ATLAS FCAL Internal Note
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24-27 February 2004, Preliminary
16 March 2004, Final
Last update: 5 April 2004 (Fig.5 added)

A summary of heat flow measurements during the ATLAS End-Cup-A cold test[1]

The variations of temperature along the cold and warm tubes during the heat leak test indicate that there is a major heat leak in the region of the bellows. The variations along the cold tube are so large it is difficult to estimate the heat leak in the vicinity of the FCAL. One can say with some confidence that the leak is less than 20 Watts/sq m and more likely to be in the region of 10 Watts / sq m.

1. The set-up

A total of 63 PT100 temperature probes were installed in the cryostat (20) , on the FCAL cold tube (8) , FCAL warm tube (18) and on the cryostat outer surface (17). Fig. 1 shows, schematically, the positions of the probes relevant for our measurement. The PT100 read-out controller was connected to a standalone laptop PC running a DAQ application under Windows 98. The temperatures were recorded every 2 minutes.

The DAQ also monitored the kapton heaters of the warm tube, by sampling their status (on/off) every 1 s. The power of each heater during the test was about 40 W (25 VAC, ~1.6 A). The duty cycle of the heaters, as well as the heater voltages and currents were also monitored my analog meters and a chart recorder.

The warm tube was closed at both ends by thick plugs equipped with rubber padding, to prevent air flow through the inner warm space during the measurements.

2. The measurements

The cryostat cooling started on Monday, February 16th, with the heaters keeping the warm tube temperature between 6 and 10°C. By Monday morning (23-Feb) the cooling was finished and we started increasing gradually the heater temperatures: 12/16°C at 10h14, 14/18°C at 16h10 and, finally, 17/21°C at 20h34. The plan was to set 20/24°C at ~2 am and continue till Tuesday morning, then stop the heaters and monitor the temperatures evolution throughout the day. Unfortunately, this plan was compromised by a power cut which occurred at ~23h on Monday. Both DAQ and the heater power supply stayed down till Tuesday morning.

[1] A full report can be found at: http://atlas-fcaltb.web.cern.ch/atlas-fcaltb/Memos/Hardware/Heatleak test/StatusReport.doc

No time remained for slow heating and stabilization, so we proceeded with 3 quick steps up (21, 40 and 60°C in the central part of the warm tube) during the day on Tuesday (24-Feb), then stopped the heaters and watched the temperature drop in the FCAL tubes overnight, till the scheduled end of the cold test, on Wednesday morning (25-Feb).

Thus, we accumulated data: a) on temperature distributions in the FCAL tubes in a stable regime, with the warm tube kept at an ambient temperature (Fig. 2) and b) on the temperature evolution in the inner warm space during cooling-down without heaters. One night was not sufficient to reach equilibrium temperatures, however the analysis of the trends permitted to estimate their values (Fig. 3).

The mean (duty-cycle corrected) power of the heaters measured during the last two days of the test is shown in Fig. 4. The total mean power did not exceed 8 W, with the warm tube temperature of up to 21°C.

3. Summary

- *Heat leak is below a critical value for the FCAL.*

The heat generated by the heaters was around 8 watts when the warm tube was kept at a temperature between 17 and 20°C. If we consider that this flows over 0.6 sq. meters[2], heat flow is 13 w/m^2. By prorating the measurements to the real temperature differential of 200°K (with a crude linear model) we get values ranging from 8-12 W/m^2 with a high value of 19 W/m^2 closer to the bellows. This is less than the 75 W/m^2 limit we set, so we can probably say that there doesn't appear to be a problem in the FCAL region.

- *The leak is mainly in the region of the bellows in the rear part of the cryostat.*

The temperature of the cold tube strongly increases towards the vicinity of the bellows. This may be due to heat transfer at the bellows or simply because the super-insulation (SI) only goes about 10 cm from the spacer in the direction of the bellows. This could well allow an easy path for heat to travel around the insulation and across the spacer. There can also be a localized heat leak "channel" around the warm tube probe 49, which was always colder by 6°K than the probes 33 and 45 located nearby. The clearance between the warm and cold tubes at the bi-metallic junction is not protected by the SI and is particularly tight. The situation during the cold test was aggravated by the probe cables stuffing this gap, see Fig. 5.

- *The forward (wide) part of the warm tube is difficult to keep well above 0°C with existing heaters.*

This matter was discussed with P. Fassnacht and A.Falou and they admitted that this is a serious issue. Proposals like adding an extra heater to that region (and re-distributing more evenly the heating power) or blowing a dry nitrogen through the warm tube during the beam operation were expressed.

[2] The area of the narrow part of the warm tube is ~0.6 m^2 (the diameter ~10 cm and the length is ~190 cm.

Figures

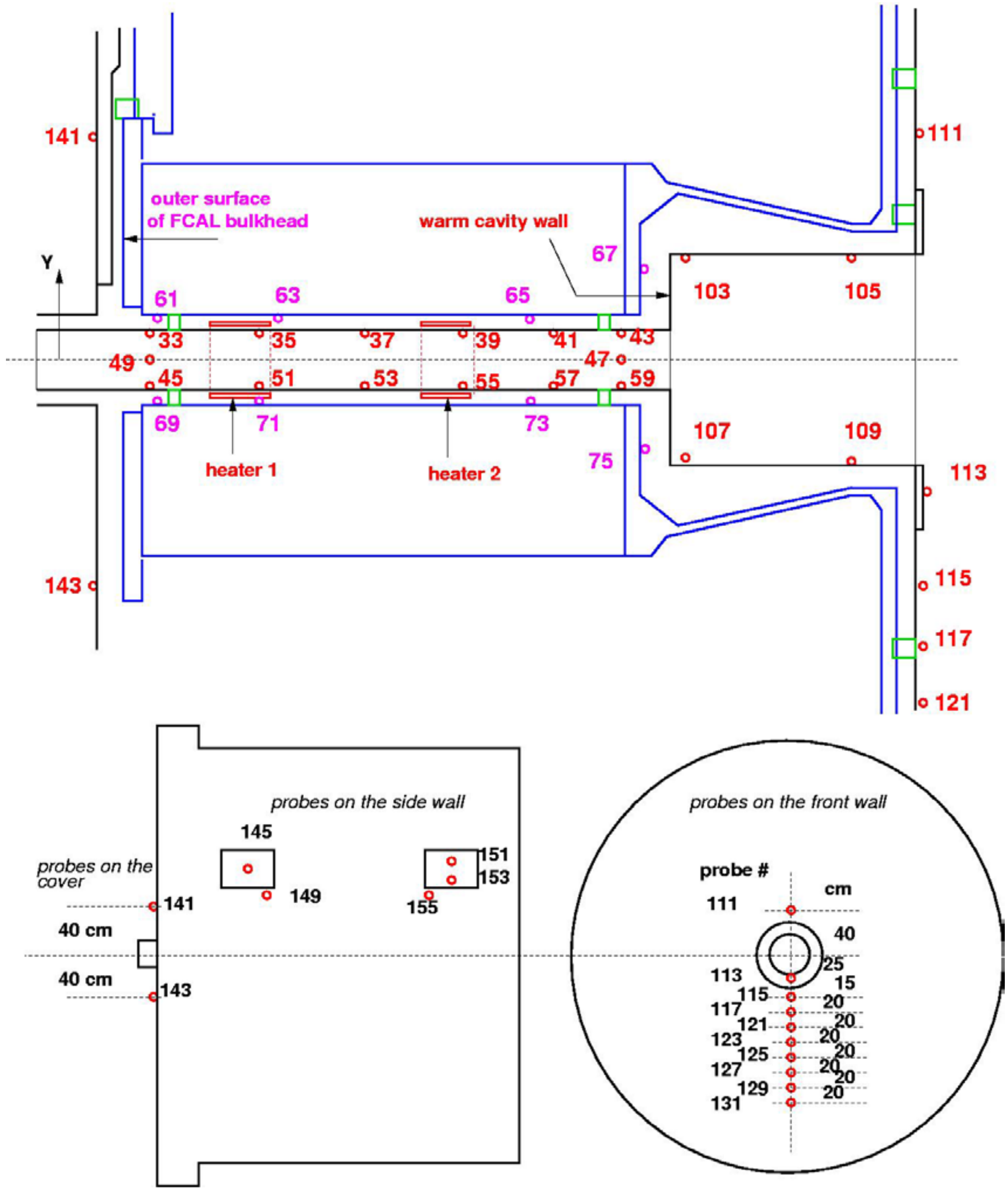

Figure 1: Locations of the PT100 sensors installed on the FCAL warm and cold tubes, as well as on the cryostat outer surface.

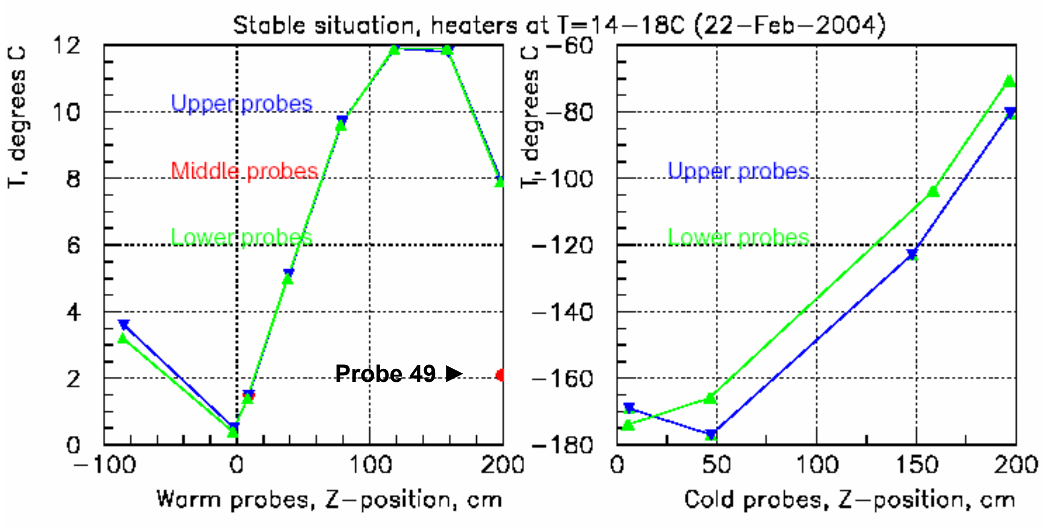

Figure 2: The warm (left) and the cold (right) tube temperature, as function of the Z-position along the tube (Z=0 corresponds to the border between the narrow and wide parts of the warm tube).

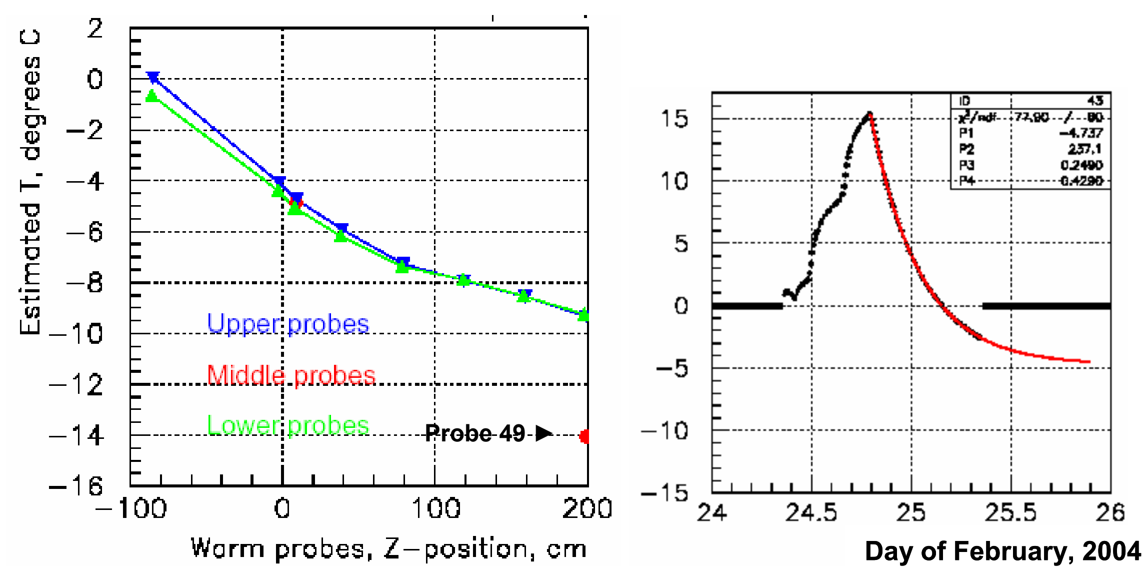

Figure 3: Left – an estimated equilibrium temperature of the warm tube, as function of the Z-position along the tube. Right – an example of the temperature trend (probe 43), recorded on 24-25th February, 2004. The three "steps" on the rising part correspond to periods of heating up to 21, 40 and 60°C in the central part of the warm tube, the falling part — to 'free' cooling towards an equilibrium temperature. The value of this emperatue is estimated by fitting the falling part of the trend with a generic exponential function.

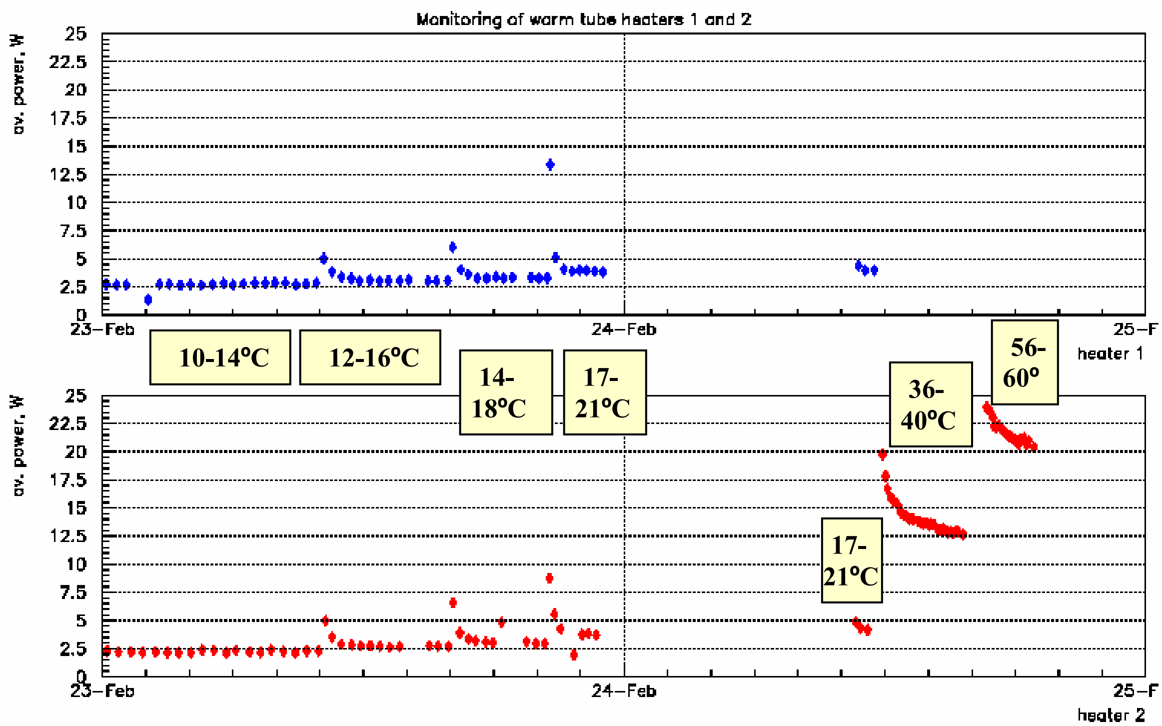

Figure 4: The average power of heaters 1 and 2, as function of time, during the period of 23-25th February. The corresponding warm tube temperature range is indicated.

Figure 5: The warm tube. The 6-mm thick ring of the bi-metallic junction, located in 11 cm from the spacer, is seen. A bunch of wires (PT100 probe signals, heater power) make the clearance between the warm and the cold tube very tight in that area. The cold sensors 61 and 69 were located in about 5 cm from the spacer.