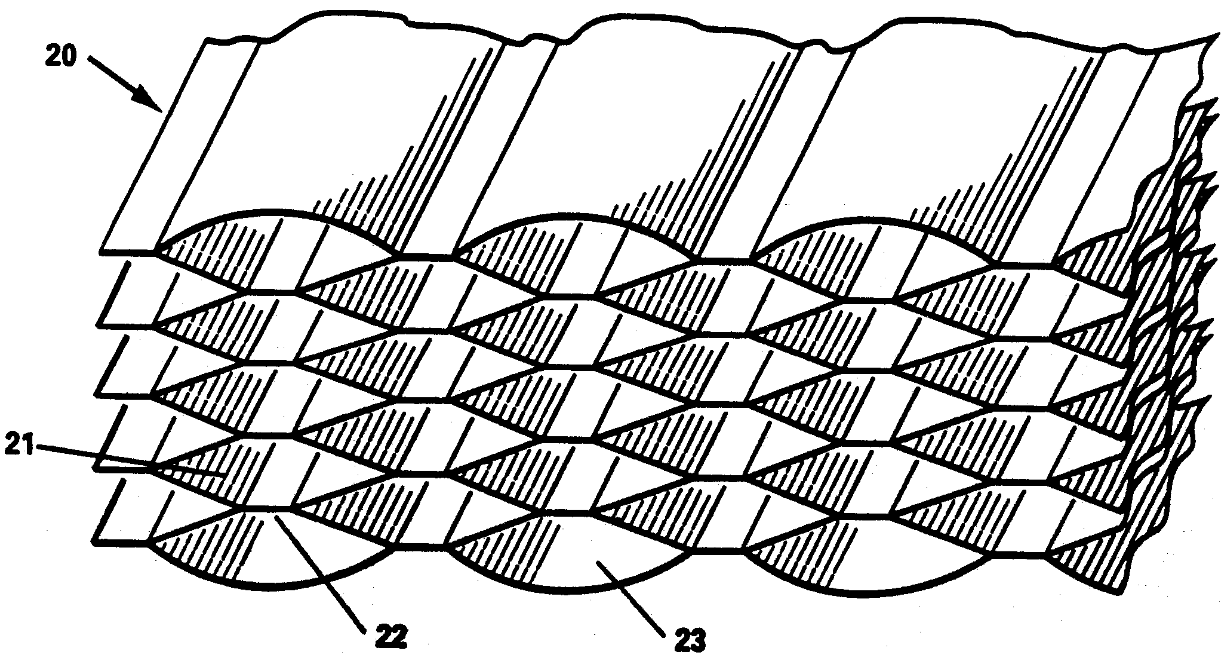

FIG. 2

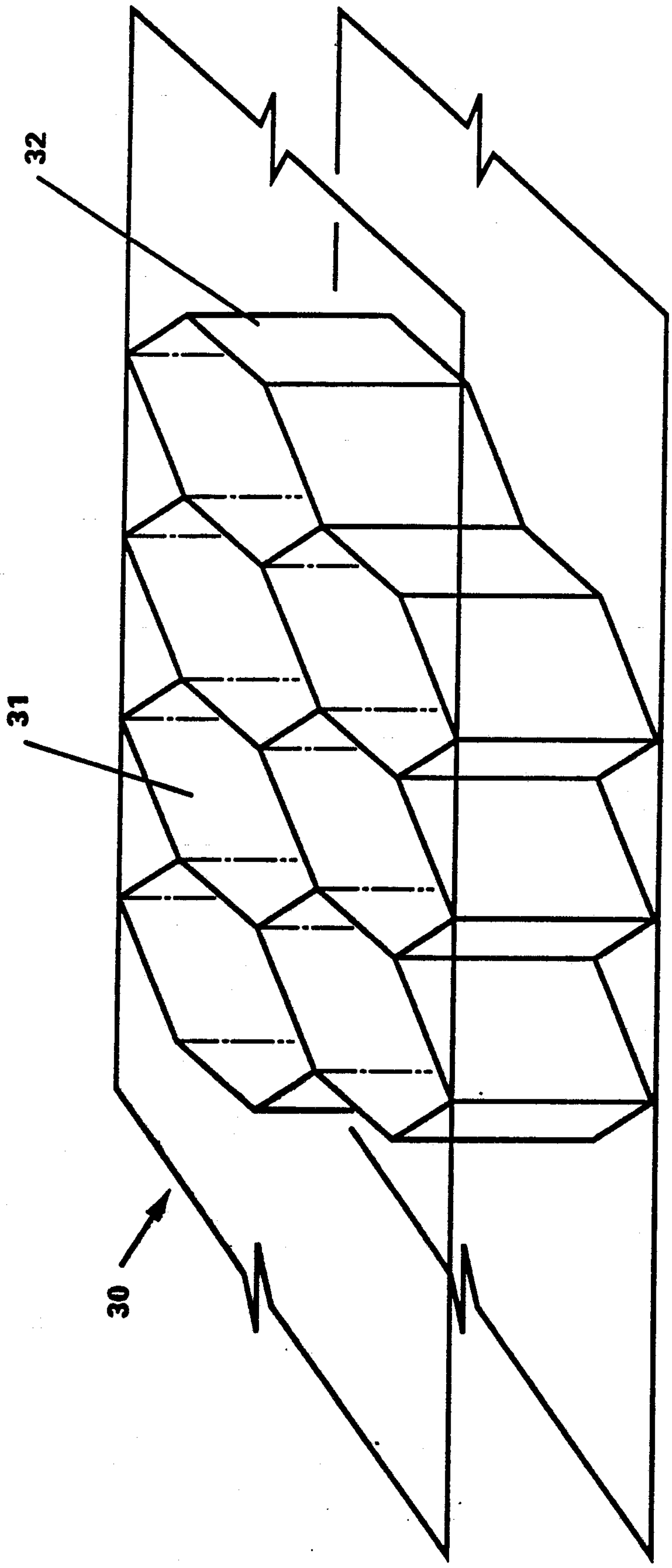

FIG. 3

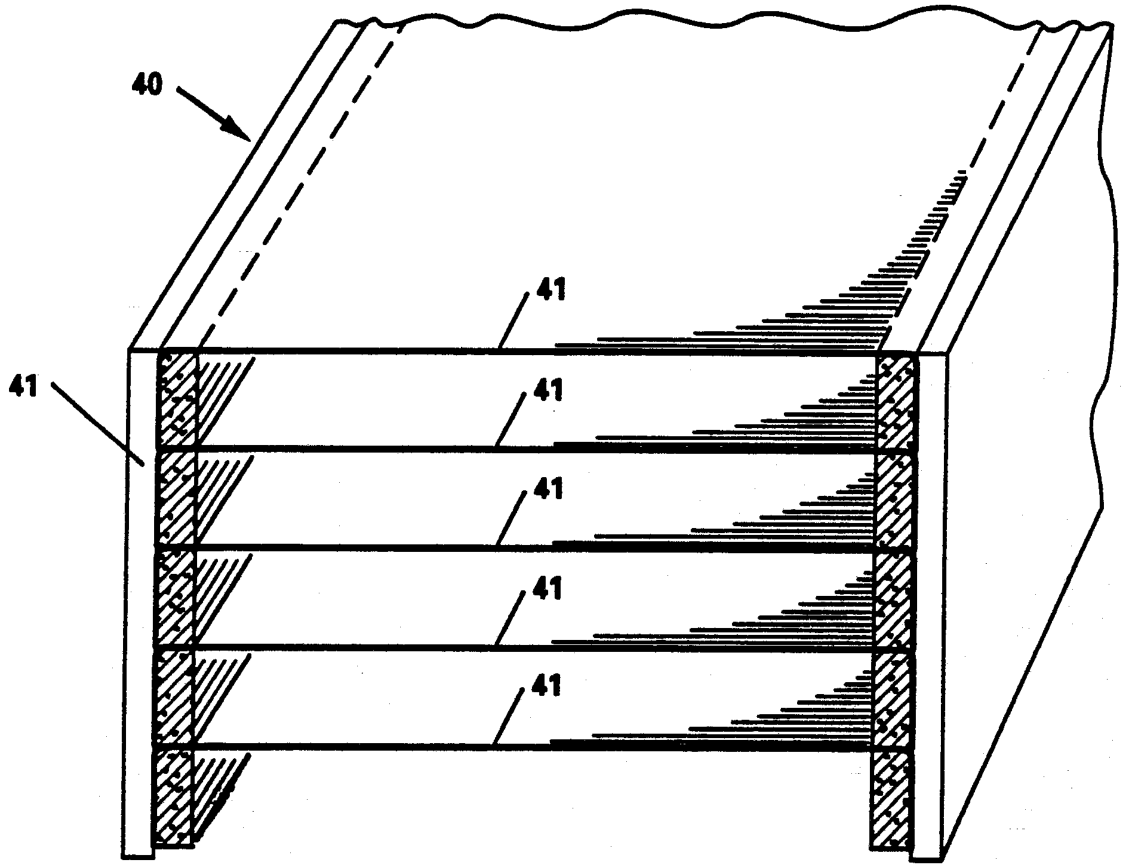

FIG. 4

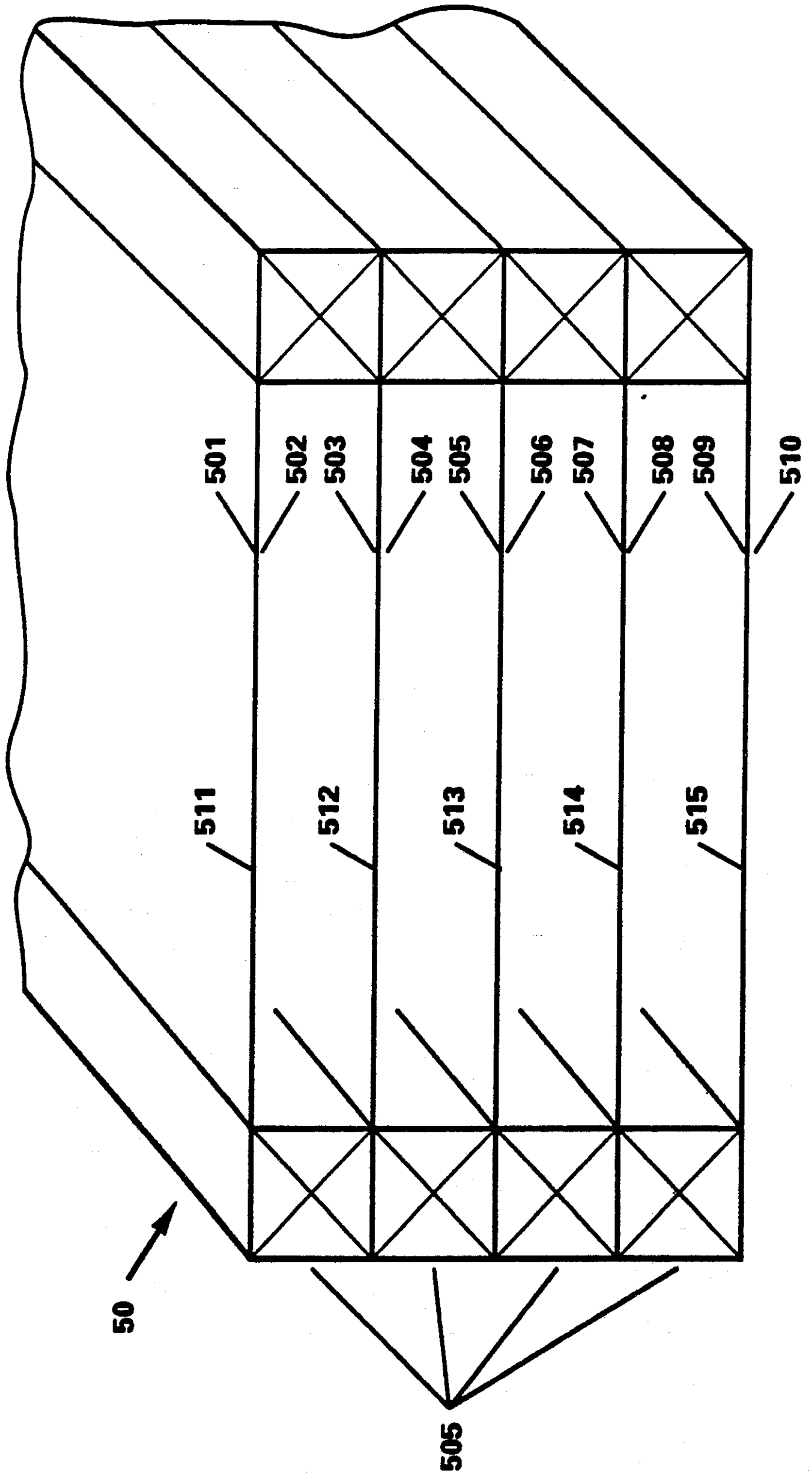
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FIG. 5

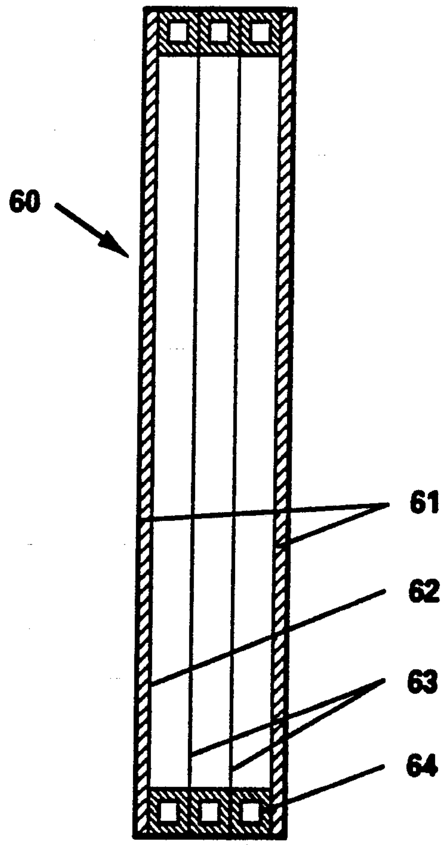

FIG. 6

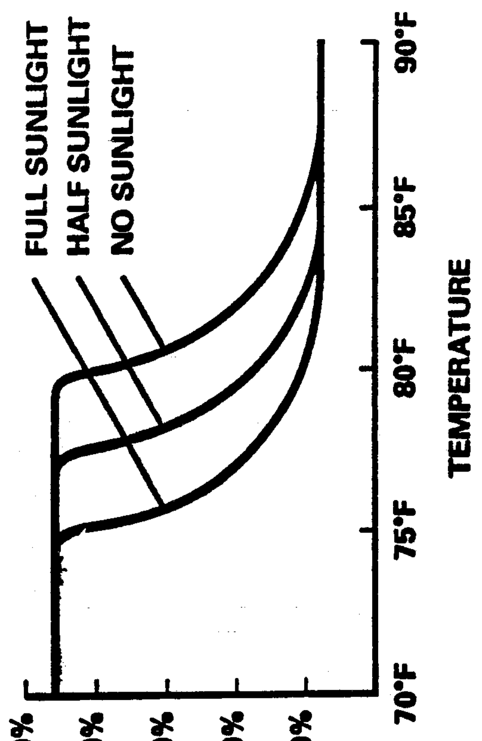
FULL SUNLIGHT
HALF SUNLIGHT
NO SUNLIGHT
TRANSMISSION
100%
80%
60%
40%
20%
70°F
75°F
80°F
85°F
90°F
TEMPERATURE

FIG. 7

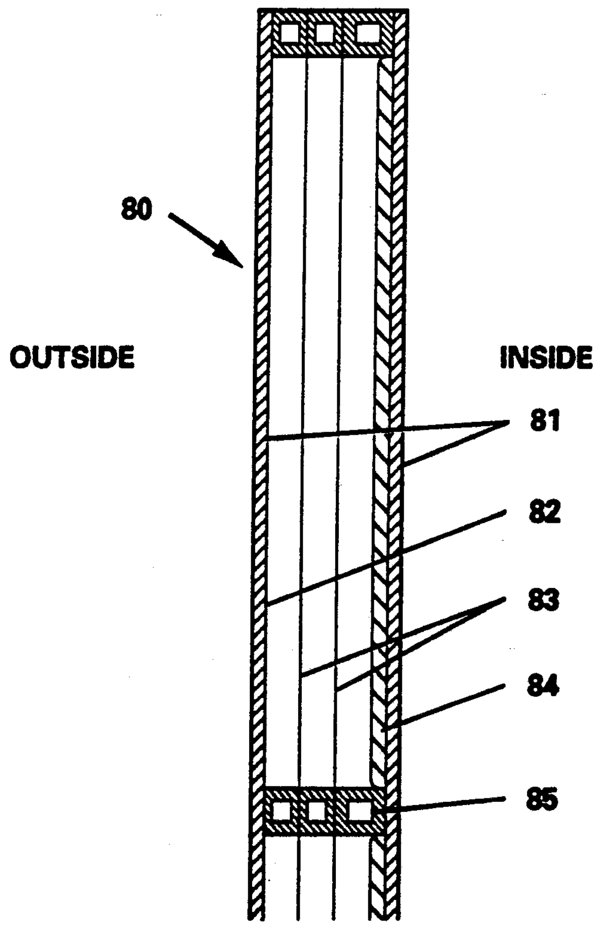

FIG. 8

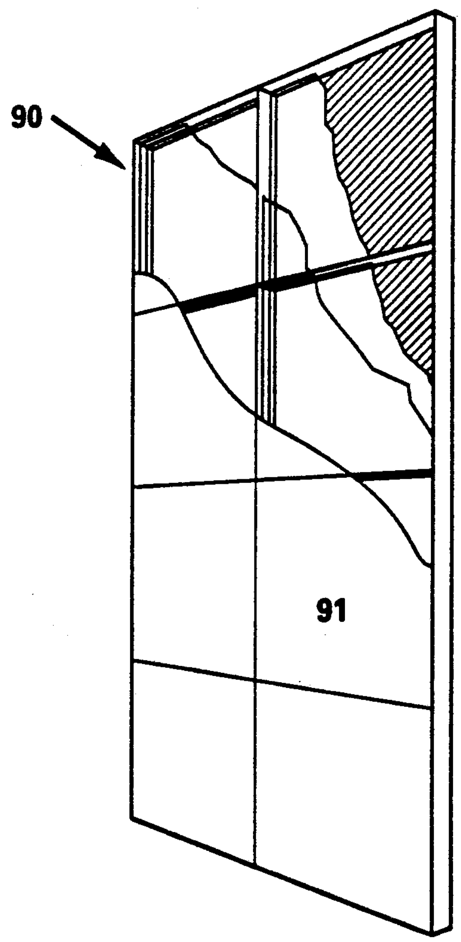

FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/07620

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5) E04C 2/54
U.S. CL. 52/790

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S. CL.	52/790, 203, 359/241

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US,A, 4,085,999 (CHAHROUDI) 25 APRIL 1978	1-29
X	US,A, 3,953,110 27 APRIL 1976	1-29
Y	US,A, 4,307,942 DECEMBER 1981	19-24
Y	US,A, 4,198,796 (FOSTER) 22 APRIL 1980	1-6,16-24

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
23 JANUARY 1992	24 FEB 1992
International Searching Authority	**Signature of Authorized Officer**
ISA/US	WYNN E. WOOD