The Effect of Heating on Epoxy and Tension

W. Ebenstein, Seog Oh, Chiho Wang
Department of Physics
Duke University
Durham, NC, 27708

Introduction.
In May 2006, due to the electronic cooling system failure, both ends of six modules in the barrel TRT were heated to ~120$^0$ C for ~18 hours. After the heating, it was noticed that one wire was broken, and one module developed a possible leak.

In order to study the effect of heating, one end of a spare production module at Duke was heated to ~120$^0$ C for 48 hours (see Figure 1 for setup). Before the heating, the tension of all wires was measured and compared with a previous measurement (October 2003). Figure 2 shows the ratio of the two measurements.

Fig. 1. Heating setup with most of the insulated box and power wiring removed. The module end was completely covered with insulator and the temperature inside the box was controlled within +/-2$^0$ C. The fan circulated air to keep the temperature uniform.
Immediately after the heating, the epoxy on the tension plate was checked using a sharp knife. Although no quantitative measurements were made, it was clear that the epoxy was softened and weakened (the end of the knife penetrated easily into the epoxy). We were also able to take out small pieces (~1 mm size) using the knife without much difficulty. However after the end cooled down completely the epoxy had hardened again, and we were not able to push the knife end into it (applying a similar force). The adherence strength seemed ok as well. We should also note that the color had changed from transparent to a slight yellowish color after the heating.

After the module cooled down, we found a large leak between the tension plate and the HV plate. The epoxy had failed between the two plates (Figure 3) resulting in a leak. The length of the gap between the tension plate and HV plate is ~5 cm.
The tension was re-measured and the ratio between the original measurement (October 2003) and that after the heating is also shown in Figure 2. Figure 4 shows the ratio of the two present measurements, after and before the heating. From the measurements, we can make the following observations:

1. There are no broken wires.
2. The wire length (or tension) has changed for the most of the channels while the average tension has not changed. The changes in the tension are ~order of a couple of percent in sigma.
3. The channels with the greatest tension loss (>3%) are located in the central part and the channels with the greatest tension gain (>3%) are at one side of the tension plate. It seems the tension plate deformed such that the central part sagged while one side pushed out.
4. There is no evidence of wire tension loss due to failure of the eyelet-pin wire holding mechanism.
Conclusions.

Using a spare production module, the effect of heating was studied. We can conclude that the epoxy did weaken during the heating but it seemed all right after the cool down (but our measurement was not quantitative enough to make a firm conclusion on the condition after the cool down). We also could conclude that the leak was due to epoxy failure during the heating. *We recommend that epoxy be reapplied between the tension and HV plate if possible.*

The tension plate deformed due to excess heat and it affected the wire tension. However the deformation was not large enough to prevent module operation. We found that there were only a few channels with larger than ~5% tension loss. Since we heated only one side, it is conceivable that some channels in the modules with both ends heated could have lost ~10% of the original tension. But this should not cause any operational problems.