Bendix
Aerospace Systems Division

Preliminary Design Considerations for Direct Radiative Thermal (DRT) Control

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PAGE 1 OF 6	
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This memorandum summarizes some of the trade-off considerations necessary in the design of a direct radiator for the ALSEP central station, utilizing second surface mirrors. Recommendations for a baseline design are derived.

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The Direct Radiative Thermal Control for ALSEP will employ second surface mirrors (SSM's) to transfer heat from the thermal plate of the central station to space by radiation. SSM's have an inherently high ratio of emissivity to absorptance and are relatively immune to degradation with the passage of time. The mirrors required are unique in that the transparent material must have a high emissivity, good mechanical properties, and low loss in the ultraviolet, visible, and infrared portions of the solar spectrum. The metallic backing must have good adhesion to the glass, good reflectance (low absorptance), and little degradation of thermal properties over a period of several years.

Two specific materials which appear to be especially suitable for DRT mirrors are Corning VYCOR 7910 glass and General Electric Fused Quartz 101. (VYCOR is 96% silicon dioxide while the quartz is over 99% pure silicon dioxide.)

Since the chemical composition of the two is nearly identical, the specific gravity, specific heat, mechanical properties, and emissivity are almost the same. Other characteristics are compared in Table 1 below.

TABLE 1

COMPARISON OF VYCOR AND QUARTZ

	Average Transmission Loss (1 cm)				Cost (4" x 4")	
Material	UV	Visible	IR	Min. Thickness Available	Rough Cut	Ground and Polished
VYCOR 7910	.18	.01	.03	1/8"	—	$13.75
Quartz 101	.11	.01	.01	1/16"	$13.00	$19.75

The thickness of glass to be used in the SSM's involves trade-off of transmission loss (which adds to the effective absorptance) and weight minimization, against ease of handling and scrappage minimization. Table 2 compares the characteristics of two thicknesses of glass.

TABLE 2

GLASS THICKNESS TRADE-OFFS

Thickness	Increase in Temp. Range Attrib. to Glass	Weight (1.39 ft^2) (Pounds)	Ease of Fabrication	Estimated Breakage
0.02"	2^oF	0.31	Very Difficult	50%
0.03"	3-4^oF	0.47	Tolerable	20%

It should be noted that 1/16" glass was also considered but rejected because of its relative inflexibility, which would result in excessive breakage in vibration testing.

The most common metallic backing materials for mirrors used in space projects are aluminum and silver. Multilayer backings can also be deposited to improve adhesion. The characteristics of three typical coatings are compared in Table 3.

TABLE 3

COMPARISON OF MIRROR COATINGS

Material	Typical Av. Reflectance	Quality of Adhesion	Protective Coating Required	Typical Deposition Cost Per Unit
Aluminum	90%	Good	Yes	$8.00
Silver	96%	Poor	Yes	$8.00
Silver over chromium	94%	Good	Yes	$9.00

There are two principal heat sources within the central station, the Power Conditioning Unit and the Transmitter. This fact introduces another design option. A single radiator can be installed on the thermal plate to handle both sources, or the radiator can be divided into two parts, located for maximum efficiency over the two heat sources.

The advantages of the dual radiator are a more uniform temperature within the central station at any given time and a slightly lower maximum temperature for a given total radiator area. Disadvantages of the dual radiator are the requirement for two dust covers and complications in the design and fabrication of the super-insulation mask.

The mirrors can be mounted directly on the thermal plate, or they can be mounted on a subplate which is then attached to the thermal plate. There are decided advantages to both techniques, summarized in Table 4.

TABLE 4

COMPARISON OF RADIATOR MOUNTING TECHNIQUES

Method	Additional Weight	Risk of Breakage	Series Assembly Time	Clearance of Sunshield
Direct	None	Great*	More than 24 hrs	.065"
Subplate	1.825# (3/32" alum.)	Low	Less than 1 hr	None

*Unless protected by special cover during handling.

The technique used for attaching the mirrors to the radiator plate must meet the following requirements:

1. Secure mechanical attachment of mirrors to plate
2. Low temperature differential between mirrors and plate
3. No degradation over temperature range of 0^{o} to 160^{o}F
4. Permit removal and replacement of individual damaged mirrors.
5. Small additional weight

6. Permit some relative motion between plate and mirrors to allow for flexure of plate and differences in thermal expansion of plates and mirrors

7. Small contribution to thermal absorption.

The only method which complies with all of these requirements makes use of an adhesive to attach the mirrors to the plate.

One adhesive which has been used successfully in this application (on Surveyor) is RTV-11. Because it is a white silicone, the adhesive exposed between mirrors contributes little to total absorption. Its usable temperature range is -75° to $+400^{\circ}F$. It cures in 48 hours at room temperature to the consistency of rubber, permitting plate flexure and mirror slippage with thermal expansion of the plate. A thickness of about 0.005" is required to accommodate the relative motion of plate and mirror. This thickness of adhesive adds a total weight of 0.04 pound and results in an average temperature differential between plate and mirrors of about $0.24^{\circ}F$.

In consideration of the above data, and ignoring such complex factors as heat leak through the thermal bag and super-insulation mask, a preliminary design for the DRT radiator can be proposed. It incorporates the following features:

1. A single symmetrical radiating surface simplifies design and fabrication of the radiator dust cover and the super-insulation mask as well as the radiator itself. Temperature differentials within the central station do not warrant complicating the design.

2. Mirrors applied directly to the surface of the thermal plate. - A sub-plate of sufficient rigidity would add too much weight and would preclude proper clearance between sunshield and thermal plate. This step in manufacturing should be postponed until just prior to acceptance testing to reduce probability of mirror breakage.

3. Mirrors silver plated over chromium sub-layer. - (These should be backed up by aluminum coated mirrors of proven design.) The better reflectance will permit a smaller radiator to be used and thus will minimize the temperature excursion of the central station. Silver, without extensive engineering tests, is a greater gamble.

4. Glass .030" thick. - Thinner glass would be more costly in terms of mirror fabrication time, assembly time, and breakage. Thicker glass is too inflexible to accommodate vibration distortion of the thermal plate without fracture.

5. No holes in mirrors. - Random location of mounting screws in the thermal plate precludes a standardized hole plan for mirrors. Installation of mirrors after integration testing will result in low probability of having to remove a mirror (or several) to gain access to component mounting screws. The required close spacing of access holes would also weaken the mirrors mechanically.

6. Total radiator surface of 1.3 square feet, giving maximum daytime temperature of 104°F and minimum night temperature of 54°F, area to be confirmed by thermal analysis.

7. Mirrors applied with RTV-11 adhesive. - Engineering tests should evaluate other adhesives, such as epoxy, which might have a shorter cure time.

8. Total radiator weight of 0.48 pound including adhesive.

9. Form factor 21" x 8", consisting of 12 pieces of mirror 3 1/2" x 4".

10. Location along front side of thermal plate.

111 Quartz is tentatively recommended for its slightly better transmission characteristics. Rough cut quartz is obtainable at about the same price as VYCOR. However, further investigation of the thermal and transmission requirements should be carried on; substitution of a cheaper grade of glass may be feasible.

12. Total cost of mirrors about $3600, detailed as follows:

144 pieces 4" x 4" quartz @ $13.00	$1870.00
grinding @ $3.00 per piece	432.00
deposition @ $9.00 per piece	1296.00