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OFFSET GLOBAL WARMING
WITH THE Earth Cooler^{TM}δ

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ABSTRACT

The Earth Cooler^{TM} has been developed to transmit thermal energy from the surface of the earth into deep space. The available energy can be utilized to produce electric power and/or radiate the excess energy created by modern conveniences away from the surface of the earth, in essence combatting thermal pollution, part of the phenomenon known as "global warming".

The Earth Cooler^{TM} radiator has been designed to transmit electromagnetic energy in the infrared range for spectral bands (or windows) that naturally occur in the atmosphere and are essentially transparent to the traveling energy. Upwards of 140W/m^2 can be transmitted unattenuated through the atmosphere into deep space utilizing a simple panel at 290K.

A one-dimensional model is used to predict the temperature difference that exists between two sections of a uniquely designed panel surface that radiates thermal energy into space. The model includes all the meteorological parameters necessary to provide meaningful information for electromagnetic waves propagating through the atmosphere, and shows that a temperature difference of up to 4°C can be produced depending on the moisture content of the surrounding air. The theoretical performance of the model coincides well with data collected from several prototypes.

The paper discusses many of the technical issues involved with the propagation of infrared thermal energy through the atmosphere. The presentation of the physical laws of nature that govern the phenomenon provides a better understanding to those on both sides of the global warming issue.

INTRODUCTION

Thermal pollution is defined as the release of waste heat into the environment that is produced by power plants, factories, automobiles, kitchen appliances, etc. The heat finds its way into our environment through the rivers, lakes and air required to control the temperatures in these products, many times increasing local temperatures. The Earth Cooler^{TM} has been developed to remove this thermal energy from the earth's atmosphere in a clean, silent, inexpensive manner.

The operation of the Earth Cooler^{TM} is simple. Deep space is at a constant temperature of about 4K (background radiation and microwave energy preclude a normally assumed temperature of 0K). The nighttime temperature at the surface of the earth varies typically between 270K (winter) and 295K (summer). The composition of the atmosphere is such that there are spectral bands that are transparent to electromagnetic energy. Thus infrared (thermal) energy can travel from the surface of the earth into deep space without being absorbed. The largest spectral band is between 8μm and 13μm, which allows slightly less than one-third of the total blackbody radiation energy to pass at about 295K. The device is set out nightly, and the driving force is nothing more than the temperature difference between the earth's surface and deep space.

The operation of the Earth Cooler^{TM} is unaffected by the controversy that exists over whether global warming is an actual problem or not. The device is designed to absorb thermal energy from the environment it occupies (in this case atmospheric air) and transmit this thermal energy into the vastness of deep space via electromagnetic waves. Therefore, whether global warming is real or not, the Earth Cooler^{TM} can be used to offset any man-made heat-producing appliance by simply taking the heat that is released into our environment and sending it safely into deep space.

The calculations and data show that the Earth Cooler^{TM} radiates thermal energy away from the earth's atmosphere into deep space. One must recognize that the waste thermal energy rejected into the atmosphere by man mixes with the natural thermal energy provided by the sun; hence there is no way to distinguish between the two energies. So whatever energy is radiated into deep space by the Earth Cooler^{TM} is counted toward offsetting the global warming energy. The Earth Cooler^{TM} has indeed earned the moniker "anti-global warming device".

BACKGROUND

The concept of the Earth Cooler^{TM} being used to offset the effects of global warming grew from research to develop this terrestrial/deep space temperature difference as a silent, pollution-free, inexhaustible supply of electric power. The Nighttime Solar Cell^{TM} is a device that is being developed to produce electric power at night to complement daytime solar panels. The Nighttime Solar Cell^{TM} can be used during the day as well to produce electric power from the sun and/or deep space, but not yet at the levels at which current solar panels are capable.

Figure 1 shows a schematic drawing of the components and operation of the Nighttime Solar Cell^{TM}. The atmospheric heat enters only through the lower part of the cell due to the insulation effect of the internal vacuum. The heat travels through the heat engine (solid state thermoelectric generators are used here) and produces electric power. The thermal energy is then radiated from the Spectral Cold Junction Plate and leaves the cell through the spectral window (to maintain the vacuum). The energy continues through the atmosphere into deep space. The Cold Junction Plate obviously transmits the thermal energy at wavelengths that are advantageous for the operation of the device, which will be discussed shortly.

With this fundamental understanding of how the Nighttime Solar Cell^{TM} operates, the Earth Cooler^{TM} came into being. Therefore the waste heat is sent directly into deep space without the electrical power production.

Accounting for all of the significant parameters that would affect the operation of the device, an order-of-magnitude analysis demonstrates the effectiveness of Earth Coolers^{TM} when used in large arrays, based on US energy consumption. The results show that in order to offset one-fourth of the annual waste heat (global warming) put into the atmosphere by all US vehicular traffic, an area of coolers equal to less than seven-tenths of one percent of the land area of Texas is required.

Therefore this can be a practical, simple, inexpensive means to offset global warming - large arrays of panels that radiate the waste heat away from the earth's surface into deep space.

ATMOSPHERIC MODEL

For the propogation of thermal energy from the surface of the earth into deep space, there are basically three regions or layers of the atmosphere that influence the energy's movement. From ground level to an elevation of about 10km is the Troposphere. This is the region that has water as well as the other constituents of air. Above this layer to about 85km is the Stratosphere, which again has the usual components of air, with no water, but including ozone. Above 85km is the Ionosphere with primarily helium and hydrogen, both of which do not affect the movement of electromagnetic energy. The CO_2 remains relatively constant throughout the two lower levels, and although the H_2O is confined to the Troposphere, this is the largest changing variable to the movement of radiation in the atmosphere.

It is well understood that the movement of thermal energy in the form of electromagnetic waves is a function of temperature and wavelength, as described by Plank's Law, with a maximum of energy transmission for different temperatures in particular bandwidths [White, 1988; Siegel and Howell, 1981]. The thermal energy that leaves the earth's surface and travels through the atmosphere as electromagnetic waves, due to ambient temperatures, occurs in the long infrared wavelength range (approximately $4\mu m$ to $50\mu m$) [Salby, 1996].

Calculations for the propogation of electromagnetic energy through the atmosphere can be daunting. But by taking advantage of the general laws of physics, simple approximations will provide very accurate data.

Diatomic gas molecules, of which the atmospheric composition is over 99%, do not influence the movement of infrared energy through them. The non-diatomic molecules, primarily CO_2 and H_2O, influence the electromagnetic energy only in particular bands [Siegel and Howell, 1981]. For example, even if the atmosphere were 100% CO_2 (or 100% H_2O), infrared thermal energy would travel freely in those bands that do not influence the movement of the energy.

Increased elevation from the earth's surface through the Troposphere results in a decrease in temperature called the lapse rate. This is advantageous because the air holds less moisture, thus reducing the amount of energy that is radiated back to the panel. In the Stratosphere where there is no moisture, the air temperature starts to increase. But radiation energy transmission by gases is a strong function of pressure [Edwards, 1976], and the air is so thin that there is very little radiation back to the panel from the CO_2.

As it turns out, in nature the two primary gases in the atmosphere that absorb the most thermal energy, CO_2 and H_2O, also absorb (thus emit) the least amount of energy in the bandwidths that are normal ambient temperatures. Carbon dioxide has two strong thermal energy absorption bands between $4\mu m$ and $5\mu m$, then again between $15\mu m$ and $20\mu m$, with relatively little absorption from $8\mu m$ to $15\mu m$. And H_2O has two strong absorption bands from $5\mu m$ to $8\mu m$ and $13\mu m$ to $22\mu m$, with very little absorption between $8\mu m$ and $16\mu m$ [Hottel, 1927; Salby, 1996].

Now consider the temperatures at which the thermal energy is transmitted. During the summer, with an average nighttime temperature of 290K, the peak thermal energy radiated for this temperature occurs at a wavelength of $9.99\mu m$. During the winter, with an average nighttime temperature around 270K, the peak radiated thermal energy occurs at $10.73\mu m$. Therefore the region of the spectrum that allows the most electromagnetic energy to travel freely through the atmosphere occurs right at the peak range of the temperatures that take place in the ambient.

Thus it is generally accepted that the atmosphere has a spectral window between $8\mu m$ and $13\mu m$. And in this band at atmospheric temperatures, approximately between 27% and 32% of the radiated energy can travel freely through the atmosphere into deep space with very little attenuation. This is the band that has been used in previous work [Parise and Jones, 2000, 2001], and used in this study to show the range of temperature differences that the prototype Earth Cooler^{TM} produced.

Ozone (O_3), which occurs in abundance in the upper Stratosphere, does absorb thermal energy in one narrow band around $9.6\ \mu m$. This does effect the movement of thermal energy through the upper atmosphere, thus reducing the total thermal energy that escapes into deep space by a few percentage points.

There may be some energy transmitted back from the H_2O vapor in the Troposphere, but this is only in particular bands. The high altitude water vapor temperatures are two orders of magnitude higher than deep space (radiation exchange is the difference of the temperatures to the fourth power, making the difference negligible compared to that of the difference with deep space at 4K), and the pressure is reduced. Thus the influence from the H_2O vapor can be neglected.

Although there are slight traces of other molecules (methane, ammonia, etc.), as well as dust, aerosols (hydrocarbons) and the like, the primary components of the atmosphere that influence the radiation transfer of energy with deep space are the CO_2 and H_2O, and these are the only two molecules that will be considered in the model.

The free movement of thermal energy through the atmosphere in this spectral band provides a tremendous resource to be explored as the energy is directed away from the earth's surface into deep space in both cooling purposes: the reduction of global warming and the production of clean, silent, usable energy. The Earth Cooler^{TM} takes advantage of these windows in the atmosphere where the thermal energy travels unadulterated into deep space. These non-absorbing windows in the atmosphere can be very useful for the production of inexhaustible electrical energy as well [Parise and Jones, 2001]. Nature can be very accommodating.

MODELLING APPROACH

A one-dimensional, steady-state thermal model of the Earth Cooler^{TM} is developed to determine the temperature of the top surface, the surface facing deep space, in the terrestrial setting. See Figure 2 for the configuration.

The Earth Cooler^{TM} panel is constructed of sections with two different thicknesses. By calculating the temperature difference between the two surfaces that face deep space, all other thermal effects except the dominating modes of heat transfer, (1) radiation from the top surface, and (2) conduction through the panel from the back, offset one another. That is, convection heat transfer on the bottom surface (facing away from the sky) and the top surface for both the thin and thick sections will be approximately the same since the heat transfer is of the order f(T), and the differences are very small.

Radiation heat transfer from the top surface is of the order $f(T^4)$, and this difference is the driving force for the heat transfer into deep space. The view factor is considered unity. Radiation from the bottom surface will be neglected because the temperatures of the bottom of the panel and the surroundings are of the same order and the difference is very small.

Any radiation from sky components (primarily H_2O and CO_2) to the plate surface is also neglected for two reasons: (1) Lower atmospheric components will be close to the ambient temperature (lapse rate notwithstanding) and the $f(T^4)$ difference will be orders-of-magnitude less than the ambient (270K winter, 290K summer) and deep space (4K) temperature difference.

(2) The concentration of H_2O in the Troposphere is greatly reduced due to the lapse rate. Hence radiation heat transfer is reduced significantly from high altitude moisture. And although the CO_2 concentration remains relatively constant throughout the atmosphere, the radiation back from it can be neglected for three reasons: (i) the CO_2 transmits in a few relatively narrow bands, (ii) the CO_2 temperature difference to the fourth power with the ambient will still be orders-of-magnitude less than the temperature difference with deep space, and (iii) the

concentration of CO_2 is still too low to cause any significant influence. Therefore the radiation from sky gasses back to the panel is neglected.

The top surface temperature difference between the two sections is then calculated for various values of the expected percentage of radiant energy that will leave the top surface of the panel and travel through the atmosphere into space.

EQUATION DEVELOPMENT

For the one-dimensional analysis, heat transfer through the panel thin section is

$$q_{conv1} + q_{condtn} = q_{conv2} + q_{rad2}. \quad (1)$$

Heat transfer through the panel thick section is

$$q_{conv1} + q_{condtk} = q_{conv2} + q_{rad2}. \quad (2)$$

Since the calculation is for ΔT, the temperature difference between section 1, the thin, and section 2, the thick section, the convection heat transfer can be neglected because $q_{conv1} - q_{conv2} \cong 0$. Also, at sections 1 and 2, q_{rad2} is $f(T^4)$ and will dominate at the surface boundary because convection is $f(T)$ and can be neglected. Therefore, equations (1) and (2) become:

$$q_{condtn} = q_{rad2}$$

and

$$q_{condtk} = q_{rad2}.$$

Or

$$(k/\delta)(T_{1tn} - T_{2tn}) = \varepsilon\sigma RAD\%([T_{2tn}]^4 - [T_{sky}]^4),$$

and

$$(k/L)(T_{1tk} - T_{2tk}) = \varepsilon\sigma RAD\%([T_{2tk}]^4 - [T_{sky}]^4),$$

where k, ε, L, δ, are the thermal conductivity, emissivity, panel thickness at the thick and thin sections, respectively; T_{1tn} and T_{1tk} are the panel bottom surface temperatures, T_{2tn} and T_{2tk} are the panel top surface temperatures, at the respective sections; and T_{sky} is the temperature of deep space. The RAD% term represents the total percentage of radiant energy that leaves the panel surface and travels into deep space.

The temperature difference between the top two sections, $\Delta T = T_{2tn} - T_{2tk}$, is then calculated as ΔT (RAD%) and compared with the data.

MODEL PARAMETERS, PROTOTYPE and DATA COLLECTION

The material chosen for the panel has a high emissivity. In the atmospheric spectral window, the average emissivity was measured at $\varepsilon = 0.94$ [Parise, 2001]. The thermal conductivity of the panel is k = 0.2W/mK, an average value for the type of polymer used. The thicknesses of the two sections were chosen at L = 7.9mm and δ= 0.76mm, respectively. The temperature of deep space, T_{sky}, is 4K. The bottom temperature of the panel, T_{1tn}, and T_{1tk}, is chosen as 290K, the temperature of the ambient.

The percentage of radiant energy that travels through the atmosphere into deep space, RAD%, encompasses all the assumptions about the spectral window that exists in the atmosphere between 8μm and 13μm. As calculated previously [Parise and Jones, 2001], this is allowed to vary from zero to about 35% in the model.

The prototype Earth Cooler™ panels were 27.31cm x 27.31cm, and mounted so that air could freely circulate on all surfaces. The surface temperatures were measured with liquid crystal surface thermometers adhered to the two top sections of the different thicknesses. Liquid crystal thermometers are read by noting a color change that represents the temperature. To ensure an accurate interpretation of the readings, four prototype panels were used to duplicate data. The accuracy of the liquid crystal thermometers was ± 0.25C.

The thin section was made thin enough so that the thermal loss from the back surface to the front surface would be negligible and in essence reflect the ambient temperature. A calibrated ambient thermometer was used to corroborate the temperature readings.

The panels were placed outside with a clear view of the sky after sunset, and allowed to thermally stabilize for 45 minutes before data was taken. Such conditions as cloud cover, fog, etc., were noted qualitatively, but relative humidity measurements were not made. The data was then plotted on the curve generated by the model for the different values of the measured temperatures.

RESULTS

The results of calculating ΔT as a function of RAD% from the model, and the data from the prototypes, are shown in Figure 3. Since the temperature readings were within ±0.25C, the uncertainty bars are shown for the data. The temperature difference measured varies anywhere from less than 0.5C up to 4C, as shown.

When the atmospheric conditions were extremely humid (typical for New England fall weather) the panel quickly became covered with moisture. This had a tendency to equilibrate the temperature across the top surface. When the moisture was removed, the temperature difference returned until more moisture collected.

DISCUSSION

For the analysis, the judicious approach of simply calculating the temperature difference at surface 2 (the surface facing the sky) between the thick and thin sections, in effect neutralizes all the other thermal effects at the panel's surfaces except the one dominant boundary condition, the radiation exchange with deep space, and the thermal conduction through the panel from the bottom surface to the top surface. That is, $\Delta T = T_{2tn} - T_{2tk}$. This shows the "insulation effect" from the bottom surface to the top surface through the two different thicknesses of the polymer.

The data was easier to collect when there was less moisture in the air. The information plotted on the figure represents data recorded when there was no moisture collecting on the panel. Therefore the data plot represents information collected over several days with various atmospheric conditions. The atmospheric conditions were not being quantified anymore than relative cloud cover and the ambient temperature. Future work will try to coordinate other conditions such as relative humidity and percentage of cloud cover.

Although using the liquid crystal surface thermometers appeared to be a somewhat crude means to determine surface temperatures of the prototypes, they provided meaningful data and showed the prevailing trends. More accurate temperature readings (RTD or thermocouple) would be needed to generate accurate quantitative data. The liquid crystal thermometers also proved useful in validating the basic assumptions of the theoretical model.

CONCLUSIONS

The model premise that the temperature difference created across the top of the single surface with two different section thicknesses negated the other heat transfer modes at the boundary proved useful in demonstrating the temperature difference that can be created with deep space as a thermal sink.

The data also shows the temperature difference that can be created between objects on the surface of the earth and deep space. Hence this difference can be used to reduce the effects of global warming, and the potential for using deep space as a thermal sink to drive a heat engine to produce electric power is real.

ACKNOWLEDGEMENT

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DEDICATION

The author dedicates this work to his late son Joey. The curiosity of an inquisitive 14-year-old can inspire and motivate a proud parent. Unfortunately, Joey was never able to see the fruition of his father's ranting and raving about the battle against global warming during Joey's long, difficult journey.

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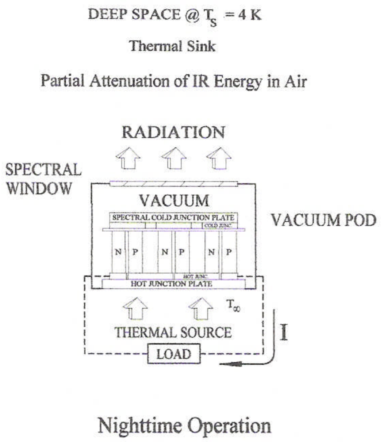

FIGURE 1: Nighttime Solar Cell™ Configuration.

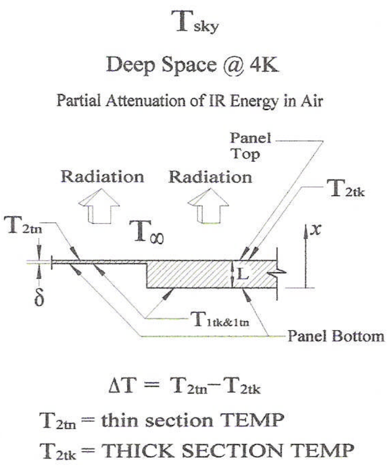

FIGURE 2: Side View of Earth Cooler™.

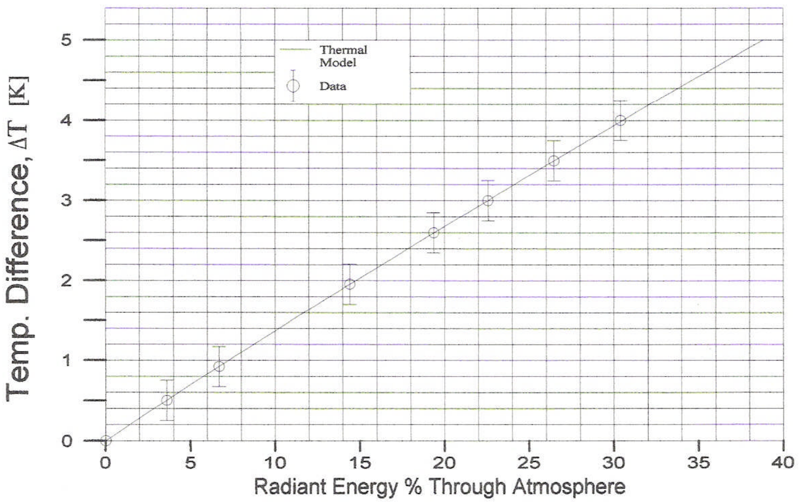

FIGURE 3: Panel Surface Temperature Difference to Predict % Radiant Energy Into Deep Space.