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PRELAUNCH THERMAL ANALYSIS OF KSLV-I PAYLOAD FAIRING

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ABSTRACT

Prelaunch thermal analysis of the KSLV (Korea Space Launch Vehicle)-I PLF (Payload Fairing) was performed to predict maximum/minimum liftoff temperatures and to evaluate of air conditioning performance. Prelaunch thermal analysis includes internal air conditioning effect, external convective heating/cooling, radiation exchange with the ground and sky, radiation between spacecraft and PLF, and solar radiation incident on PLF. Analysis was performed at two extreme conditions, hot day condition and cold day condition. The results showed that the maximum liftoff temperature was 53°C and the minimum liftoff temperature was −3.8°C. It was also found that conditioned air supplying, in 20 ± 2°C and 1200 m^3/hr, is sufficient to keep the internal air in required temperature range.

Keywords: prelaunch thermal analysis, KSLV-I, thermal radiation, air conditioning, liftoff temperature

1. INTRODUCTION

Before the flight, space launch vehicle is set up a few days at launch pad to check process and to supply fuels, etc. During the prelaunch process, the payload is exposed to the thermal environments conditions such as incident solar radiation, external/internal convection and radiation exchange with ground & sky. In order to protect the payload from the thermal environment, the temperature controlled air should be supplied to the payload. Through the prelaunch thermal analysis, the maximum/minimum liftoff temperatures can be predicted and the air conditioning performance can be evaluated.

2. THERMAL ENVIRONMENT FOR PLF

2.1 Convection Effects

Air conditioning system provide internal forced convection to the PLF. Heat transfer coefficient of 3.97 W/m^2K or somewhat less are commonly used in the previous design (Oh 1995). External convection due to wind depends on air temperature and wind velocity. Average wind speeds at the

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Table 1. Hot and cold day conditions.

	Solar Flux (W/m^2)	Air Conditioning Inlet Temp.(°C)	Day of the Year	Absorptivity
Hot Day	Max. 1420	22	July 23	0.433
Cold Day	No Flux	18	January 24	-

launch complex located in Oenarodo is 4m/s (Min 2003) with the heat transfer coefficient of 7.61 W/m^2K.

2.2 Sky and Ground Radiation

Thermal radiation exchange between the PLF and the surrounding ground & sky can be considered when the radiation view factor and temperatures are known. The ground temperature is assumed to be the same as the air temperature and the effective sky temperature is calculated by using Swinbank equation (Oh 1995).

$$T_{sky} = 0.0552(T_{air} + 273.15)^{1.5} - 273.15 \qquad (\text{in } ^\circ\text{C}) \tag{1}$$

2.3 Incident Solar Radiation

Solar radiation incident, S^*, on the PLF depends on the direct normal incident solar flux S and the solar incidence angle i. The solar radiation on the PLF is given by $S^* = S_{cos}(i)$

Incidence angle depends on time, day of the year, surface azimuth angle, surface elevation angle, latitude, and longitude. We developed a program, SfluxE, which calculate S^* and the result of SfluE has a good agreement with result of INCFLUX1, which was used for Delta II prelaunch thermal analysis.

3. CONDITIONS FOR PRELAUNCH THERMAL ANALYSIS

The conditions of analysis are obtained for Oenarodo launch complex. Two extreme conditions, hot day and cold day, are used for prelaunch analysis. The hot day condition is the combination of the hottest external air temperature and the maximum incident solar flux, while the cold day condition is for the coldest air temperature and no solar flux. These two conditions are shown in Table 1.

Figure 1 shows the diurnal variation of external air temperature and effective sky temperature for the hot and the cold day conditions. Figure 2 shows the variation of incident solar flux on the nosecap of the PLF for the hot day as the surface azimuth angle.

4. RESULTS

Prelaunch thermal analysis of KSLV-I PLF is conducted with a general thermal & flow Analyzer, Sinda/Fluint. For the validation of KSLV-1 modeling, the prelaunch analysis for the PLF of Delta II was performed and compared with the Delta II report. The skin temperature of Delta II and internal air temperature for the hot day are shown in Figure 3 and Figure 4. The two results show a good agreement within 5°F difference.

4.1 Hot Day Result

The temperature histories of the outer surface of the nosecap, nosecone and cylinder sections are shown in Figure 5 for the hot day condition. The maximum temperature is 53.0°C at approximately 14 hours on the nosecap surface of azimuth angle 285°. The temperature histories of the internal air are shown in Figure 6 at the position of the nosecap, nosecone and cylinder section of the PLF.

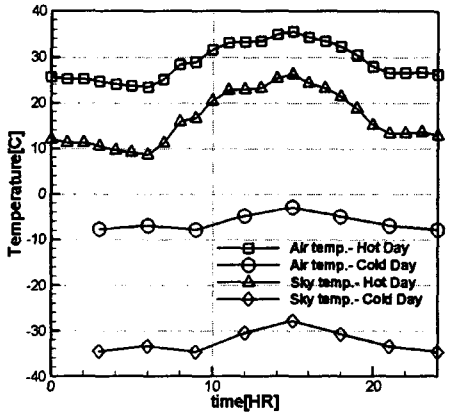

Figure 1. Air & Sky temperature.

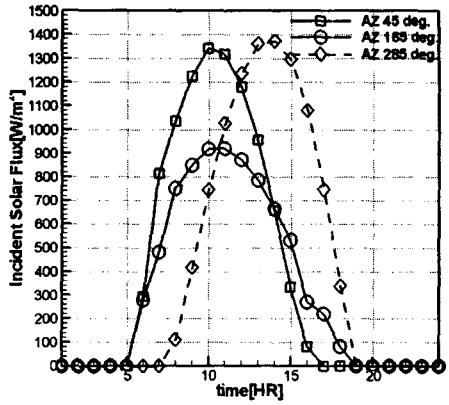

Figure 2. Solar flux on the nosecap.

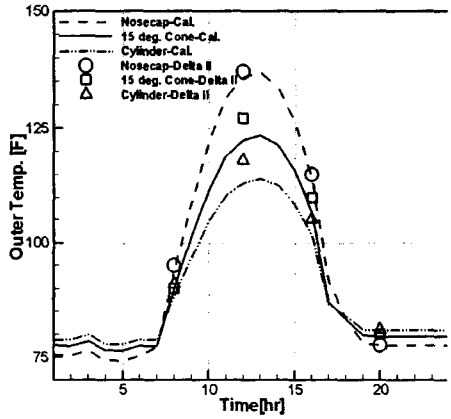

Figure 3. Skin temp. of Delta II PLF.

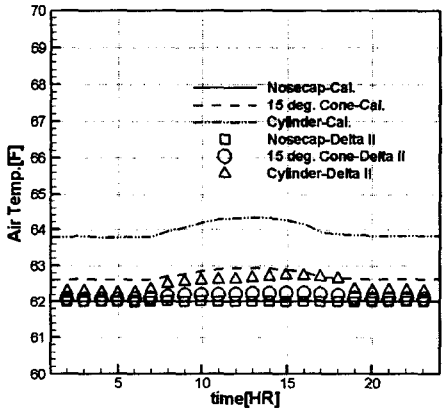

Figure 4. Internal temp. of Delta II.

The supplied air temperature is 22°C. The maximum air temperature is 27.2°C at the end of cylinder section, which is belower than the maximum allowable temperature of 30°C.

4.2 Cold Day Result

The cold day results are shown in Figure 7 and Figure 8. The minimum temperature of the skin is −3.8°C. The supplied air temperature is 18°C. The minimum temperature is 11.1°C at the end of cylinder section, which is above the minimum allowable temperature of 10°C.

5. CONCLUSIONS

Prelaunch thermal analysis of the KSLV-I PLF was performed to predict the maximum/minimum liftoff temperatures and to evaluate air conditioning capability.

(1) The maximum liftoff temperature at hot day condition is 53°C and the minimum liftoff temperature at cold day condition is −3.8°C.

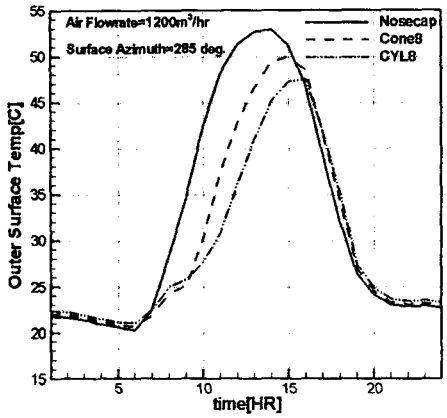

Figure 5. Outer surface temperature of PLF at hot day.

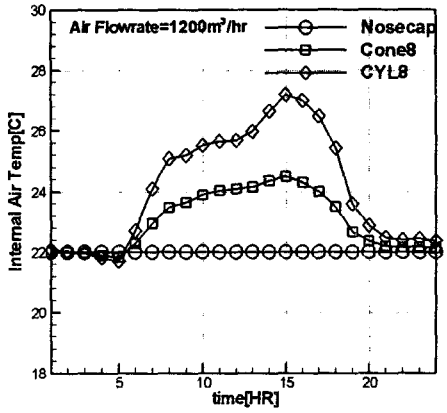

Figure 6. Internal air temperature of PLF at hot day.

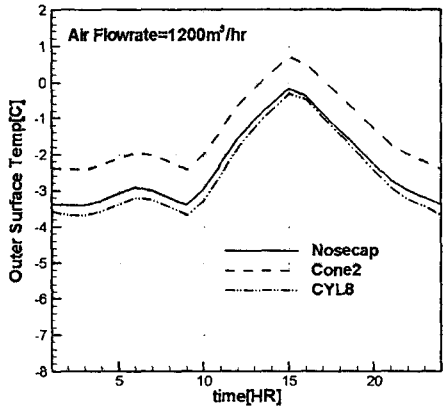

Figure 7. Surface temp. at cold day.

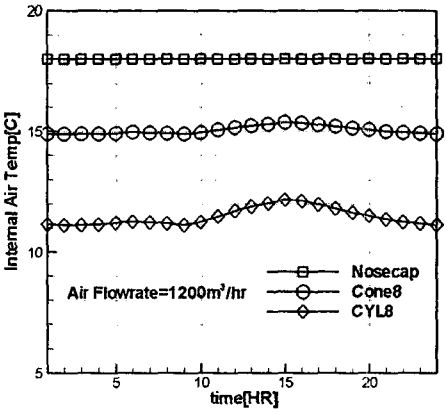

Figure 8. Internal air temp. at cold day.

(2) At supplied air temperature 20 ± 2°C, outlet air temperatures are 27.2°C for the hot day and 11.1°C for the cold day. Air flow rate of 1200 m^3/hr is adequate for the proper thermal control at both hot and cold days.

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