SPIRE CQM2 Thermal Test Results Memo

THERMAL ENGINEERING GROUP				
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SPIRE PROJECT				
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1. Scope

This memo is looking at a possible new explanation for the inconsistency observed in the SPIRE instrument temperature readings during the CQM2 thermal balance test campaign in September 2004.

2. Background

The graph below is an example of the discrepancies observed on the instrument L1 temperature stage during the testing. The temperatures measured at the cryostat L1 interfaces (described by the green curves) appears to run warmer than others parts of the instrument, like the mechanisms and mirror.

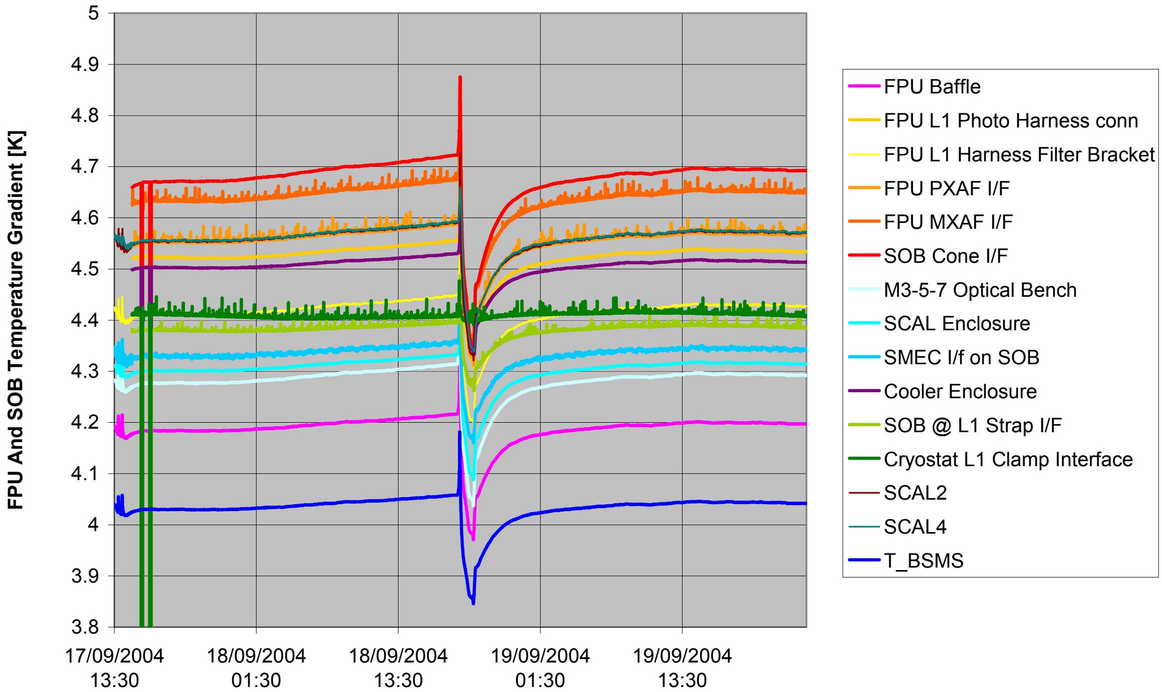

Figure 1 - SPIRE Level-1 Temperature during Cooler Hold Time Thermal Test [CQM2 Test Campaign]

A possible clue as to what could be happening is the fact that the FPU Baffle and BSM temperatures were running at 4.2K or less[1]. It was initially thought that the baffle may have a view to the L0 pot at 1.7K. In addition, it was found that the BSM temperature sensor calibration was only made of a few points around 5K. Finally, the temperature at the L1 cryostat interface (dark green curve) was itself running warmer than the temperature at the instrument SOB L1 interface. From these observations, it was concluded that the two L1 EGSE temperature sensors were at fault. Possible causes envisaged at the time were that they were not heat sunk properly and/or that their calibration was not accurate or had shifted.

[1] This is unrealistic as the cryostat L1 stage cannot be cooler than 4.2K.

Another possibility which had not been envisaged at the time is: could it be that all temperature readings from the flight temperature sensors are inaccurate? This aspect has since been looked at in more details and some new evidences emerged, as described in the following paragraphs.

3. Flight Temperature Sensor Analysis

To have a better idea of what could be happening with the flight temperature sensors, it was suggested that the flight and EGSE temperature sensors data be plotted on separate graphs. In addition, a set of temperature data where the L0 stage of the instrument had been warmed-up to 4K has been used for this analysis. This allows to discard any possible radiation exchange between the FPU baffle sensor and the cryostat L0 pot. This also allows to more or less discard any error due to the sensor self-heating (which is less predominant at these temperature range).

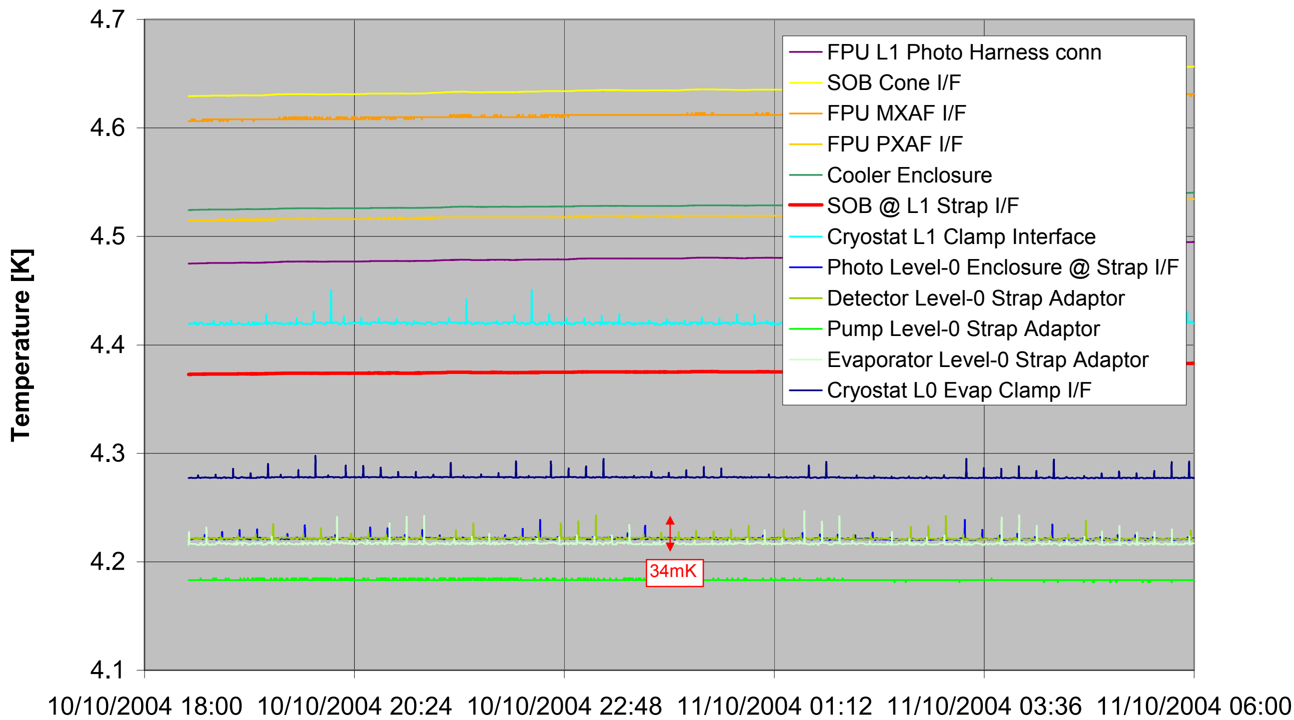

Figure 2 - SPIRE EGSE L1 and L0 Temperature Sensor with L0 Stage warmed-up to 4K

Figure 2 describes the instrument L1 and L0 temperature profiles when read out with the EGSE sensors only. The red curve corresponds to the L1 cryostat interface temperature at the SOB and can be used as a reference (it should be the coldest part of the instrument but no less than 4.2K). The following observations can be made:

- With the exception of the sensor at the cryostat L1 interface (which reads warmer than the SOB L1 interface temperature), all others L1 temperatures appear consistent.
- The temperature sensors on the L0 photometer enclosure and on two of the L0 strap adaptor run at the same temperatures. One would expect this behaviour, as the L0 cryostat temperature stage had been warmed-up to 4K during this test.

- The only questionable temperatures are:
  - The one measured at the L0 pump strap adaptor, which seems to be running cooler than the other ones by 34mK.
  - The one measured at the cryostat L0 evaporator interface, which runs warmer than all the other temperature sensors at L0.

Using a similar approach, Figure 3 below describes the instrument L1 and L0 temperature profiles when read out with the flight temperature sensors. The red curves (from EGSE sensors) are used as reference for the instrument L1 interface temperatures at the SOB, at the pump L0 strap adaptor and at the evaporator L0 strap adaptor.

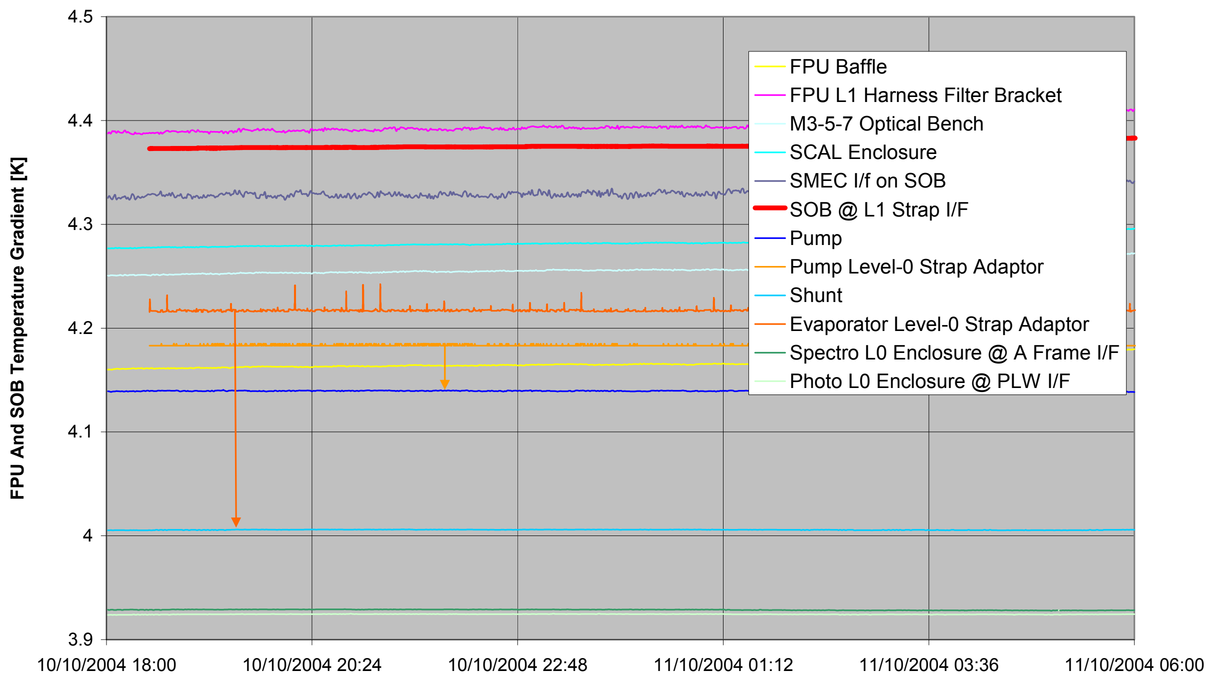

Figure 3 - SPIRE Flight L1 and L0 Temperature Sensor with L0 Stage warmed-up to 4K

The following observations can be made:

- With the exception of the FPU filter bracket, all flight temperature sensors are reading cooler temperatures than at the SOB L1 interface (top red curve),
- Both L0 enclosures (green curves) seems to run at identical temperatures, which would be as expected except that again, they run a lot cooler than the instrument L1 interface temperature which cannot be lower than 4.2K,
- The pump temperature (dark blue curve) which is thermally coupled to the L0 pump strap adaptor is cooler than the strap itself (as indicated by the arrow to one of the red curve),

- The shunt temperature (medium blue curve) which is thermally coupled to the L0 evaporator strap adaptor is again cooler than the strap itself (as indicated by the arrow to the other red curve),

- Finally, the FPU baffle temperature is again reading lower than 4.2K despite the fact that the L0 pot is now at ~4K instead of ~1.7K (therefore eliminating any possibility of radiative exchange between the two).

From these observations, it appears that all flight temperature sensors may have a tendency to read lower temperatures by about 0.3K.

4. Discussion

Until then, the EGSE temperature sensors were thought to be at fault. These news observations and initial conclusion mean that this issue of inconsistent temperature readings remains open and that further investigation is required. New possible sources of errors in the flight temperature sensor readings have therefore been considered and/or re-evaluated in more details:

- Sensor Integration Method

The sensors integration method could only introduce self-heating error: this would add a positive offset to the temperature readings rather than the negative one currently observed. In addition, all sensors on the L1 stage of the instrument are unlikely to see any parasitic load, as the harness is isothermal.

- Sensor Calibration

Most flight sensors have been calibrated by Lakeshore. The calibration is therefore probably not the real problem, unless the sensor calibrations have shifted with time and/or handling.

- Temperature to Resistance Transfer Function

The temperature to resistance transfer function for the baffle sensor was looked at in more details. The table below provides an overview of the resistance versus temperature for the operating range we are concerned with.

Temperature	**Resistance**	**Delta Resistance**	**Delta Temperature**
K	Ohms	Ohms	K
3.99492	406.169	-	-
4.19771	394.887	-11.3	0.20
4.6074	375.025	-19.9	0.41

Table 1 – Baffle Temperature Sensor Temperature to Resistance Transfer Function Analysis

One can see that at these temperatures, an additional 20 ohms in the resistance measurement can introduced a negative temperature offset up to -0.4K. As the flight software is using a DC measurement, any DC offset on the sensor voltage lines would not be compensated for. Could this be the explanation and how could we check it?

5. Way Forward

If a DC offset is present on the flight sensor voltage lines and is important enough to affect their temperature readings (this is highly dependent on their temperature versus resistance transfer function), then a possible way to check/confirm this would be by monitoring the redundant side of the flight temperature sensors on an AC Bridge during the next thermal balance test campaign.