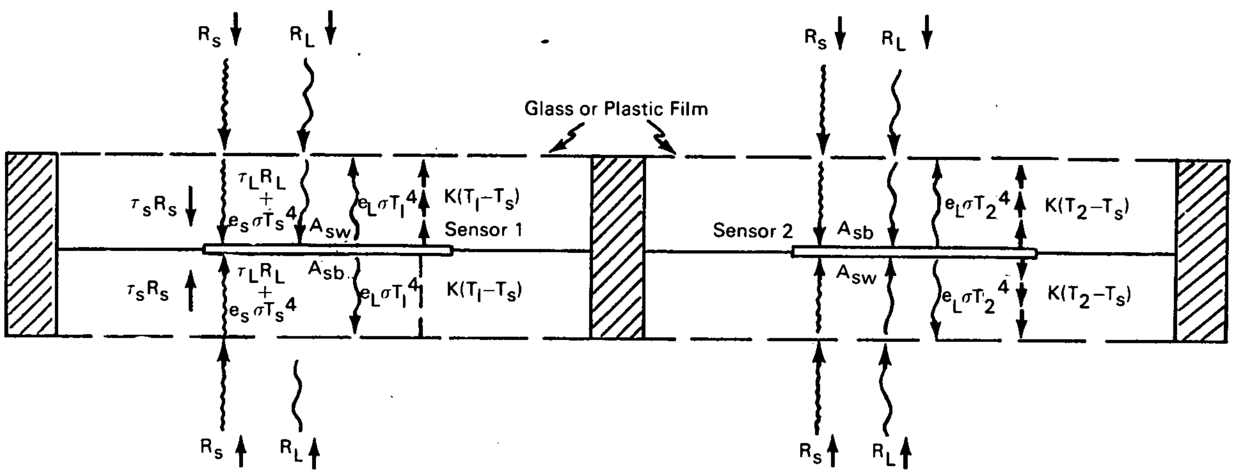
NASA TECH BRIEF

Inexpensive Net Solar Flux Radiometer



An inexpensive instrument has been developed for measuring the net solar radiational flux density through a plane. This radiometer measures the absorption and reflection of solar radiation by opaque and translucent surfaces. Simple surface-coating modifications would permit measurements over selected broad wavelength bands within the solar spectrum. Commercially available instruments of comparable accuracy cost from 10 to 100 times as much as the new radiometer.

The basic instrument consists of two thin sensors of high thermal conductivity upon which the solar radiation is incident from both sides. Opposite sides of the disk-like sensors are coated with materials such as black and white paints having essentially equal infrared (4 to 50 μ) emissivities, but with markedly different broad band (0.3 to 1.5 μ) absorptivities. The sensors are mounted so that one has its low solar absorptivity (A_{sw}) side facing upward and the other has its high solar absorptivity (A_{sb}) side facing upward. Convective-conductive heat losses from the radiationally warmed surfaces are controlled by quarter-inch air layers confined on both sides of the sensing surfaces with thin plastic or glass covers. With this arrangement, heat transfer occurs at the small conductive value associated with still air, rather than at the much larger, fluctuating value of convective transfer. The sensing surfaces are identical on all sides with respect to their average infrared absorptivity (A_L) and emissivity (e_L). The energy gained by absorption of radiation at these wavelengths, therefore, does not contribute to any temperature difference between the two sensors. Since the sensors are very thin and have high thermal conductivity, the temperature difference developed across each one is negligible.

Equating energy gains and losses for sensor 1 at an equilibrium temperature T_1 yields

(continued overleaf)

$A_{sw}\tau_s R_s\downarrow + A_{sb}\tau_s R_s\uparrow + A_L\tau_L(R_L\downarrow + R_L\uparrow) +$
$2A_L e_s\sigma T_s^4 = 2K(T_1 - T_s) + 2e_L\sigma T_1^4.$

The corresponding equation for sensor 2 at an equilibrium temperature T_2 is

$A_{sb}\tau_s R_s\downarrow + A_{sw}\tau_s R_s\uparrow + A_L\tau_L(R_L\downarrow + R_L\uparrow) +$
$2A_L e_s\sigma T_s^4 = 2K(T_2 - T_s) + 2e_L\sigma T_2^4.$

The symbols in the equations are defined as follows:

A_{sw}	av absorptivity of the white surface to solar rad.
A_{sb}	av absorptivity of the black surface to solar rad.
A_L	av infrared absorptivity of the surfaces
e_L	av infrared emissivity of the surfaces
e_s	av infrared emissivity of the convective shield
τ_s	av solar transmissivity of the convective shield
τ_L	av infrared transmissivity of the convective shield
$R_s\downarrow$	solar flux density from the hemisphere above
$R_s\uparrow$	solar flux density from the hemisphere below
$R_L\downarrow$	infrared flux density from the hemisphere above
$R_L\uparrow$	infrared flux density from the hemisphere below
K	thermal conductivity of the confined air layer
σ	Stefan-Boltzmann constant
T_s	convective shield temperature (essentially air temperature)

The net solar radiation, R_s (Net), is obtained by subtracting the first equation from the second and combining physical constants:

$$R_s(\text{Net}) = R_s\downarrow - R_s\uparrow = K_1(T_2 - T_1) + K_2(T_2^4 - T_1^4)$$

Thus, it is only necessary to monitor the temperatures of the two sensors (with thermocouples or thermistors) to determine the net solar radiation.

The last equation can be linearized with tolerable error and the instrumentation simplified by noting that for $T_2 \approx T_1$, $(T_2^4 - T_1^4)$ may be approximated by $C(T_2 - T_1)$, giving R_s (Net) $= K_3(T_2 - T_1)$. The latter equation requires that only the temperature difference between sensors be monitored.

Modification of the basic instrument to include two additional sensors, one white on both sides and one black on both sides, will allow the simultaneous observation of $R_s\downarrow$ and $R_s\uparrow$ as well as net solar radiation. Sensor coatings whose only difference is in their absorptivities in a portion of the solar spectrum will develop temperature differences proportional to the net flux in that portion of the spectrum. For measurements involving small angles of incidence of a substantial portion of the solar energy with the plane of the sensors, it is advisable to replace the flat convective shields with shields having some curvature. Ordinary laboratory watch glass covers have been used successfully to avoid the complications due to the rapidly changing solar reflectivity of glass, and many plastics, at angles of incidence less than 40°.

Notes:

1. Applications of this radiometer are suggested in (a) routine astro-geophysical measurements of the absorption and utilization of solar energy by natural surfaces and atmospheric layers; (b) measurements of solar energy absorbed and reflected by various complex surfaces and materials such as building walls, roofs, and windows; and (c) studies of solar energy utilization by plants and forest canopies.
2. No additional documentation is available. Specific questions, however, may be directed to:

   Technology Utilization Officer
   Headquarters
   National Aeronautics
   and Space Administration
   Washington, D.C. 20546
   Reference: B70-10296

Patent status:

No patent action is contemplated by NASA.

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