14 UD Tank Opening Report

#118

25 October – 23 November 2012

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Contents

1 Reason for Tank Opening

This tank opening was unscheduled and was required due to the sudden failure of chain #3. Some tasks planned for the next scheduled opening where brought forward.

The length of the tank opening was due to the arrival of a brand new chain during the tank opening, after a spare chain was installed as a replacement for the broken chain. It was thought best to use the brand new chain and so it was installed to replace the replacement.

There was a second "minor" tank opening performed on this occasion to troubleshoot a suspected gas actuator leak at the tank cup. During this re-entry, the platform was not fully deployed and the plan was to enter, examine, repair and exit. This second tank entry has not been separated out into another section in this report.

Plan of action:

- Perform initial 30kV insulation test of the column.
- Perform electrical and mechanical tests and inspect all idlers, chains, pulleys, bearings, shafts and resistors.
- Replace chain #3
- Perform leak testing on gas stripper components at elevated ambient pressure
- Install terminal cup electronics and associated hardware
- Investigate why tank cup suppressor supply was shorting
- Test modified CPO electrodes

Additional unplanned tasks were performed as opportunities presented themselves. These included changing of unit posts.

2 Summary of Work

2.1 25-10-12 Thursday

- The SF6 was pumped from the 14UD into the storage vessel.
- The 14UD was vented with air, the porthole doors were opened and the fresh air ventilation system was run overnight.

2.2 26-10-12 Friday

- Gas tests showed the atmosphere within the 14UD was OK and compliant with the Confined Space regulations and was safe to enter.
- The in tank platform was deployed and the initial pass down the column completed the 30kV insulation grouped ring tests. The current readings were within specs and recorded.
- Chain 3 (#3L) was found to have broken in two places. A small six-link length was found in the bottom of the terminal. The remainder of the chain was at the bottom of the tank, with half piled up in unit 28 and the other half on the tank floor. A survey was performed to inspect the damage broken down side inductor mount at the terminal and a bent current pickup on the down side at the bottom of the tank. Small fragments of a nylon chain link were found distributed near the terminal. There was also damage to pulley shim stock, thought to be from rubbing on the displaced inductor (there are marks on the inductor). The chain 3 down side petals in unit 15 also suffered impact damage. These were removed for repair.
- Chain 3 was removed and spooled for failure analysis at a later time.

- The leak tester was installed on the roughing valve on the tubing to the stripper housing with the valve closed, isolating the gas manifold from the stripper housing. Leak testing of the gas stripper system began with testing of the components in the gas box. This included the fine valve and the Convectron gauge. The solenoid had been removed at the last tank opening. No leaks were found. The isolation valve was then opened up to the tube and helium injected into joins in the terminal area. After delays on the order of minutes, a small upward drift in the leak rate was observed, from base leak rates of the order of 1×10^{-10} up to 1×10^{-9}. No specific location could be pinpointed

2.3 29-10-12 Monday

- The gas stripper has box was removed in preparation for pressure testing of individual components. Leak testing on the beam tube in the vicinity of the terminal was repeated, with much the same response as on Friday.
- Pressure testing was performed on individual components of the gas stripper gas box, including the bellows. No leaks were found. Only two Swagelok stainless steel tubes left to test tomorrow.
- Design of a mounting bracket for the terminal cup log amplifier and suppressor supply has begun
- A relay has been ordered to allow a design modification to the terminal cup log amplifier so that the polarity selection can be performed using 12VDC, which is available in the Group 3 box (instead of the 24V required using the existing relay).
- Begun searching for resettable fuses to replace fuses in terminal cup log amplifier and suppressor supply.
- Shorting problem at tank cup suppressor was traced to a faulty BNC crimp at the connection to the BNC bulkhead on the inside of the tank housing. The problem is mostly intermittent and looks to be dependent on the position of the centre pin. Furthermore, to alleviate any potential problems due to small bend radii in future, a BNC 90° connector will be used.
- Work to repair/replace shim stock on chain 3 pulley wheel has begun.

2.4 30-10-12 Tuesday

- Continued pressure testing of components of the gas stripper system and associated feed connections to the tube. There is a definite, repeatable leak response that appears at ~30psi of He through the Swagelok roughing valve to which the leak tester is connected . After a series of pressure tests, the leak was identified to be at the bellows seal. Tightening of the "bonnet" of the valve results in immediate improvement of the leak. A rebuilt valve will most likely be reinstalled into the tank.
- Replaced shim stock on chain 3 pulley wheel at terminal.
- Ran conduit and all required cables (bare ended) from terminal cup housing to shielded box. Connected wires to micro-switches inside cup housing.

2.5 31-10-12 Wednesday

- Repaired chain pickups and petals were reinstalled into the machine (terminal down side inductor still to be reinstalled).
- A spare high-hour chain was installed into the chain 3 position. This is likely to have been chain 3M or 3K (there is some confusion in the records). This chain is a nickel plated chain.

- Pressure testing on rebuilt valve still showed a very small leak, much improved from before, but a leak nevertheless. Further tests were carried on a brand new valve – which now use Teflon coated stainless-steel gaskets to seal the bellows – with a very small leak found only through the stem seal. The polymer o-ring seal in one of the older valves was replaced with a metal gasket and while testing continues overnight, no leaks are yet observed at the bellows seal.

2.6 1-11-12 Thursday

- Repaired inductors were reinstalled and replacement chain was shortened
- Four brand new metal seal bellows valves were leak tested and found to leak until the bonnet was tightened. These are now suitable for installation into the machine. The second bellows valve that isolates the beam tube from the gas stripper feed system will also be replaced. This will require venting of the LE end, planned for Monday.
- Gas stripper box was reinstalled after leak testing on the bench. Leak testing on the reinstalled system is still yet to be done.
- Repaired tank cup suppressor supply wiring was installed, no shorts evident with mega ohm meter and -300VDC appears at the suppressor input at the cup without any issues. Job is considered complete but suppressor supply sent to EU for repair.

2.7 2-11-12 Friday

- Ran PFA tubing from tank base to terminal cup location. PFA tubing did not have any painted labels on its surface, therefore did not require its removal as is our standard procedure
- There was also no need to offset the tubing in the casting plates as was done for the tubes containing the optical fibers.
- Identified SF_6 input line (line 6) from outside of tank into tank to operate terminal cup. Fitted copper line from tank base to bottom casting and connected PFA tubing.
- Ordered 24VDC solenoid control valve for terminal cup control
- Removed O_2 gas stripper bottle and two fitted leak tested valves. Bottle was leak tested and refilled.
- TS-7520 IOC box was provisioned for use on level 2, initially to control the pneumatic valve to operate the terminal cup. Relevant EPICS process variable were added.

2.8 5-11-12 Monday

- Installed new pressure tested gas stripper system isolation valve.
- Vented low-energy end of beam tube to enable replacement/inspection of valves and O-rings
- Removed and inspected KF O-ring to lower turbo exhaust (near traps) and observed surface cracks and metal particulates (suspected to be aluminum). Removed O-ring in same position at upper turbo. Replaced both O-rings.
- Installed 24VDC solenoid control valve at level 2. Valve body is the same as the existing ones, so existing fitting were reused.

2.9 6-11-12 Tuesday

- Evacuated low-energy end of beam tube and baked gas stripper turbo traps for 35 minutes after which the vacuum returned to a base of 3×10^{-10}. Leak testing at terminal was carried out prior to this.
- Fitted PFA tubing to terminal cup end. Pneumatic circuit is now complete and ready for testing.
- Second power board fitted and connected in Group 3 box at terminal in order to power cup log amp and suppressor supply.
- Terminal cup log amplifier was modified with a 12VDC relay replacing the existing 24VDC relay that controls the current polarity selection. Relay is TE Connectivity 1617037-7 general purpose DPDT 12V relay, sourced from Digi-Key (P/N: A107303-ND)

2.10 7-11-12 Wednesday

- Installed ASCO 24VDC solenoid valve (catalogue number SCD320A184 77) at level 2 to operate terminal cup. Using line 6 of SF6 manifold.

2.11 9-11-12 Friday

- Began additions of grounding straps to terminal cup log amplifier and suppressor supply
- Added terminal cup process variables (PVs) to EPICS
- Installed TS-7520 IOC box at level 2 after running ethernet cable from level 2 to target area 1

2.12 12-11-12 Monday

- Began installation of new posts in units 18 & 22
- Completed grounding modifications to terminal cup log amplifier and suppressor supply and installed into the terminal.
- Tested integrity of terminal pneumatic line at level 2 and the operation of the terminal cup. Cup movement is OK. Still need to check connections to C2L3 Group 3.

2.13 13-11-12 Tuesday

- Completed installation of new posts in units 18 & 22
- Received new chrome plated chain from NEC. Chain was hung in preparation for installation and no discernible angle of twist/rotation was observable. This is designated as Chain 3P.
- Testing began on terminal cup electronics and connections to Group 3 board. Problem was found with circuit to toggle polarity of terminal cup log amp. Additional TTL relay will have to be used.

2.14 14-11-12 Wednesday

- New chrome plated chain 3P was installed at chain position #3 (S/N: 2DA010142 – 10543.1628). A single link was removed leaving 85mm under stop leg. Will be run overnight.

- TTL relay did not solve terminal cup log amp polarity switch because Group 3 board cannot supply enough current. Ordered alternate optoisolator parts from element14 for overnight delivery.

2.15 15-11-12 Thursday

- After overnight running, chain 3 had 29mm under stop leg. Removed additional 3 links, leaving 100mm under stop leg. Will be run again overnight.
- Fitted test CPO electrode on the right side (from inside tank, looking toward port hole).
- Blow down of low-energy end
- Replaced charred resistor leads in unit 2 tube 1 and unit 6 tube 3.
- Fitted AQV253H PhotoMOS relay (element14 p/n 1124062) inside Group 3 box at terminal to enable the Group 3 TTL 5V to drive the 12V relay in the terminal cup log amp (which controls the current polarity reading). Successfully tested polarity switching. Ran shafts and tested all terminal functions except for foil changer.
- Closed terminal

2.16 16-11-12 Friday

- Tested new CPO electrode design. Applying $700V_{pp}$ to the terminal results in a CPO signal of $930mV_{pp}$ on the new electrode (mounted 25mm from the tank wall, measure from the back of the electrode) compared to $180mV_{pp}$ on the old electrode. Exaggerating the electrode distance from the wall to 62mm (not possible in normal operation) results in a CPO signal of $1.4V_{pp}$.
- Mounted 2nd new CPO electrode design – both CPO electrodes in the tank are of the new design.

2.17 19-11-12 Monday

- Filled chain oiler reservoirs and observed operation of oilers. They operate at about 1 drop per second (bottle pressure is at ~500kPa).
- Wiped down column
- Performed HV testing and found that units 18 and 22 – in which new posts have been installed – showed a consistent current of ~22uA@30kV (above the usual ~7uA) for all sections. Testing bare posts (no resistors and no rings) showed a higher than normal leakage current.

2.18 20-11-12 Tuesday

- “Baked” posts in units 18 and 22 in-situ using heat gun
- Time delay for first oil drop from oilers was observed. Was 5 s for Chain #1, 11 s for Chain #2 and 4 s for Chain #3.
- Closed up tank and pumped down

2.19 21-11-12 Wednesday

- Transferred SF6 into tank
- Found that tank cup was not operational and in the default “in” position. Appeared to be leaking SF6 into tank, without any movement of the tank cup piston, as confirmed

by beam current measurement and cup position microswitches. When solenoid valve was open, could hear continuous gas flow at SF6 bottle and at entry into tank.

2.20 22-11-12 Thursday

- Pumped out tank and vented in preparation for tank cup troubleshooting

2.21 23-11-12 Friday

- Entered tank to troubleshoot tank cup and found that cup was perfectly operational. No leak was found at all. Decision was made to reverse the piston so that the default position of the cup – with no gas pressure applied – would be out instead of in. If the cup still fails at full tank pressure, the 14UD is still usable while troubleshooting can continue.
- Reversed tank cup operation by by-passing die-cast box on level 5
- Corrected EPICS operation of tank cup and connected position micro switches to level 4 IOC. Readback is now available on GUI.

3 Gas Stripper Component Pressure Testing

Detailed notes can be found in the 14UD Terminal Gas Stripper Folder

Team – Justin Heighway, Tom Tunningley

Initial leak chasing of the gas stripper box was done while still installed in the terminal of the 14UD. No leaks were discovered so the box was removed from the machine for further testing of individual components.

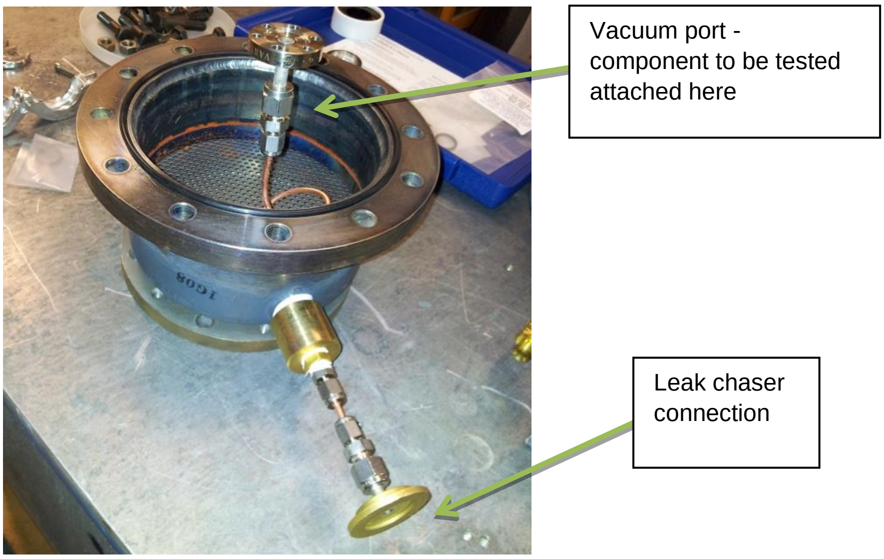

Figure 1 Pressure chamber

A test chamber made from a cryo pump adsorber had been used previously for testing electronic components at pressures encountered in the 14UD pressure vessel. This chamber was modified by adding a port for attaching components via a feedthrough connected to the helium leak chaser. A gas inlet line at the top of the chamber allows it to be pressurized by a helium cylinder with regulator, while monitoring the internal leak rate of the attached component.

The stripper box was disassembled into components small enough to fit in the chamber. Each component was tested for a good base leak rate before pressurizing up to 100 psi abs of Helium in the chamber, which was read on a digital pressure gauge. Typical base leak rate was ~ 1 x 10^{-10} mBar ls^{-1} or better and if there was no noticeable change when pressurizing to 100 psi the component was considered to have passed the test.

Components that passed testing were as follows;

- Flexible swagelok line
- Granville Philips mini convectron gauge
- Granville Philips variable leak valve – inlet and outlet ports, and in closed and open positions
- Pipework from inside box

At this stage all of the components from the stripper box were passed as leak tight so we had to look further downstream for a source of the leak. This left the stripper roughing port valve and the stripper isolation valve as priorities for testing. Other valves in the system are on the oxygen cylinder for isolation, and another for reading the pressure in the cylinder by attaching a gauge. These are all quite old bellows sealed 4BK Swagelok valves.

Leak chase of stripper roughing valve in closed position:

- @ atmosphere 1.8 x 10^{-10}
- @ 30psi leak rate started increasing
- @ 100psi 4.6 x 10^{-8}

Similar result for leak chase in open position with outlet capped so we believe the valve was leaking through both the body-to-bellows gasket and stem tip. On disassembly of valve we found that the gasket material was a plastic (not listed in current parts for these valves) and the stem tip was PCTFE. After venting the accelerator tube we could also leak chase the stripper isolation valve. Similar leak rate was observed for this valve.

New 4BK Swagelok valves were available so we pressure tested one of these straight from the box. These valves have a PTFE-coated 316 SS gasket and a PCTFE stem tip. At atmosphere as designed these valves were fine, ~ 10^{-10} leak rate, but at pressure leaked up to ~ 10^{-8}. We decided to try and tighten the body-to-bellows gasket. Nut moved with out too much force about a quarter of a turn. This valve and another three new valves (with extra tightening) all passed testing and were ready for installing on the stripper system.

Typical leak chase of new valve with extra tightening:

- @ atmosphere 1.2 x 10^{-10}
- @ 100psi 1.1 x 10^{-10}
- After at least 10 minutes @ 100 psi leak rate remained steady or even improved to 1.0 x 10^{10}

Box was reassembled and drowned in helium and tested all okay. Returned to the machine and reinstalled with the new valves.

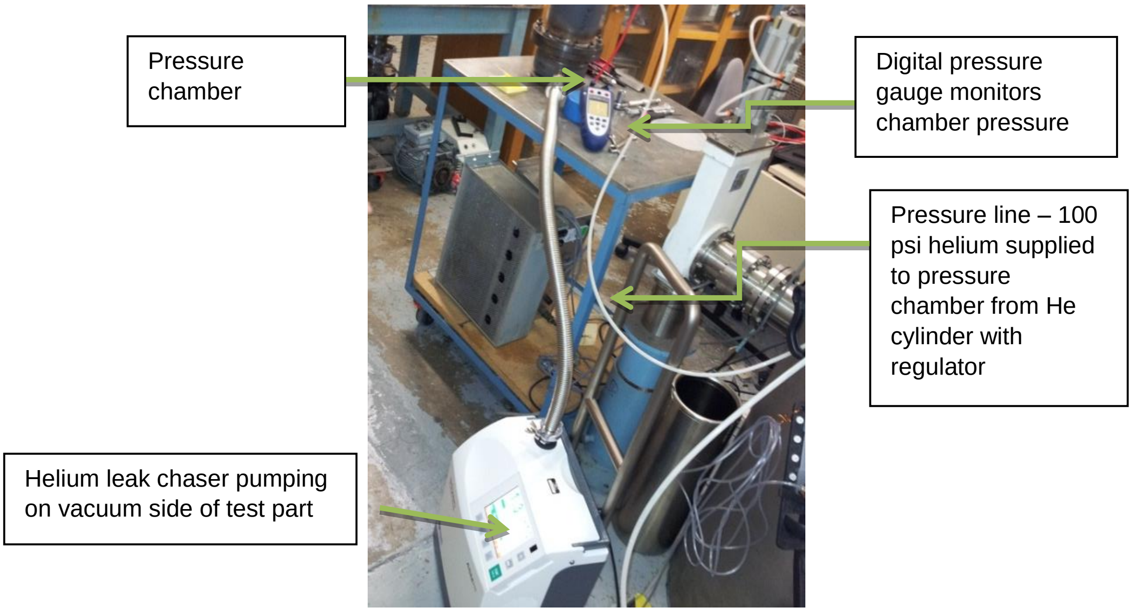

Figure 2 Helium leak chasing of gas stripper parts in pressure chamber

4 Charging Chain Failure and Replacement

The accelerator developed a breakdown/spark threshold at charging system voltage of 15 kV. As a means of diagnosis, each of the charging chains was run individually and listened to, for any unexpected sounds, at Level 2. On testing chain #3, only the drive-motor could be heard running leading to suspicion that chain #3 was broken. The suspected breakage was confirmed on entering the tank and the following observations were noted:

- Most of the chain was gathered at the bottom of the tank and in U25.
- There was a clean break across the link waist, with one half of the broken link remaining attached to the chain, while the other half was broken into pieces, which were later found in castings.
- The link pin remained attached to the pellet.
- A six-pellet long piece of chain was found in the terminal
- Casting Idler petals at U16 were found to be scoured by broken chain, were removed.
- Found top half of broken chain in U23
- One damaged petal in U21
- Damaged petal set in U25

Figure 3 Location of broken chain #3

Figure 4 Six link piece showing link fracture

The following rectifications were performed:

- Shim stock replaced on terminal pulley #3.
- Broken chain replaced with a nickel plated chain (#3O) that had been previously installed in the 14 UD but removed during TO #114 due to lip-to-lip spark damage.
- New studs were fitted to inductors in terminal, at position #3.

- The scoured casting idler petals at U16 were removed (replaced/refurbished).
- Chain #3 inductors under at tank base were adjusted.
- Chain #3 was found to require shortening by 1 link.

Just after chain installation was complete, a new chrome plated chain arrived from NEC. On 14/11/2012 the new chain (Serial #/P/N: 2DA010142; 10543.1628) was installed in position #3. This chain is identified as chain #3P. Installation involved:

- Preparation
  - General inspection, as to the condition of the chain, was performed.
  - All screw-pin joiners, but one, were replaced with rivet-pin ones
  - The chain hung in tower stair case overnight.
  - The next day it was inspected for twist and no twist was observed.
- Installation
  - The chain was installed as per usual procedure.
  - One pellet-link pair was removed.
  - A gap of 85mm was measured between the bottom of motor-stop leg and tank floor, before running the chain
- Performance
  - The new chain ran with a growling noise, which was more pronounced than normal and louder compared to chains #1 and #2.
  - It seemed to run straight, observed from the face of the pulley but proved to run out when observed perpendicular to the axis of the pulley, i.e. with the observer looking at both the upward and the downward length of the moving chain in line, one behind the other.
  - A dial test indicator measurement of 15 pellets was done and run-out ranging between 0.45mm and 0.65mm was observed. Video footage of this test was taken

Additional work was performed on chains #1 and #2 and the drive motors:

- Idlers in U21 were adjusted.
- U22 chain #1, upward direction idlers were adjusted.
- U22 chain #2, downward direction idlers were adjusted.
- Motor #3 bracket on suppressor pick-off broken as a result of broken chain.
- Insulation, under the plumber block, broken down.
- Insulation under plumber blocks of motors #1 and #2 were tested and found to be of strength greater than 20MΩ.
- Insulation material under plumber blocks was found to be *nylon sheet* for motors #1 and #3, and *nylon film* for motor #2.
- Stroboscope investigation of chains slippage revealed the following:
  - Chain#1 18s;
  - Chain#2 14s; and
  - Chain#3 15s.

5 Post Replacement

While the tank was open and other work was stalled, it was determined that there was sufficient time to replace some posts. There were 2 sets (8) of new NEC posts in stock. Inspections were done and based on ceramic deposits, break down product, and spark damage, Units 18 and 22 were earmarked for the post replacement.

The posts were replaced over two days (12th-13th Nov) using a hydraulic jack between units as support while the posts were swapped. The serial numbers of the posts installed and removed and their positions are shown in Table 1. Five of the eight posts replaced had silver loaded epoxy on the post end flanges. In most cases, the epoxy was discoloured.

Table 1 Serial numbers of exchanged posts

	A in	A out	B in	B out	C in	C out	D in	D out
Unit 18	2642	318 (epoxy)	2643	249 (epoxy)	2645	290 (epoxy)	2647	265 (epoxy)
Unit 22	2648	2344	2646	2346	2650	253 (epoxy)	2649	2342

When it came to high voltage testing, it was found that there were issues with current leakage on the units where the posts were replaced. The rings were removed on these units so individual posts could be checked. The readings from Unit 18 were compared to Unit 17 (a known good unit). Table 2 shows this comparison.

Table 2

		Unit - Post		
		18-A	**18-B**	**17-A**
Gaps – Volts	**3G - 3kV**	-	-	0.05uA
	4G - 3kV	-	0.9uA	-
	3G - 10kV	2.6uA	3.2uA	0.2uA
	4G - 10kV	2.2uA	Sparking	0.2uA

Heighway recalled that replaced posts in previous tank openings exhibited the same behavior and that heating of the ceramic was done to improve things. Wiping 3 gaps with ethanol and acetone followed by brief heating reduced the leakage across the insulator surface. However this treatment was not recommended by NEC (see email below). So Post B on Unit 18 was heated without using solvents and new readings were taken, these are shown in Table 3.

Table 3

		Unit - Post		
		18-A	**18-B**	**17-A**
Gaps – Volts	**3G - 3kV**	-	0.05uA	0.05uA
	4G - 3kV	-	0.05uA	-
	3G - 10kV	-	0.2uA	0.2uA
	4G - 10kV	-	0.3uA	0.2uA

An email was sent to NEC querying the behavior of the new posts and the response from NEC confirmed the suspicions:

TO: Nikolai Lobanov <lobanov@iinet.net.au>
CC: Nikolai <Nikolai.Lobanov@anu.edu.au>
SUBJECT: Acceleration Post
DATE: November 19, 2012
E-MAIL No. 11-6172

Dear Nikolai,

From your description, this sounds relatively normal. The very last step in the manufacturing process for an insulated support post is glass beaded blasting which is a very dry, inorganic surface treatment.

The fact that the leakage was reduced by heating the insulator is very good news and to be expected. Please note, these 8 posts were shipped on October 26, 2011, more than a year ago. It is highly likely there has been significant moisture absorption by the unglazed ceramic.

We do not recommend wiping the ceramic surface with acetone or ethanol. It may be a superstition on our part. However, we worry about organic deposits into the unglazed ceramic.

We do not recommend any surface treatment. Baking out before installation and dry nitrogen would speed up any conditioning process for the support posts.

Regards,

Greg
##
Dr. Gregory A. Norton Phone: (608) 831-7600
Vice President, Marketing Fax: (608) 831-9591
National Electrostatics Corp. E-Mail nec@pelletron.com
P.O. Box 620310 Web:
http://www.pelletron.com
Middleton, WI 53562-0310 USA
##

Following this email, the remaining posts on Units 18 and 22 were heated and measurements on these showed an immediate reduction from 1uA to 0.1-0.2uA @10kV. In some cases this leakage degraded back to 0.5uA over 30mins, however many stayed in the 0.2uA zone. After reinstalling the rings on the units, the full HV testing was performed, and the results were quite good (note the entries in the HV test records). It was thought that these units would continue to improve under operating temperature and SF6 conditions.

6 Tank Faraday Cup Suppressor Short

Prior to the tank opening, it was evident that the tank cup suppressor supply was shorting out and blowing many fuses. The short was traced to the RG 306 coax BNC connector on the inside of the tank cup housing. Moving the RG316 coax around would create and break the short. This cable had been assembled by EU.

A new coax cable was assembled by EU and an additional 90° BNC connector was installed in an attempt to relieve strain on the coax cable. The new wiring was tested and operates without exhibiting an electrical short.

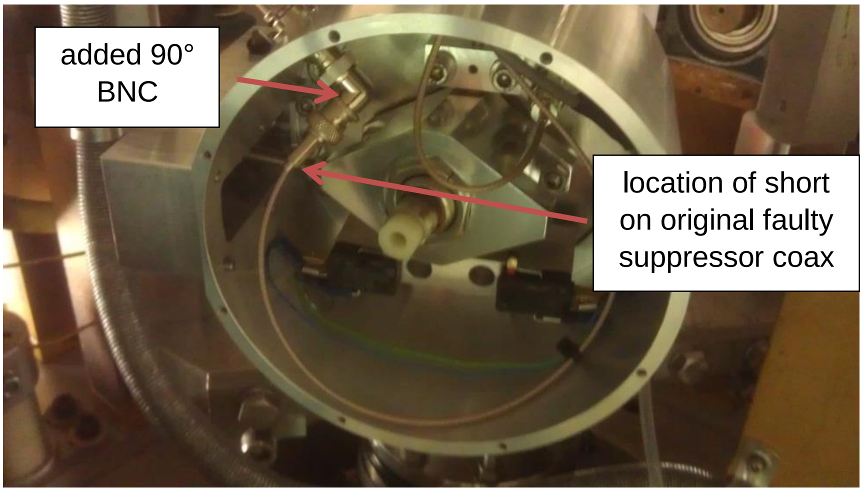

Figure 5 Tank cup housing after suppressor coax replaced

7 Terminal Faraday Cup Control Electronics

A faraday cup was installed at the terminal as described in tank opening report #117. The associated wiring and control electronics were installed during this tank opening. The control electronics consist of a NEC 2HA032281 1nA-1mA 0-6VDC “bipolar” log amplifier and a NEC 2HA048140 400VDC suppressor All wiring to cup housing is through metal conduit as used elsewhere in the tank.

Wiring:

- Cup to log amp – RG316 coax PTFE insulated MHV-BNC
- Cup to suppressor – RG316 coax PTFE insulated BNC-MHV
- Cup micro-switches to Group 3 box – multicore shielded cable
    - Pins 7 & 8 on digital IO
- Log amp polarity control to Group 3 – multicore shielded cable
    - Pin 24 digital IO via AQV253H PhotoMOS relay
- Log amp output voltage to Group 3 – multicore shielded cable
    - +ve channel, pin 6 analog input
    - –ve channel, pin 7 analog input

Brackets were fabricated to hold the suppressor supply and log amp, which were then mounted into the lower terminal shield box located at the terminal. An additional US style power board was also required to supply AC power to both boxes.

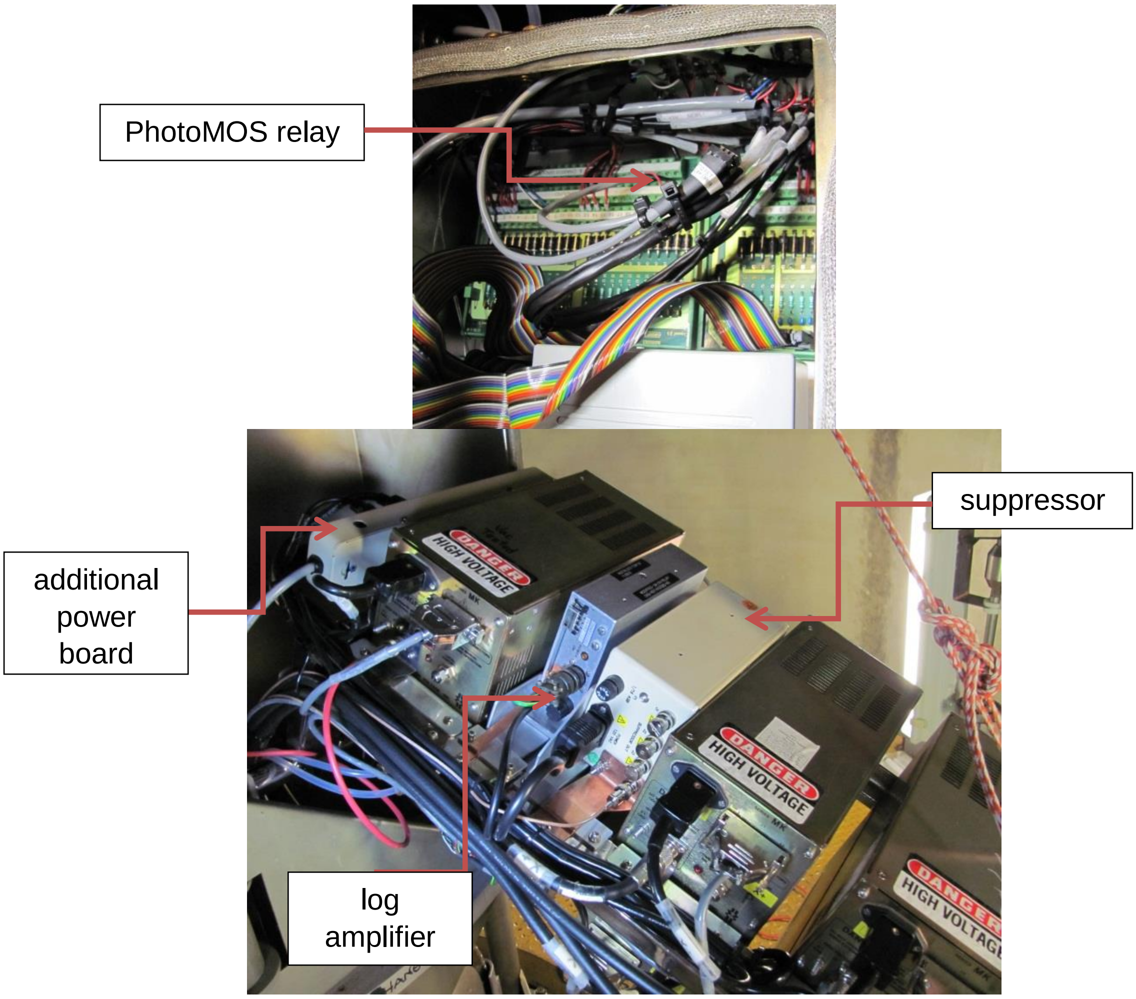

Figure 6 Terminal Faraday cup electronics

The polarity selection of the log amplifier functions by operating a relay to switch between two channels, one that reads positive currents and the other negative. As supplied, the relay required 24VDC to operate. No 24VDC supply is available in that shielded box, so a drop in replacement 12VDC relay was bought (Digi-Key A107303-ND, manufacturer's #HFW5A1201G00) and installed into the log amplifier box. The Group 3 digital IO cannot source enough current to operate the relay directly, so a AQV253H PhotoMOS relay (element14 p/n 1124062) was used to drive the polarity selection relay via the Group 3 digital IO.

All cables were tested and log amp output voltages observed against a known input current.

SF6 pneumatics for cup movement is run from the manifold at level 2, into the bottom of the tank via copper tube and up through the column through polymer tubing. A new ASCO 24VDC solenoid valve (Catalogue number: SCD320A184 77) controls the flow. This valve is a drop in replacement for the old 240V solenoids. Solenoid control is via a TS Box IOC also located on level 2.

8 CPO Test Electrodes

A previous attempt to adjust the gain of the NEC CPO amplifier showed that even with the gain set to maximum, we got about an order of magnitude less voltage than the 1 V per 500 V at the terminal required (CPO manual).

In order to increase the probe-terminal capacitance and therefore the output of the CPO amplifier, a new CPO probe was constructed. The new CPO probe has a dome shape to increase the surface that sees the terminal and is also placed 25mm from the tank wall, unlike the old CPO plate.

Figure 7 Modified CPO electrode install

A cable was attached to the terminal and brought out through the tank door at level 2. Another cable was attached to the bottom of the tank (ground). The voltage was produced by a variac connected to the 36 V winding of a 36 V/240 V transformer via a 120 ohm resistor (current limiting). The variac voltage was adjusted to produce a 247 VAC RMS (700 V peak-to-peak) at the 240 V winding of the transformer. The 240 V winding was connected to the terminal and the ground cables.

Channel A of the CPO amplifier was connected to the CPO #1 which had the new dome installed, while channel B of the CPO amplifier was connected to the CPO #2 which had the old plate installed. According to the NEC CPO manual, section 3.4, a 500 V terminal voltage should appear as a 1 V CPO output voltage, so a 700 Vpp terminal voltage should produce (after gain adjustments) 1.4 Vpp at the CPO amp output. The following spectrogram is from channel A (new CPO probe):

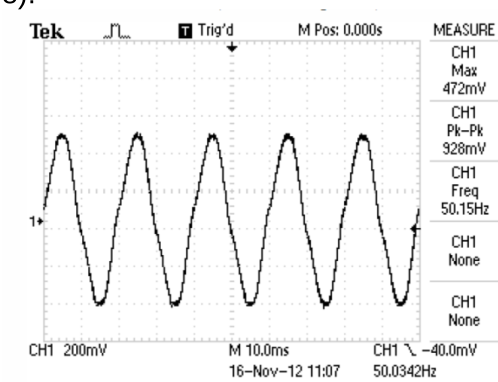

Figure 8

This shows a 0.93 Vpp voltage.

Channel B (old CPO probe) shows a much lower voltage (0.15 Vpp):

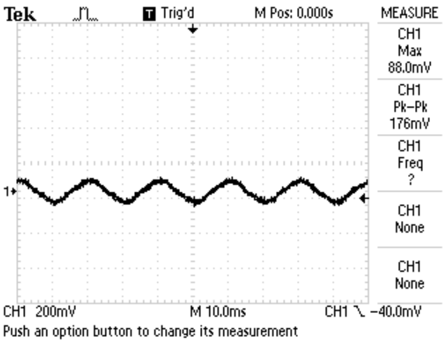

Figure 9

We removed the spark protection disk from the new CPO and re-measure the voltage at the amplifier. This showed no change. We connected the CPO amplifier to the CPO via a very short cable, approx. 0.5 m long. This had a very minor effect in the CPO amplifier voltage output, showing a difference of about 0.04 V. We increased the distance of the new CPO probe to the tank wall from 25 mm to 62 mm. This caused a measurable increase to the output voltage. The voltage was now 1.42 Vpp which is now exactly the voltage NEC suggest we have for a 700 Vpp terminal voltage. However, as 62mm is too high a protrusion for normal operation, both new CPO plate were installed at a 25mm distance from the wall.

We measured the capacitance of the new probe (34.6 pF), the old probe (42 pF) and the cable (~1 nF). From this we concluded that the CPO probe capacitance to ground is not affecting the performance of the amplifier.

9 Tank Cup Default Position Reversal

Team – Alan Cooper, Peter Linardakis, Gareth Crook

During TO #117 an NEC manufactured, replacement swing cup was installed below the slit assembly, in the low energy section of the 14UD. Operation of this cup after commissioning has been satisfactory, but during the SF-6 gas fill this opening (TO #118) there was a significant internal SF6 leak from this system. As a result the cup decommissioned and gas supply shut off, returning it to its default position (cup in), we had no ability to remove it from beam axis.

The question was posed – “why would we install a cup with a default position IN?”

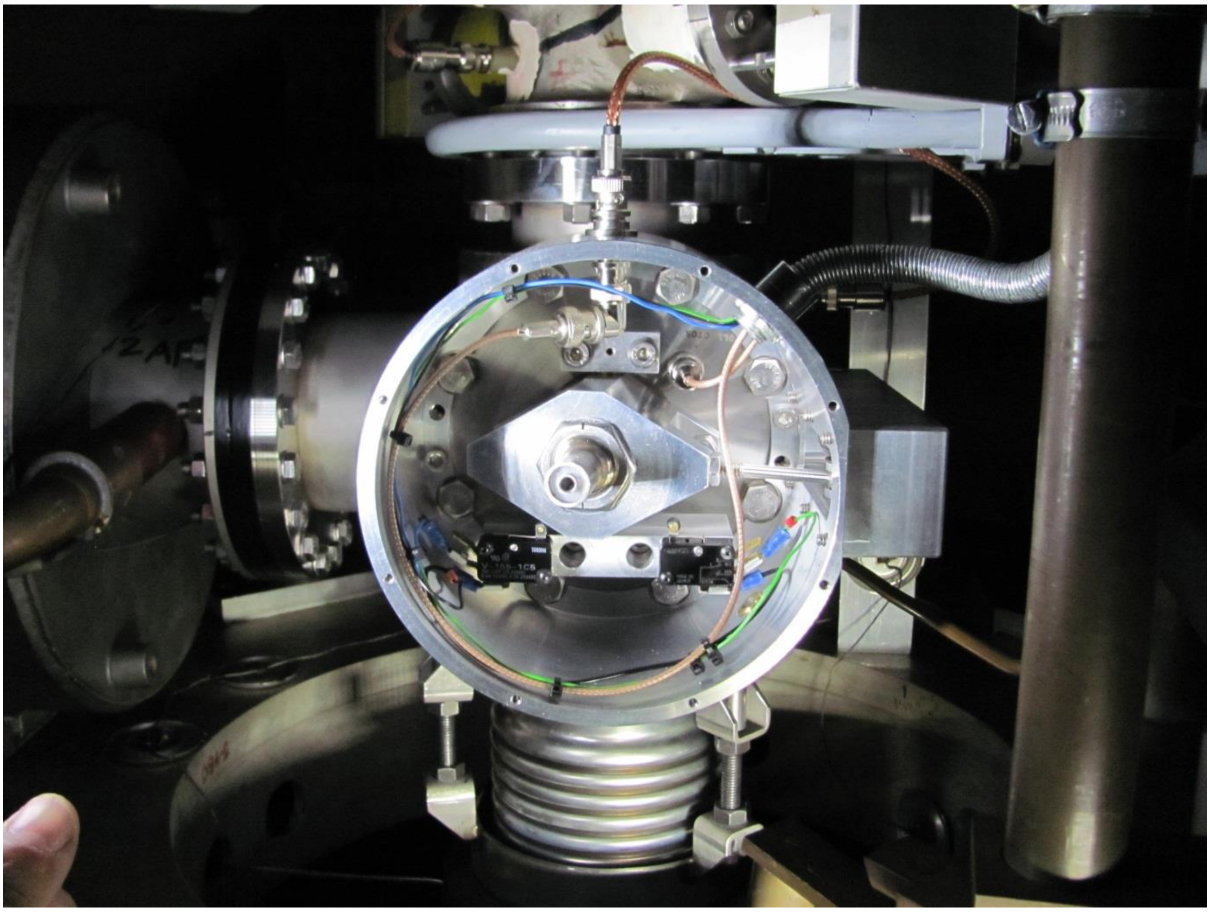

Figure 10 Actuator box and cylinder before modification to default "OUT" position

It was necessary to re-open the 14UD on the 23/11/2012 as the machine was rendered inoperable from this fault. On inspection there were no apparent causes of the internal leak, all external plumbing was inspected and found to be operating correctly. The SF6 supply regulator for this cup was adjusted down in pressure (80psi over atmosphere) for testing purposes, we continued to test the operation and found no faults what so ever, all joints and plumbing were checked and found to be leak tight under atmospheric pressure.

A possible theory for the leak, after the 14UD was filled was considered – *There was a possible issue with the pneumatic actuator seal being exposed to tank pressure (from the outside), while the cylinder pressure was at atmosphere, this could have affected the way the seal seats on the shaft, as it was taking pressure from the side not designed for it.*

The modification to change the unit to default position "OUT" was considered, and while we did not have any "smoking gun" evidence for the leak, it was agreed at the time, it was worth changing the operation of this cup. In the event of another leak/actuator failure, it would leave the cup in the out position, and the machine would still operable.

The design of the linkage and actuator assembly that operated the cup, was such that we were able to swing the pneumatic cylinder and outer actuator housing 180 degrees, to act on the opposite side of the swing cup lever, in turn having the opposite reaction.

While carrying out this change the ¼"copper tube running to the cylinder required re-routing, there was minimal but adequate clearance between the shorting rod tube and pneumatic cylinder as shown below

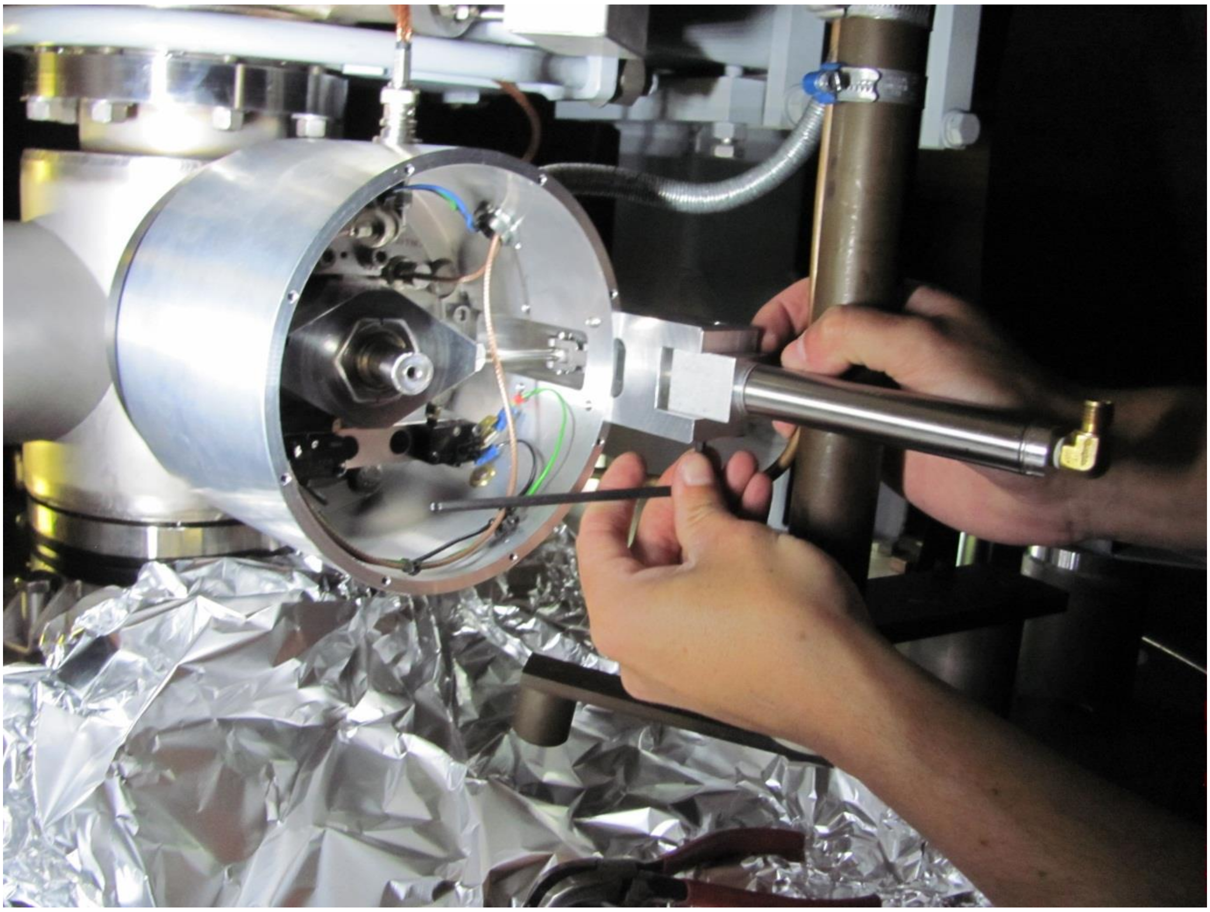

Figure 11 Actuator assembly now acting on the opposite side of the swing cup lever

Testing of the cup after mods proved successful, and has continued to work effectively while under tank pressure, however it would be beneficial to keep 100-120psi in the cylinder while adding gas in the tank, this will ensure the high-pressure side of the actuator seal is seeing more pressure than the outside of it, keeping the seal seated correctly.

10 Machine Hour Meter Readings

TO #118 Chain hours etc Chain # 3L was found broken and was disposed of. Its life ended after 68.219 khrs.

The new chain identified as 3P is a Cr plated, warranty replacement of Chain # 3O from NEC. hain # 3O was returned to NEC following spark damage to the pellet plating. The plating on Chain # 3O was Ni.

Table 4 - Machine hour meter readings

Date compiled	25-10-2012					
Team member	AGM					
Reading	CHAIN #1 (**2M**)	CHAIN #2 (**1N**)	CHAIN #3 (**3L**)	LE SHAFT	HE SHAFT	CH VOLTS
Notes	New @TO111 Swapped from pos 2 @TO#114	New @TO94 Swapped from pos 1 @TO#114	Chain 3L broke. The deceased was disposed of New chain is 3P			
Hours at 13-10-2012	17369	17308	17425	31986	31984	19088
Hours at 20-08-2012 (TO#117)	16713	16651	16752	30597	18430	15127
Change in hours	656	657	673			
Accumulated total hours	8.388k	26.462k	68.219k			

11 Initial Performance

The accelerator initially conditioned to 14.5 MV over a one week period in early January 2013 and was a bit of a struggle. Spark activity was in the gas space and in the vacuum tube. The tank gas pressure was 104 psi. It is now end of January 2013 and plans are under way for the 14UD to inject beam into the LINAC in July and November. The stability of the 14UD is not ideal with small sparks disturbing the terminal voltages and occasional recoverable drop out reducing voltage to 13.3-13.7 MV with long reconditioning time. Preliminary conditioning of sections of 2-4 units revealed that the possible problem might be in the units 13 and 14. More conditioning is to be done to find out if this phenomenon is recoverable or caused by hardware failure in the SF6 space.