Internal Report No. 3

Gondola Temperature Study

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Following is a summary of conclusions reached by studying temperature vs time curves of p α e and electron gondola balloon flights; and by calculations. Details of data and calculations are available in a notebook labeled "Temperature Study." (References such as 4:2 refer to section 4 in notebook, page 2).

Chart of Numerical Information p α e

Item	Source
Heat Cap'y	
$C = 7$ k cal/°C	4:1 calculation from weight
$C = 4$ k cal/°C	4:1 lab heat test calc.
Heater Effect	
$\Delta\dot{T}_{htr} = 5^{\circ}$C/hr at 30 W	1:1 66C6P slope change from T curve
$= 7^{\circ}$C/hr at 30 W	4:1 heat test result
$= 4^{\circ}$C/hr at 30 W	4:2 C = 4 heat cap'y calculation
$= 4^{\circ}$C/hr at 60 W (!?)	2:3 67C3P slope change on curve
$= 8$ to 14°C/hr at 60 W	2:2 67C4P slope change on curve
Solar Effect	
$\Delta\dot{T}_{sol} = 3$ to 10°C/hr	2:1 66C4P to 66C5P difference in cooling
$= 4$ to 6°C/hr (AZ)	2:2 67P3P to 67P2P difference in cooling
$= 1$ to 2°C/hr (AZ)	2:3 67C3P slope change of curve
$= 9^{\circ}$C/hr	10:1 calc. from net heat input of sun based on 50 W & C = 7

Chart of Numerical Information p α e (cont.)

Item	Source
Radiation Loss	
$\|\Delta\dot{T}_{rad}\| = 5$ to $6^{o}C/hr$	2:2 67P3P float compared to $\Delta\dot{T}_{sol}$
$= 1 - 2^{o}C/hr$	2:3 67C3P float compared to $\Delta\dot{T}_{sol}$
Convection Loss*	
$\|\Delta\dot{T}_{conv}\| \sim 5^{o}C/hr$	2:1 66C4P & 66C5P slope changes
$= 4^{o}C/hr$ (AZ)	2:2 67P3P slope change
$= 3^{o}C/hr$	2:3 67C3P slope change
Loss thru Ethafoam	
$U \angle 1.5\ W/^{o}C \times (T_{in} - T_{out})$	6:1 calc. based on $0.95\ W/m^{2\,o}C \times 1.6\ m^{2}$
Loss thru Ears	
$U \angle 3/4\ W$	6:1 calc. based on steel screw conductance
Loss during Ascent w/out Sun	
$\|\dot{T}_{asc}\| = -9^{o}C/hr$	1:1 67C2P & 66C6P
$= +8-17^{o}C$	2:1 66C4P & 66C5P
Window Losses during Ascent	
$U/(A\delta T) = 1.5\ W\ m^{-2}\ {}^{o}K^{-1}$	7:3 calculation
$U/\delta T = 2.5 \times 10^{-2}\ W/^{o}K$	
$\dot{T}/\delta T = 4.3 \times 10^{-3}\ hr^{-1}$	
Window Losses due to Rad'n	
$U/(A\delta T) = 0.5\ W\ m^{-2}\ {}^{o}K^{-1}$	7:3 calculation
$U/\delta T = 8 \times 10^{-3}\ W/^{o}K$	
$\dot{T}/\delta T = 1.4 \times 10^{-3}\ hr^{-1}$	

*Convection was assumed to be "that factor which, present and dominant during ascent, is not present at float altitude."

Chart of Numerical Information E gondola

Item	Source
Heat Cap'y	
$C = 22 \text{ k cal}/^{o}C = 90 \frac{kW - sec}{oC}$	5:1 calculation
Heater Effect	
$\Delta\dot{T}_{htr} = 1\text{-}2^{o}C/hr$ at 60 W	1:3 67P1E, 67P3E
$= 2\text{-}3^{o}C/hr$ at 60 W	5:1 heat cap'y estimate from wattage
Solar Effect	
$\Delta\dot{T}_{sol} \sim 3^{o}C/hr$	2:4 67C1E compared to 2E, 4E
$\sim 3^{o}C/hr$	10:1 based on 70 W (and heat cap'y) from solar effect estimate
Radiation Loss	
$\Delta\dot{T}_{rad} \sim 1^{o}C/hr$	p α e average of $\sim 3^{o}/hr$ scaled by $\frac{A_e}{A_{p\alpha e}} \times \frac{C_{p\alpha e}}{C_e} = \left(\frac{2.5}{1.6} \times \frac{5}{22}\right)$
Convection Loss*	
$\Delta\dot{T}_{conv} \sim 1\text{-}2^{o}C/hr$	scaled from p α e by $\left(\frac{2.5}{1.6} \times \frac{5}{22}\right)$
Loss thru Ethafoam	
$U < 2.4 \text{ W}/^{o}C \times (T_{in} - T_{out})$	6:1 calc based on 2.5 m^2, 0.95 $W\, m^{-2}\, {}^{o}C^{-1}$
Loss thru Ears	
$U < 3/4 \text{ W}/^{o}C \times (T_{in} - T_{out})$	6:1 calc based on steel screw conductance
Loss during Ascent w/out Sun	
$\dot{T}_{asc} = -4^{o}C/hr$	2:4 67C2E & 67C4E
Variation of Float Loss/Gain in Sun	
$\dot{T}_{float} = 0 \pm 3^{o}C/hr$	1:4 67C1E

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*Convection loss has been taken to be "that loss which, dominant during ascent, disappears at float."

Chart of Numerical Information   E gondola

Item	Source
Window Loss during Ascent	
$U/(A\delta T) = 1.5\ W\ m^{-2}/^{o}K$	
$U/\delta T = 3.2 \times 10^{-2}\ W/^{o}K$	7:1 calculation
$\dot{T}/\delta T = 1 \times 10^{-4}\ hr^{-1}$	
Window Loss due to Rad'n	
$U/(A\delta T) = 0.5\ W\ m^{-2}/^{o}K$	7:1 calculation
$U/\delta T = 1 \times 10^{-2}\ W/^{o}K$	
$\dot{T}/\delta T = 3 \times 10^{-5}\ hr^{-1}$	

Qualitative Conclusions

Consideration of the 66C1P flight which had one inch of ethafoam insulation [3:1] indicates that most losses are thru ethafoam. This conclusion is verified by the calculations of heat loss thru Aℓ ears on base plate [6:1] and thru windows [7:2]. The temperature gradient which exists between top and bottom panduxes of the electron gondola would seem to argue in favor of large losses thru base plate; however, the fact can be explained on the basis of settling of cooler air especially in view of the fact that the gradient was no less in the upside down flight. Thus a third inch of ethafoam might be expected to cut losses by almost 1/3.

Sixty watts of heater necessary and sufficient for p α e [1:2]. Furthermore 60 W are not sufficient for E gondola [1:4 and others]. Heater should be pro-rated to surface area - about 90 W for E gondola.

Overheating due to the sun did not occur or threaten in p α e or E gondola. On the average the sun just compensates radiation losses; it can for limited amounts of time overpower them [see summary "Variation of Float Loss/gain in Sun"] (in 67C2E it overpowered by 3°C per hour for 7 hours but this started from ~0°C). However, it seems that overheating is unlikely but with a flight like 67C2E it is hard to say what the sun would have done had there been effective heating aboard.

The window is not the major source of loss [7:2]. However, for a gondola with a large window such as $E^{\pm}$, it might be worthwhile to improve the window's thermal resistance by

(1) Aluminum cover over outside of window in ethafoam (painted white on outside) [7:2]

(2) Intermediate paper barrier to break up dead air space

Making sure that dead space is not thereby made air-tight

Pressure dependence of convection may be as weak as $P^{1/4}$ [9:1]

66C4P - C5P seem to show convection up to 10 MB pressure [2:1]

Contents of Gondola Temperature Study Notebook

Part I

Table of contents, flight summary, temperature conversion, sources for graphed information.

Part II

p α e flight graphs

Part III

E flight graphs

Part IV

Misc. results of earlier investigations, but including surface area established for p α e

Part V

Sections referenced in conclusions

1 Heater effectiveness
2 Solar heating
3 Insulation
4 Heat capacity of p α e
5 E gondola heat capacity
6 Heat loss mechanisms
7 Heat loss from window
8 Solar heating calculation
9 Pressure dependence of convection
10 Heat input effectiveness

Part VI

Conclusions