TECHNICAL REPORT INDEX/ABSTRACT

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ABSTRACT

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ATOMICS INTERNATIONAL <small>A Division of North American Aviation, Inc.</small> TECHNICAL DATA RECORD		NAA-SR TDR NO 7726	APPROVALS <div style="border: 1px solid black; padding: 5px; text-align: center;"> </div>
AUTHOR P. M. Gresho		DEPT & GROUP NO 722-28	PAGE 1 OF 13
TITLE Equilibrium Panel Surface Temperatures in the SNAP-2 Instrument Compartment		DATE 9/14/62 GO NO 7562	RECOMMENDED FOR OUTSIDE DISTRIBUTION ☐ YES ☐ NO
PROGRAM SNAP-2		SUBACCOUNT TITLE Performance Evaluation	
DISTRIBUTION USE AN ASTERISK (*) TO INDICATE THOSE WHO ARE TO RECEIVE COMPLETE COPIES SNAP-2 Standard System Eng. Unit E. Abrams E. Baumeister D. Burgess D. Berman M. Berthold B. Forslund P. Gresho L. James R. Lancet W. Miller J. Stultz J. Crosby R. Kean M. Perlow		STATEMENT OF PROBLEM Determine the equilibrium surface temperatures of the panel surfaces for the SNAP-2 instrument compartment as functions of panel area, emissivity coating, and electrical component heat loads.	
		ABSTRACT By equating net radiation to space to I^2R heating in the instrument compartments, and neglecting internal radiation between compartments, the panel surface equilibrium temperatures were computed for hot and cold temperature extremes. These extremes are defined by: 1) Cold- Pre-start phase in the shade, 2) Hot- Full power phase facing the sun.	
		The results of the heat balances for hottest and coldest cases are presented graphically in Figures one through six. These figures relate the equilibrium surface temperatures to the I^2R heat load dissipated by the panel surface for hot and cold orbits before and after startup. Included as parameters are effective panel area (dependent on Agena-interface design details) and the R/C ratio for the surface coating. If $R/C = .3/.9$ and $A = 1 \text{ ft}^2$, the extremes of temperatures suffered are from -191°F to $+212^\circ\text{F}$.	
		This study shows that the normal R/C surface coating ($R/C = .3/.9$) is acceptable regarding allowable maximum surface temperatures, if the effective panel area is not less than 1 ft^2 . It also indicates that further work is warranted regarding internal radiative distribution of heat in order to limit the lowest temperatures to -65°F .	

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Method of Solution:

The cold orbit is the shade side of a constant-sun constant shade orbit and the following equation applies:

$$\epsilon A \sigma T_c^4 = 8.27 \epsilon A + 3.41 I^2 R, \text{ Btu/hr}$$

where $I^2 R$ is given in watts per panel and the $8.27 \epsilon A$ is the earth thermal radiation (Btu/hr).

The hot panels are those on the sun side of the same orbit, the equation being:

$$\epsilon A \sigma T_h^4 = 470 (\alpha A) + 8.27 \epsilon A + 12.8 + 3.41 I^2 R$$

where $470 \alpha A$ is the sum of direct and reflected solar radiation. The 12.8 Btu/hr accounts for the steady state heat leak per panel (design value) from the APU. (See Reference 1). It is not included in Equation 1, because only the extremes of temperatures were considered. Equation 1, thus, represents the panel temperature on the cold side before startup and, Equation 2 represents the hot side temperature at full power.

Equation 1 is plotted in Figure 1 for values of ϵA from 0.4 to 1.2 ft², covering the range of possible "effective" panel areas. Figures 2 through 6 are plots of Equations 2 for the same range of ϵA and a range of α/ϵ from 0.2 to 0.8.

A quick calculation shows that at these low temperatures, the 0.1" thick aluminum fin (panel surface) will radiate with a fin effectiveness (η) of at least 90%. This number was assumed in the calculations.

Table I indicates the current estimates of the $I^2 R$ losses from each of the 16 panels for both pre-start and steady state conditions. Also listed are the estimated maximum allowable temperatures. Assuming an allowable minimum temperature of -65°F (until proven differently via testing) for all components, sufficient information should be available to estimate the required α/ϵ for the instrument compartments once ϵA is fixed.

Table II, thus, shows the worst cases to be encountered for each of the three maximum allowable temperatures. It is seen that, even though internal radiation was neglected, the tailored R/C coating with $\alpha/\epsilon = 3/0.9$ will limit the maximum temperatures obtained to the allowable values, if the panels can be made such that $\epsilon A \approx 1 \text{ ft}^2$.

It is suggested that the current tailored R/C emissivity coating with $\alpha/\epsilon = 0.30/0.90$ be used on the outside of the panels. The very low equilibrium temperature of $\sim -190^\circ\text{F}$ (Figure 1) for zero $I^2 R$ load indicates that some sort of heating of these cold panels may be required prior to startup. The current method of attack suggested is to coat the inside surface of the instrument compartment with a "high ϵ "

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(.80 or better) coating and the thermal barrier with a low ϵ ($\sim .05$) reflective coating in order to promote internal radiation heat transfer with a resulting "smear" of surface temperatures between the high and low extremes. The details of the radiative heat transfer from each module to all others is worthy of further study and will be done after obtaining the required APU-Agena interface data from Lockheed. Also to be considered in this next study are:

- 1) The effect of tailoring custom coatings as required for each panel surface
- 2) The effect of a more judicious arrangement of high and low ϵ modules to aid in the promotion of internal radiation between modules.
- 3) The effect (thermal, mechanical, and weight) of altering the thermal barrier so as to provide the modules with more direct views of each other.

Appendix:

The effective height of the instrument compartment is currently somewhere between 11" and 13". This height will be fixed by Lockheed's design of the mating ring and is the cause of the uncertainty in discussing the effective radiating area.

Thus,

$$1) 11": (\epsilon A) \text{ min.} = .9 \times \frac{60 \times}{16} \times \frac{11}{144} = 0.81 \text{ ft}^2$$

$$2) 13" (\epsilon A) \text{ max.} = .9 \times \frac{60 \times}{16} \times \frac{13}{144} = .96 \text{ ft}^2$$

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NO. NAA-SR-TDR-7726DATE September 14, 1962PAGE 4 OF 13**TABLE I**

Panel No.	Panel Designation	Power Dissipation, Watts		Maximum Allowable (1) Surface Temperature, °F
		Pre-Start	Steady State	
1	Nuclear Inst./Signal Conditioning	12	12	165
*2	NaK Pressure and Flow	21	21	165
*3	Hg Pressure and Flow	11	11	200
4	Startup Programmer	0	5	165
5	Startup Pump Controller	5	6.5	165
6	Temperature Bridge B	9	9	200
*7	Parasitic Load Controller Phase C	2 ⁽²⁾	45	250
*8	Parasitic Load Controller Phase B	2 ⁽²⁾	45	250
*9	Parasitic Load Controller Phase A	2 ⁽²⁾	45	250
10	Parasitic Load Controller, Discriminator, and Pre-amplifier	2 ⁽²⁾	21	165

* These are the panels with the highest heat loads for given allowable temperature.

1) Minimum temperature for all components = -65°F

2) Ascent amplifiers located on panel back - all other components are on outside Al skin.

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DATE September 14, 1962PAGE 5 OF 13**TABLE I**
(Continued)

<u>Panel No.</u>	<u>Panel Designation</u>	<u>Power Dissipation, Watts</u>		<u>Maximum Allowable (1) Surface Temperature, °F</u>
		<u>Pre-Start</u>	<u>Steady State</u>	
11	Short Circuit Protection Capacitors	2 ⁽²⁾	10	250
12	Short Circuit Protection Capacitors	2 ⁽²⁾	10	250
13	Load Switch	2 ⁽²⁾	5	200
14	Temperature Bridge A	9	9	200
*15	Position Indicator, Signal Conditioner	21	21	165
16	Reactor Temperature Controller	9	10	165

2) Ascent amplifiers, located on panel back- all other components are on outside Al skin.

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TABLE II

Performance of Tailored R/C Coating on Panel Surface ⁽¹⁾

Maximum Allowable Temperature, °F	Maximum Panel Heat Loss for this Temp., Watts	Equilibrium Surface Temp., °F	
		=0.8ft ²	=1.0ft ²
165	21	184	165
200	11	153	140
250	45	240	212

1) $\eta/\epsilon = .3/.9$

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NOMENCLATURE

A_2	Panel area, ft^2
I^2R	Joulean dissipation from electrical components, watts
T_c	Equilibrium cold surface temperature, $^{\circ}\text{F}$
T_h	Equilibrium hot surface temperature, $^{\circ}\text{F}$
α	Solar absorptivity
ϵ	Thermal emissivity
η	Fin effectiveness, assumed = 0.9
σ	$.171 \times 10^{-8}$ Btu/hr ft^2 $^{\circ}\text{R}^4$

References:

1. IOL from R. Welsh to Those Listed, 12-4-61

STEADY-STATE PANEL FOR VIRGINIA
 TEMPERATURE IN FULL SUN

$EA = 0.6 \text{ ft}^2$

K-E 10 X 10 TO THE CM. 359-14
 REUPPEL & EDGER CO. 3071 N. 12

STEADY-STATE PANEL EQUILIBRIUM TEMPERATURE IN FULL SUN

$$\epsilon_A = 0.8 \text{ ft}^2$$

STEADY-STATE PANEL EQUILIBRIUM TEMPERATURE IN FULL SUN

$EA = 1.0 \text{ ft}^2$

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