HEC Spike Studies Summary – 6/20/2013

**Large HEC Electrodes**

Focus has been on trying to duplicate previous cold tests. Not much new news from this front. Large PAD board 1N (Nominally constructed) was used for all three data runs. PAD1N was placed between brass plates with hex cell spacer keeping the electrode from touching the brass. The plates were grounded, while the resistive coating was held at 1400V (HV would trip at higher voltages), readout of the electrode was located on the 4 copper pads and connected to the UA Test Bench electronics.

Procedure for the runs were as follows:

1. Assemble test setup as described above. Leaving the cryostat open, HV is applied to test for shorts. UA Test Bench is set to record triggers.
	1. This is run for 2-3 days to establish everything running properly and spikes are present
2. HV is shut off while the cryostat is raised into position. The cryostat is not sealed at this point.
	1. HV is again applied to test for shorts, and UA Test Bench is set to record data.
		1. This step is run for 2-3 days to ensure everything is running properly, and spikes are still present.
3. HV is again shut off while the cryostat is sealed. Once sealed, HV and UA Test Bench are turned back on and run at atmospheric temperature, humidity (at time of sealing), and pressure.
	1. This step is run for approximately a week to establish a baseline for the spike and noise burst rates.
4. Pump down and cooling/liquid argon filling.
	1. HV is shut off, UA Test Bench is allowed to continue to run.
	2. For these runs the pump down procedure consisted of a short vacuum pumping period, followed by an argon gas flush, a second pumping period, a final argon flush, and a final short pumping period. This is to simulate the pumping/filling procedure used in the ATLAS liquid argon portion of the detector.
	3. The cryostat is then filled with a continuous flow of gaseous argon where it is condensed using liquid nitrogen.
		1. This step continues until the liquid level is above the top of the electrode.
		2. HV remains off during this step due to the ease at which gaseous argon breaks down in the presence of an electric field.
5. Once the liquid level is above the electrode, HV is again turned on.
	1. This step continues until we believe we have enough data (approximately one week).
6. Upon completion of data collection the liquid argon is dumped and the next test can begin.

Changes between runs:

1. Between the first and second run, the cryostat was not opened. To allow humidity back into the system, a vacuum was placed on the system, a port on the cryostat was submerged in a small beaker of water, and opened. This pulled in a small amount of water making the system humid.
2. Pumping on the cryostat to attempt to reduce the humidity levels and remove the liquid water resulted in no observable spikes over the course of a week. No cool down was performed on the second run.
3. Too much pumping during the second run resulted in no spikes, thus the cryostat was opened and several other PAD boards were placed in the system. Spike rates were extremely low on these other PAD boards. The final solution was to place the original PAD1N in a bag with a small water tray and allow it to sit for a week. PAD1N was then placed back into the cryostat following the procedure steps above.

Results/Observations:

Run1 (4/15/2015 – 5/2/2013:

1. Before cool down, spike rate averaged around 5 spikes per hour.
2. Large noise burst spike and HV Spike occurred when vacuum was turned on and before the HV was shut off.
3. Once the cryostat was full and HV turned back on:
	1. Noise burst rate dropped by about half with no noise occurring in the evening hours indicating that activity in the lab and building probably contributes to most of the noise we see.
	2. Spike rate dropped significantly, only a handful of spikes occurred after the HV was turned back on.
		1. Pump down procedure may have been too aggressive.

Run2 (5/6/2013 – 5/16/2013):

1. After water was pulled into the cryostat, a large number of spikes were observed. Water droplets were also visible inside the cryostat. Knowing how much water was pulled into the system, and calculating how much liquid water could be condensed out of 100% relative humidity air, we concluded that 25 to 50 times the water needed to make the air 100% humid was pulled into the cryostat. We decided to turn on the vacuum pump to pull out the excess water.
	1. During the pump down HV was off.
2. When the HV was turned back on, no spikes were observed over a one week period, we decided to end the run, open the cryostat and attempt to use a different PAD board.
	1. Two other PAD boards were placed into the system, and step 1 of the procedure was followed.
	2. Very low spike rates were observed with the different PAD boards. They had been sitting in the dry air of the lab for months (15% – 20% humidity). Spike rates were approximately one spike per day. Much lower than what was needed for this study.

Run3 (6/3/2013 – 6/14/2013):

1. After the changes discussed in #3 of the Changes section above, PAD1N was used again. The procedure described above being used.
2. Initial Spike rates were lower than in Run1, averaging about 2-3 per hour.
3. Again the large spike and noise rate spike occurred when the vacuum was applied to the cryostat but before HV was turned off.
4. Once the cryostat was full of liquid argon, and the HV turned back on, the observed spike rate was very similar to what we observed in Run1.

**Small PAD Board**

We’ve observed humidity having an impact on spike rates with both the large and small HEC electrodes. We can eliminate the spikes entirely by placing the electrodes in the cryostat and exposing them to a vacuum long enough that spikes disappear. On the other end of the spectrum, we can also significantly increase the spike rate by exposing the electrodes to high humidity levels. What we don’t know is what is really happening to the electrode as humidity levels change.

Out of curiosity, we measured the capacitance of a small PAD board and a small EST board in the relatively dry air of the lab, and then placed the electrodes in a bag with a small tray of humidity and again recorded the capacitance.

We observed a change in the capacitance on the PAD board, and less of an effect in the EST board. This led to us using a clear chamber that could be semi isolated from the lab environment (chamber has heat transfer, and very little humidity transfer). A new LCR meter that had computer readout was purchased and a Precon HS-2000 humidity and temperature sensor (used in previous HEC studies) was also purchased for the chamber. Because more change was initially observed in the PAD board, that component was connected to the LCR meter. Data from the LCR meter and humidity sensor was recorded into text files that were then converted to Excel and graphed.

Initially the humidity was kept at what the lab conditions were. Then a tray of water was placed into the chamber which increased humidity. Data was recorded as the water evaporated and the small transfer between the room and the chamber, allowing the humidity to drop back to low levels. This process was repeated a second time, again recording the data through the rise and fall of humidity.

The graphed data revealed a complex relationship with the PAD board capacitance readings and humidity. It also revealed that a better system to control humidity levels was needed. We developed a humidity monitoring system that uses an Arduino Uno microcontroller, a second humidity sensor, and a humidifier.

This monitoring system reads the humidity in the test chamber and compares the reading to a preset humidity level. If the reading is lower than the set humidity level, a humidifier is turned on in a separate chamber and the humid air is pumped into the test chamber until the humidity level reaches a set level above the predetermined humidity level. Once that level is reached, everything is shut off and monitored. The setup relies on the humidity transfer between the lab and the test chamber to maintain a nearly constant humidity setting.

Using this monitoring system, and starting at low humidity levels, the capacitance was measured as humidity levels were slowly increased. The increase was accomplished by setting the desired humidity levels in the control program.

This lead to a much greater control over the large range of humidity studied. After graphing the data in Excel, we observed that the same complex curve that occurred in the relationship between capacitance and humidity develop again. We also observed the capacitance taking longer to stabilize than the humidity, this can be observed in the Capacitance versus Humidity plot as the vertical stretching of the data. If these outliers are removed from the plot, the complex capacitance-humidity relationship becomes more pronounced.

The data collected is from one run starting at low humidity and continuing through high humidity. The low humidity levels were reliant on how low the humidity in the lab was. Lower levels are not reachable at this point with this setup. The stopping point, around 85% humidity was chosen when the humidifier no longer shut off due to the humidity being pumped in was equal to the humidity transfer between the test chamber and the surrounding lab environment. It should be noted that when this data run started, it was more humid than average in the lab and when the run concluded, the atmosphere was significantly drier (Starting lab humidity ~30%, ending lab humidity ~17%).

At the present time, we are starting a run using a large PAD board. It will be placed in the test chamber and capacitance readings will be measured as humidity levels change.