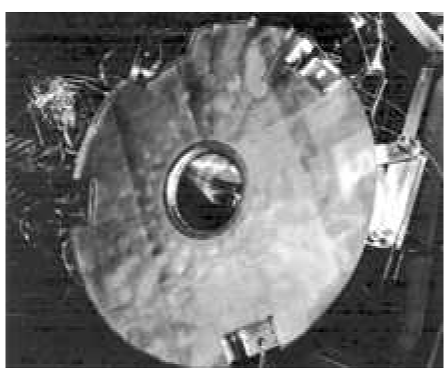
High-Temperature, High-Flux Multifoil Shield Developed for Space Applications

Spacecraft employing solar dynamic power systems typically use parabolic, point focus concentrators to collect solar power and direct it to the aperture of a heat receiver. Solar fluxes several thousand times the intensity of one solar constant are typically produced in the focal plane of such concentrators. Under heat loading this severe, passively cooled surfaces constructed of most engineering materials would rapidly melt. Therefore, high-temperature shielding is required to protect heat receiver surfaces and other spacecraft surfaces that may be exposed to high flux.

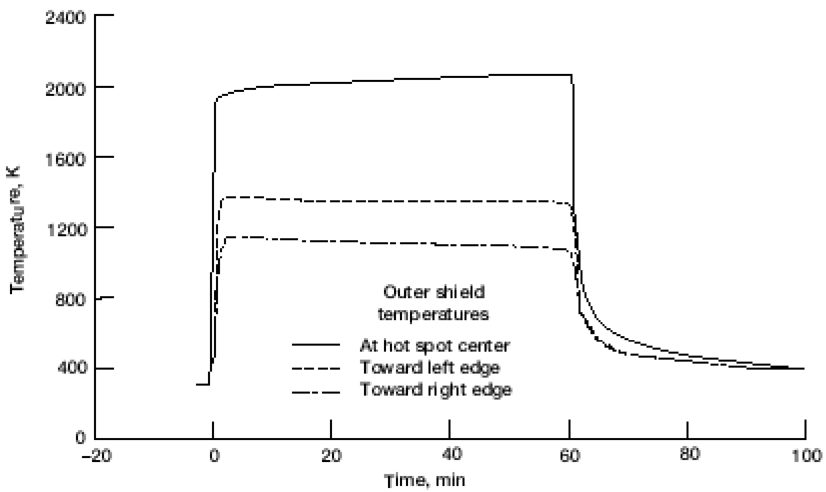
To meet this challenge for the joint U.S./Russian Solar Dynamic Flight Demonstration Program, AlliedSignal Aerospace (ref. 1) and the NASA Lewis Research Center developed a high-temperature, high-flux multifoil shield tolerant of extreme heat loading conditions in a vacuum environment. The shield is passively cooled, obviating the need for pumped fluid loops and/or heat pipe cooling systems with their attendant cost, mass, complexity, and reliability issues.

Only 1 m in diameter, the shield comprises a series of refractory metal foil layers separated by refractory metal screens in the hottest region (closest to the concentrator) and ceramic spaces in the cooler regions (ref. 2). In the hottest outer layers, the foil layers (40 total) and screens are made from tungsten, and the cooler inner layers, from molybdenum. The foil stackup is mounted to a stainless steel backplate that provides for assembly and for structural support for launch loads. The layers are stitched together and mounted to the support plate with tungsten attachment wire. A center supporting ring, 0.24-m in diameter and made of tungsten/25 vol % rhenium, adds structure to the foil stackup and defines the receiver aperture. For thermal growth and fabrication ease, the ring is segmented into eight circumferential sections. The top of the stackup is enclosed by a tungsten screen, which provides support for the attachment wires. At the outer circumference, a stainless steel skirt encloses the outer edges of the foil layers.



Aperture shield test article.

The aperture shield shown in the photo was built and successfully tested at Lewis' Tank 6 thermal-vacuum test facility. This shield survived 1-hr exposures to concentrated solar fluxes up to 800,000 W/m^2. Although a peak temperature of 2072 K was reached, no signs of structural damage were observed after two separate tests. The graph shows outer shield temperatures in the hot spot center and toward its right and left edges during a 1-hr test in Tank 6.



Aperture shield temperature data during high-flux, thermal vacuum testing at NASA Lewis.

On the basis of the outstanding test results and supporting thermal-structural analyses, we believe this shield design is tolerant of heat flux levels many factors higher than those tested. Such high-temperature, multifoil shield designs are not only promising for solar dynamic power system applications but also for solar thermal propulsion, planetary aerobraking systems, and solar probe missions. In all these applications, high-temperature, high-flux, vacuum-compatible shields with low mass, high reliability, and high launch load durability are required.

References

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