Tucson 6/19/95

Assembly of Sampling Liquid Argon Calorimeter for 7/95 CERN Test Beam Run

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We present a summary of the methods used for the EEPP calorimeter assembly (under the supervision and design specifications of primarily Leif Shaver), as well as the results of electrical tests (in air) of the 364 capacitors in the calorimeter after assembly.

Assembly technique:

0) All calibration end holes were reamed to about 0.252” (from about 0.251”) so that the copper tubes would fit in easier. The tubes that would hold calibration rods were crimped at the calibration end so that they would be slightly elongated (major axis 0.252’, minor axis 0.248”; originally circular 0.250” diam.) and make a mechanical electrical contact with the calibration endplate. During reaming the ground pin on the calibration end near pin C1R2 was broken.
1) After ‘thee-step’ soap/rinse/alcohol ultrasound cleaning , we assembled all the honey-combed brass plates with tie-rods and dowel pins.
2) We cleaned all the copper tubes with a 0.22 caliber gun-bore cleaning tool (cotton swab) with AWESOME (Adchemco) enzymatic soap, prior ro ultrasound in alcohol and jetting with air. The brass rods were cleaned with the AWESOME soap and cloth.
3) All kapton washers (both rectangular and triangular) were cleaned in alcohol ultrasound.
4) The copper tubes were inserted into the brass matrix until only 2mm remained for them to be pushed into the calorimeter. The ‘rectangular’ kapton washers were inserted with a short brass rod/pin into the read-out end of the calorimeter, so that they were in the correct orientation. Then we pushed the tube in the remainder of the way, and lightly tapped the tube with a mallet to properly seat the washer and ensure that the washer would not slip out easily.
5) The fiber (nylon (0.009” diam) or kapton-coated quartz (about 0.0095” diam.)) was inserted from the readout end, and threaded to the calibration end by one person. After the threading (which tended to be time-consuming), the other person inserted the brass-rod with triangular kapton washer on the end about a quarter inch into the copper tube and wrapped the fiber 6-8 times around the rod. Then slowly and with about equal force, one person would pull the fiber and consequently the rod through the copper tube, while the other person would push the rod and ensure that it remained precisely centered in the copper tube. The equal force and slow speed, as well as the centering and the proper placement of the triangular washer were all especially important when kapton-coated quartz fibers were used, since these fibers were very brittle and tneded to break. Upon breakage, we pulled out the brass rod, air-jetted the copper tube, replaced the kapton washers and the fiber and started over. We estimate that there was over 20% breakage rate for the kapton fibers.
6) We measured the resistance, the capacitance, and checked for high-voltage breakdown for all the capacitors. The resistance measurement checked for electrical contact of the tube and the rod (i.e. electrical shorts). The capacitance measurements (Figures 4-10) varied between 261pF to 274pF and could almost distinguish between kapton-coated quartz-fiberred capacitors and nylon-fiberred capacitors, as well as a check for anomalous capacitor assembly and shorts by subtle (assembly) or huge (shorted) differences in the capacitances. The high voltage breakdown test was most sensitive -- some of the breakdown voltages were less than half of the nominal breakdown voltage of near 1100V (see Figs. 1-2).
7) We replaced all those rods/fibers/kapton-washers which had a breakdown voltage of less than 800V (a total of 34 suspect capacitors). We probably should have raised this threshold up to 900 or 950V, as evidenced by the tails in the histogram (Figure 2), but 800V is probably high enough, since the capacitors will have a voltage during the test beam of less than 400V. Note that there

were many more kapton/quartz-fiberred capacitors (about 20% failure rate) than nylon-fiberred capacitors (about 3% failure rate) that failed the 800V test.

8) After replacement, we checked all the capacitances, as well as for high voltage breakdown below 800V. We replaced a total of 7 capacitors in this second round -- 5 from the original 34 suspect capcitors had to be replaced a second time. And 2 capacitors which had not been originally suspect had to be replaced. All the capacitors after this second round passed all electrical tests. Also the breakdown voltages measured at this stage for the first few columns of capacitors were about the same for each capacitor (repeatable!!), if not 50V higher than measured several days earlier.

9) Prior to shipping, we trimmed the fibers at both ends of the calorimeter, so that we could place the PC boards and Delran plugs on the calorimeter end plates with the fibers out of the way. The Delran plugs and one PC board would prevent the rods from slipping out the calibration end, and the other PC board would prevent slippage out of the read-out end. We did snip off three improperly placed ground pins on the read out end (near C20R13, C16R17, C12R21). After fiber-trimming and PCboard/Delran plug placement, we did remeasure the capacitances and we did check the breakdown voltages. **Two tubes failed the breakdown voltage test** (C5R15 had a direct short, C6R10 brokedown at 600V, as opposed to 800V). **These kapton/quartz-fiberred tubes need to be replaced at CERN (presumably with nylon fiber).** Also the capacitances have shifted down by an average of about 2pF (this may be due to the rods being more properly centered with the PC boards in place).

Figure Captions:

Figure 1: **Map of Tube Coordinates**. The Columns and Row numbering scheme we used to keep track of our work, including the region which was originally fiberred with kapton/quartz prior to replacement. The column labelled ‘C1’ is the lower right hand column of capacitors when looking at the read-out end, so that ‘R1C1’ is the bottom-most capacitor and ‘R12C1’ is the last capacitor in that row (the row-numbers increase from bottom left to top right). The column labelled ‘C22’ is the upper left hand column of capacitors when looking at the read-out end of the calorimeter. Columns 5 thru 10 are the columns of capacitors that originally had all kapton-coated quartz spacer fibers, prior to replacement.

Figure 2: **Breakdown Voltages**. We list the breakdown voltages for the 364 brass-rod/copper-tube capacitors, as measured on 6/12/95. The gray-shaded cells denote breakdown voltages less than about 800V; these capacitors were later replaced. After column 8, we did not measure the readout voltages, but just confirmed that the breakdown voltage was above 800V.

Figure 3: **Histograms of Breakdown Voltages on 6/13/95**. We compare the distribution of breakdown voltages for the first four columns of nylon-fiberred capacitors to the breakdown voltages of the first four columns of kapton-coated quartz-fiberred capacitors. Both distributions are centerred at about 1150±125V, however the kapton-coated quartz-fiberred tubes have many more outliers below about 900V. These distributions are prior to replacement of tubes with a breakdown voltage of 800V.

Figure 4: **Individual Capacitances after replacement**. All capacitances are measured and charted in picoFarads (pF), using the CLR meter with a lead capacitance of roughly 12 to 15 pF (unsubtracted). We tabulate the individual capacitances of all the tubes after replacement (6/14/95). We include the gang-of-four groupings by drwaing a plygon around the gang and we also indicate which tubes have kapton/quartz fibers with a gray shading. Column averages and RMS's and a total average (AveColAve) and total RMS are also included, as well as averages and RMS's for the differently-fiberred tubes (KC=Kapton-coated; Ny=Nylon fiber).

Figure 5: **Gang Capacitances after replacement**. We tabulate the the calculated capacitances for each gang of four (calculated by adding the four tubes' capacitances in each gang). Column averages and RMS's and a total average (AveColAve) and total RMS are also included, as well as averages and RMS's for the nylon-fiberred tubes. A total Average and total RMS for the kapton-coated quartz-fiberred tubes was not included because many of the original kapton/quartz fiber gangs had been desegrated after tube replacement since we ran out of kapton-coated quartz fiber.

Figure 6: **Histogram of Individual Capacitances after replacement**. A histogram of all individual capacitances after tube replacement is presented. The distributions for the different types of fibers are evident, but not separable -- the kapton-coated quartz-fibers constitute the majority of the distribution below 266 pF.

Figure 7: **Individual Capacitances after replacement, after fiber trimming, after placement of dummy PC boards**. We tabulate the individual capacitances of all the tubes after replacement, and after all the fibers had been trimmed and the dummy PC boards had been placed on the calorimeter for shipment purposes (6/16/95). See Fig.4 for more details. The capacitor in C5R15 had shorted in the shipment preparation process, and the breakdown voltage of the capacitor in C6R10 was only 600V due to changes during the shipment preparation. Neither of these tubes were replaced prior to shipment to CERN.

Figure 8: **Gang Capacitances after replacement, after fiber trimming, after placement of dummy PC boards**. We tabulate the the calculated capacitances for each gang of four (calculated by adding the four tubes' capacitances in each gang) after replacement, and after all the fibers had been trimmed and the dummy PC boards had been placed on the calorimeter for shipment purposes (6/16/95). We also indicate which tubes are 'calibration tubes' (C), as well as which tubes have ground pins broken nearby (GPB) See Fig.5 for more details.

Figure 9: **Histogram of Individual Capacitances after replacement**. We present a histogram of all individual capacitances after tube replacement, and after all the fibers had been trimmed and the dummy PC boards had been placed on the calorimeter for shipment purposes (6/16/95). See Fig. 6 for more details.

Figure 10: **Histogram of Capacitance differences from 6/14 to 6/16**. We calculate the measured capacitance differences from before fiber-trimming and PC board placement, to after. The capacitance measurements are repeatable without calorimeter modification, so that the capacitance differences are probably real. Note that the differences in capacitance are peaked at about -2pF, with a spread of about 1.5pF, with significant non-gaussian tails.