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Gravity Probe B Relativity Mission

Flow Meter Verification

(PL Ver II)

S0547, Rev. -

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ITAR Control Req'd? ☒ Yes ☒ No 3/7/02

Purpose:

This document clarifies the verification tests performed in Payload Test II regarding the Flow Meter. The calibration of the Flow Meter was accomplished using GSE tests. The performance of the Flight ECU was then verified at a single point using the parameters developed in the GSE calibration tests. The results of the ECU tests was compared to the GSE tests and and found to be within 5% of the GSE generated curve.

Requirement:

PLSE-12 #	Title	Requirement	Method	Compliance Data
3.7.5.11.2	Flow Meter	A flow meter shall be provided for measuring the helium flow rate to the spacecraft thrusters while in orbit, to within +/- 5% of its true value.	I,T	P0841 SMD Flow Meter Calibration was run in PL Phase B. The intent of this requirement is a calibration exercise of the flow meter.-

Acronyms and Abbreviations

GP-B – Gravity Probe B
GSE – Ground Support Equipment
LM, LMMS, LMSC – Lockheed Martin (by various current and old names)
SMD – Science Mission Dewar
ECU – Experiment Control Unit
mW - milliwatt
He - Helium

Discussion

The Flow Meter was calibrated using the cryogenic GSE over a number of flow ranges and heater power inputs. This data was obtained on 7/9/01 and is shown in the plot of Figure 1 - SMD Flow Meter Calibration using GSE Compared to ECU Data. The heater input powers used was 80.7 and 106.8 milliwatts. Quadratic curve fits were made and resulted in the following:

Power = 80.66 mW
Mass Loss = 0.0501*T^2 - 2.153*T + 25.808

Power = 106.8 mW
Mass Loss Rate = 0.0329*T^2 - 1.794*T + 27.243

In which “T” represents the temperature difference in degrees Kelvin between the flow meter temperature sensors, T18D or T19D, and the top of the main tank, T10D or T11D.

The effect of changing the power level for a given mass flow rate of 3.25 mg/s was made and the results were shown in the plot of Figure 2 - Temperature Difference vs. Heater Power for Mass Loss rate of 3.25 mg/s (1.07 slpm flow). A linear fit to the data gives:

Temp = 0.1943*Power (mW) + 2.704 (mW)

ECU data was obtained for a single flow rate of 3.25 mg/s using approximately 80 mW power input to the heater. This data is plotted in Figure 1 for the flow meter temperatures, T18D and T19D, and using two base temperatures taken from T10D and the initial flow meter temperature. The spread of this data from the GSE data is approximately +/- 5%.

Results:

Table 1 – Flow Meter Mass Flow Rate Percent Difference

ECU Mass Loss	delta T	Mass Loss mg/s (80 mW)	ECU % Difference
9.456	9.597	9.760	-3.2%
9.456	9.485	9.894	-4.6%
9.517	10.207	9.052	4.9%
9.517	10.314	8.932	6.2%
9.517	9.869	9.440	0.8%
		Absolute Average =	+/- 3.9 %
		STD =	0.001657

Conclusions:

Using the GSE the SMD flow meter was calibrated and then compared to a single point for the ECU. This resulted in good, ~ 5%, agreement and will provide the requisite on-orbit data for end-of-life forecasting. A heater power input of 80.7 mW was found to give good results and must be used for flight data acquisition in order to use the calibration curve given here.

Figure 1. SMD Flow Meter Calibration using GSE Compared to ECU Data
7/9/01 and 7/12/01

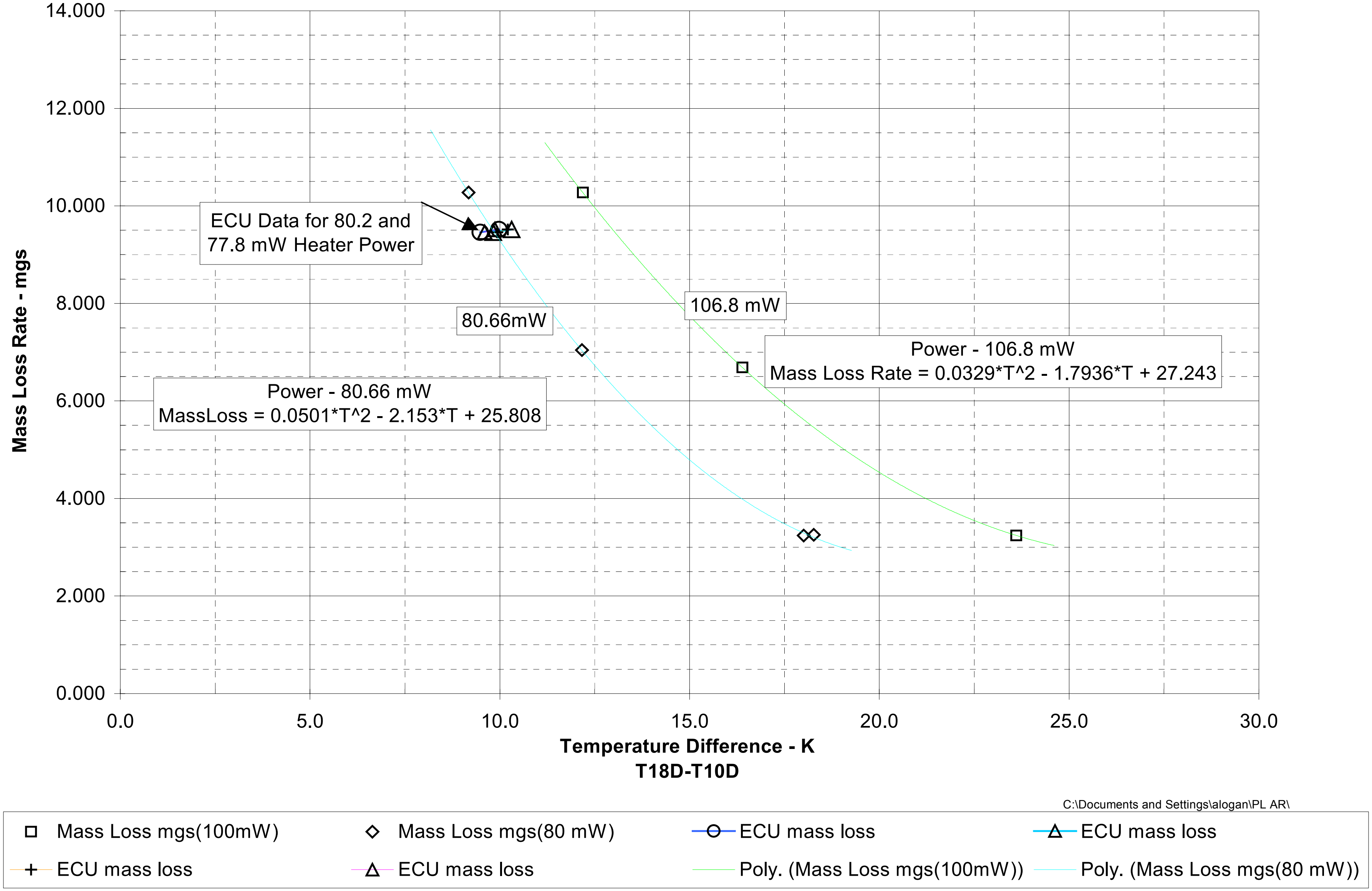

Figure 2. Temperature Difference vs Heater Power for Mass Loss rate of 3.25 mg/s (1.07 slpm flow)