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QUALIFICATION OF A THERMAL GAP FILLER TO BE USED AS ELECTRONICS TO STRUCTURE INTERFACE

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Abstract

A thermal gap filler has been selected, and its performance measured before and after irradiation, to qualify it for the use in TOTEM T1 telescope. Experimental results are presented and commented.

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1. INTRODUCTION

TOTEM T1 detector components located on the external periphery, approximately 1000 mm away from the beam axis, are expected to withstand a total radiation dose of 300 Gy during their lifetime. Electronic boards are estimated to produce an heat budget of 1800 W per telescope. A cooling system has thus been foreseen (1), to drain the heat out of CMS gap, where the detector is positioned while in operation.

As chips of different heights are installed on the boards, the effectiveness of their thermal coupling with the cooling system could require expensive and heavy cooling plates, shaped after boards components layout.

Thermal gap fillers, available on the market, are an interesting alternative. They look as light, soft mats, that adapt themselves to the geometry with a modest amount of compression stress, so that electronic components are not damaged but experience a good thermal link with the cooling plate underneath the mat. They feature a reasonable thermal conductivity, while guaranteing a satisfactory electrical insulation. Their price is reasonable too, and further savings can be achieved because of the simpler design of the cooling plates.

Unfortunately, it seems that no experience exists on their behaviour under radiation.

2. THE MATERIAL

After a preliminary market survey, Thermagon (3) has been identified as the most viable supplier, and specimens of their T-flex 3100, T-flex 5100 and T-flex 6100 have been procured. Their main characteristics, as stated in Thermagon official data-sheet available on the web, have been summarised in Table 1.

PROPERTY	UNIT	T-flex 3100	T-flex 5100	T-flex 6100
Composition	-	Ceramic-filled silicone	Silicone	Boron nitride filled silicone
Hardness	Shore 00	20	40	25
Ultimate strenght	psi	15	46	15
Thermal conductivity	W/m K	1.2	2.8	3
Temperature range	°C	-40÷160	-45÷200	-45÷200
Breakdown voltage	V AC	> 10000	> 10000	> 5000
Dielectric constant @ 1 kHz	-	5.5/4.4	13.61	3.1
Volume resistivity	Ohm cm	6e12	9.6e12	2e12

Table 1: selected thermal gap filler properties, after (3)

After available literature data, summarised in Table 2, silicone compounds should feature a good radiation hardness, especially when compared with the relatively low radiation dose expected in the TOTEM T1 lifetime. In particular, filled silicone compounds seem to be radiation-sensitive only at the highest doses.
According to expected data, T-flex 5100 looked to be the most suitable candidate in the restricted list, as its general performances, physical handling included, are generally better, except for slightly lower thermal conductivity.
A qualification program has thus been launched, in order to confirm the choice with measurements in operating conditions.

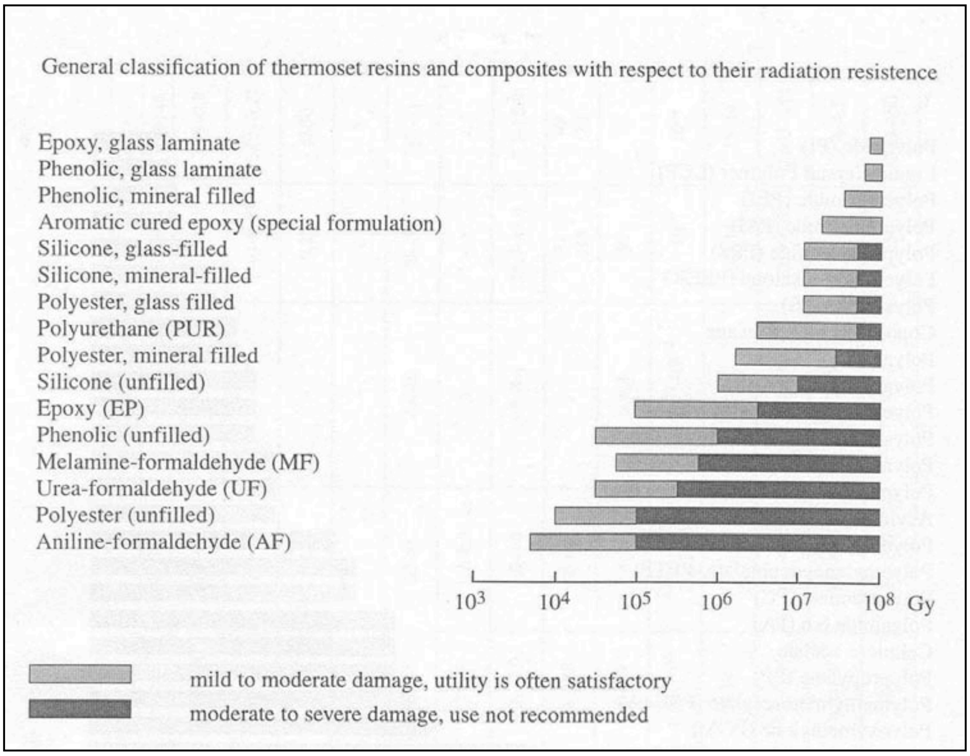

Table 2: radiation resistance of thermoset resins, after (2)

3. TEST SET-UP

The test method applied is essentially the one outlined in (4): given a thermal flux through a stack of materials of known thicknesses, the temperature drop in steady conditions has been measured and thermal conductivity value has been derived after Fourier's law. Unfortunately, because all the available specimens were 2 mm thick, it was not possible to filter the effect of the contact resistance; thus, the results should not be considered as absolute values, but a measure of what you can expect to get in actual application.
Figure 1 details the experimental set-up. 19x47 mm specimens of the three materials under investigation have been placed on a 20x70x330 mm massive aluminium bar. A 7.3 Ohm resistive electric heater of the same dimensions of a specimen has been placed on top of

every specimen, and DC feed switched on. After 15 minutes, necessary to let the system stabilise, temperatures have been measured, with a contact probe, on the 5 locations A, B, C, D, E on heater surface and on metal surface right below the heated specimen (see figures 2 and 3).

Heating power has been limited in order to keep temperatures rather low, thus reducing convection and radiation heat exchange to minor contributions.

Six specimens (two per type) have been measured: three (one per type) as delivered and three (one per type) after suffering a radiation dose; all the specimen have been cut from the same raw sheets. The samples have been irradiated at the Gamma Irradiation Facility at CERN using a ~600-GBq ^{137}Cs gamma source. The estimated absorbed dose is about 600 Gy.

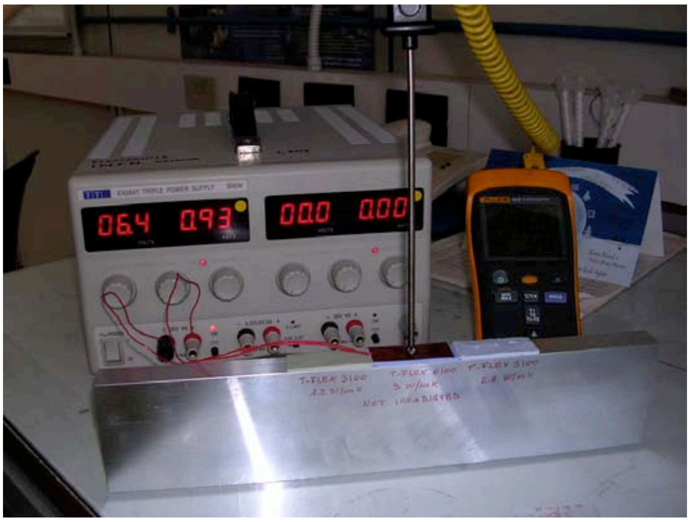

Fig. 1: thermal conductivity measurement test setup

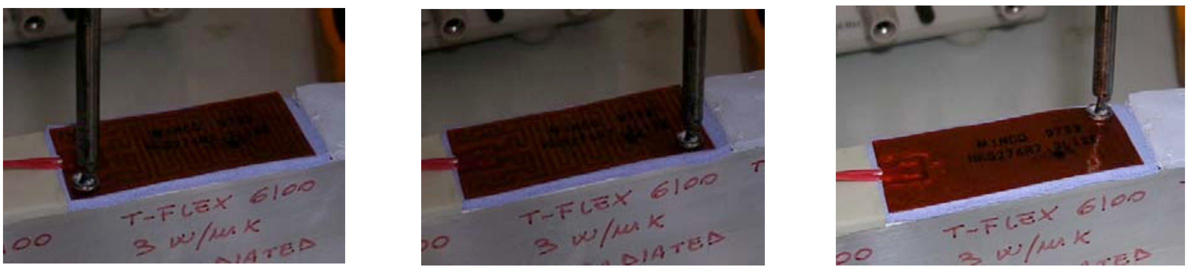

Fig. 2: from left to right, temperature measurement location A, B, C

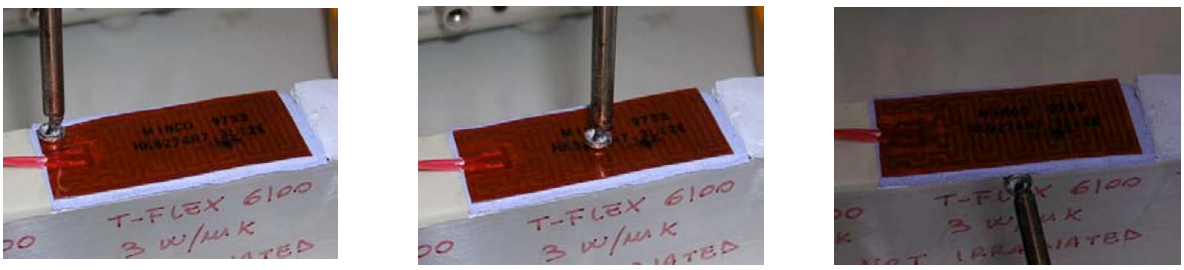

Fig. 3: from left to right, temperature measurement location D, E and base

4. RESULTS

Table 3 list summarises the measurements. An estimate showed that the contribution to the overall heat exchange given by convection and radiation summed up to 2% and 1% of the electric power respectively, being therefore negligible in the budget.

PARAMETER	UNIT	T-flex 3100		T-flex 5100		T-flex 6100	
		not rad	rad	not rad	rad	not rad	rad
t_a	°C	44.3	39.2	41.2	39.9	41.5	41.6
t_b	°C	48.8	46.2	44.5	41.5	44.9	45.2
t_c	°C	49.3	46.6	44.6	44.1	44.9	46.3
t_d	°C	42.8	40.3	40.6	39	40.3	39.2
t_e	°C	55.4	52.5	47.9	46.6	47.2	49.2
t_{avg}	°C	48.1	45	43.8	42.2	43.6	44.3
t_{amb}	°C	26.4	22.9	26.4	24	26.4	24
t_{base}	°C	36.6	33.8	36.5	36.4	34.6	37.3
P	W	5.95	5.95	5.95	5.95	5.95	5.95
$\square_{avg}$	W/m K	1.12	1.15	1.79	2.23	1.45	1.85

Table 3: results summary

Temperature distribution over the surface, far to be uniform, evidenced the effect of the contact resistance. Being the gap filler pretty soft and self-adhesive, and the aluminium bar precisely milled, the large majority of the effect was probably due to planarity faults of the heater. In particular, a hot spot is present at the center of the surface. However, such effect seems about the same on all the specimens, thus it should have a negligible influence when comparing the performance of the different materials.

Finally, electrical resistence of the specimen has been measured, with a digital multimeter, through a 40 mm^2 area over a length of 5 mm. On both non-irradiated and irradiated specimen the multimeter went out of scale, measuring a virtually infinite resistence. More accurate measurements with electrometer allowed to evaluate resistences of the order of 10 GOhms on all specimen. Therefore, we can conclude that the foreseen radiation dose is expected not to produce any significant variation of the dielectric properties of the material.

5. CONCLUSIONS

Measurements confirmed that, given the unavoidable and unmanageable effect of the contact resistance at the interface between the various materials, the overall thermal conductivity a gap filler can provide is significantly lower than the value stated by the supplier and measured according to (4).

T-flex 3100 is the closest to its nominal conductivity, probably because it is also the softest, which allows it to better compensate the geometry and overcome poor contact resistance problems.
T-flex 5100 shows the best performance, although 35% worse than stated by the Supplier, but surprisingly higher even than T-flex 6100.
Radiation effect showed a general improvement of thermal conductivity, more evident for T-flex 5100 and T-flex 6100. On the other hand, all the specimens were soft and self-sticking more or less as before radiation.
We can thus conclude that all the three tested Thermagon grades can fulfill the requirements of the application.

6. REFERENCES

(1) TOTEM Technical Proposal, CERN/LHCC 99-7;
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(3) www. thermagon.com
(4) ASTM D5470-06, "Standard test method for thermal transmission properties of thermally conductive electrical insulation material"