Australian National University

14 UD Tank Opening Report

#124

14th May – 12th June 2015

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Contents

1 Reason for tank opening

This tank opening was a scheduled maintenance operation. The main goals were:

- Allow CHLE to load test the service platform and sign-off on the remediation work that they have performed over the last few months.
- Rebuild the gas stripper system using VCR seals to eliminate all possible paths of SF_6 into the acceleration tube.
- Swap the O_2 stripper gas for N_2 gas to improve conditioning performance of the acceleration tube.
- Install second stainless steel CPO electrode
- Monitor items on watch list

2 Summary of work

2.1 14-5-15 Thursday

- The SF_6 was pumped from the 14UD into the storage vessel.
- The porthole doors were opened, and the fresh air ventilation system was run overnight.
- Work by CHLE to tension new cables continued

2.2 15-5-15 Friday

- Gas tests showed the atmosphere within the 14UD was OK and compliant with the Confined Space regulations and was safe to enter
- CHLE completed work on the platform drive system and was ready to begin a load test.
- The platform was deployed and moved down to level 2 in preparation for this test. This included connection of lighting and communications necessary to facilitate testing.
- There was some last minute clarification of the safe working load (S.W.L.) that the platform would need to be tested to. This included trying to determine a better estimate of the weight of the platform itself.

2.3 18-5-14 Monday

- Modelling of the platform structure produced an estimated weight of 1750 kg, with the weight of the counter balance calculated at 2000 kg
- With this information, CHLE load tested the platform system to a S.W.L. of 500 kg
- Safety barriers were reinstated around cable shafts
- HE cup was valved off and solenoid disconnected during AMS cycling test.
- Performed initial 30kV HV entry test. Unit 15, tube 1 showing slightly elevated current of 7.4 µA.
- Also noticed small clumps of black material on rings near chains at the high-energy end.

2.4 19-5-14 Tuesday

- Wiped down column for an initial clean
- There was an unusual amount of white/grey breakdown products around unit 3 and unit 4, which pushed up into a powdery type material when wiped off. Some material was saved for later analysis
- The brown oily stain on the terminal opposite the corona needles was present again this tank opening and there was about six to eight breakdown marks in the middle. The corona needles themselves look a bit blunt.
- There was an excessive amount of black power on the down side of chain 1 and chain 3 on the underside of the castings near the terminal. It is probably chain pulley material and it is a bit "chunkier" than normal. Review of logs show the chains have been oiled on maybe four occasions since the last tank openings.
- Found an unseated ring screw in unit 20
- Ran mechanicals (shafts and chains)
    - Chain 1, unit 16 down side idlers are noisy
    - Chian 2 unit 25 down side idlers are noisy
    - Unit 28 shaft bearing is a bit noisy but OK, no need to maintain watch
    - Unit 5, bottom shaft bearing requires replacement
    - Chains 1 and 3 have a bit of wobble in them as they go onto the terminal pulleys. Coincidence maybe, but these two are also the ones that show the worst amount of black deposits on the exit side of the terminal pulley.
- Just as an FYI, Chains 1, 2 and 3 took ~40, ~54 and ~45 seconds to come to a stop after motors were switched off.
- Completed low-voltage testing on the entire accelerator. There were no pressing issues found[1].

2.5 20-5-14 Wednesday

- Began process to remove terminal spinnings. Took notes to prepare for life without the direction of Muirhead.
- Found some black rubber material on the inside of the casting cover directly opposite the unit 15 shaft bearing.
- Looked at Chain 1, unit 16 down side idlers. Idler bearings were changed during tank opening 120 and they look OK. The noise may be mechanical from a dry chain hitting the idler wheels during movement.
- Terminal chain pulley area for Chains 1 and 3 is covered in black material as expected.
- Chain 3 is showing lip-to-lip spark damage on its pellets.
- Closed Weisser valve at terminal foil stripper and vented low-energy end of the acceleration tube. A constant flow of dry N_2 was left to flow through the acceleration tube.
- Checked pressure of O_2 stripper gas bottle, was 0.224 barg. Also used SF_6 detector to check for signs of SF_6 in stripper bottle. No definite reaction to SF_6 observed.
- Removed stainless steel CPO electrode because its weight was causing undue strain on the feed through. An attempt will be made to modify the design to remove as much material as possible.

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[1] Low-voltage testing method is described in the conference paper N. Lobanov et al. *"Ultra High Impedance Diagnostics of Electrostatic Accelerators with Improved Resolution"*, to appear in the proceedings of HIAT 2015.

- The gas stripper box, all valves and all pipe work up to and including the manifold (with the micromaze traps) was removed in preparation for new hardware using only welded or VCR joints.

2.6 21-5-14 Thursday

- Removed unit 5 shaft bearing. The problem turned out to be a work bottom bearing carrier. The bearings themselves were not too bad, but of course, new bearings were used for the repair anyway.
- Removed corona needle assembly
- Test fit of unit conversion hardware on unit 5
- Work began on the gas stripper system outside the tank. VCR joins were welded into the turbo backing manifold. Some of pipework inside the gas box was also welded.
- Low-voltage measurements inside the tank continued
- New needles were soldered into all three available corona needle point assemblies

2.7 22-5-14 Friday

- One set of corona needles was reinstalled into the machine. Use the spares next time!
- Reinstalled unit 5 shaft bearing. There are now two stripped threads on the bottom shaft mount flange.
- Work continued on VCR/weld conversion of gas stripper.

2.8 25-5-14 Monday

- With the benefit of a relaxing weekend, two stripped threads in a bearing carrier was thought to be too much. So out came the unit 5 shaft bearing again. A new set of holes will be tapped into the bottom.
- Entered the bottom of the tank for an initial inspection. Shards of nylon were found everywhere, which was due to an “up” charging system standoff insulator exploding. Another nearby “down” charging system insulator standoff was also damaged. These were installed new last tank opening with new, larger end caps that were intended to provide better protection. Cleaned up as much as we could and removed the insulators for inspection.
- Measured chain leg clearances:
    - Chain 1: 75 mm
    - Chain 2: 85 mm
    - Chain 3: 82 mm
- Reinstalled gas stripper backing manifold.
- Performed initial clean of terminal chain pulley area, mainly to get rid of most of the black dust.

2.9 26-5-14 Tuesday

- Started pumping down on low-energy end of the acceleration tube
- Applied power to gas stripper micromaze trap heaters to start bake-out

- Inspected both charging and suppressor system tank feed through insulators in case they were damaged in the same event that damaged the charging system stand offs. They were fine, so after a precautionary clean up, they were reinstalled.

2.10 27-5-14 Wednesday

- Cleaned chain 2 and chain 3 began removing downside casting idler petals for cleaning.

2.11 28-5-14 Thursday

- Work continued

2.12 29-5-14 Friday

- Checked for gross play in the chain wheel bearings
- Cleaned chain 1 and refitted unit 19 idler petals
- Gas stripper bottle was evacuated and filled with N_2 to a pressure of 0.302 barg
- Fitted bottle to terminal and completed all gas box plumbing
- Started He leak testing of gas stripper system. They were all OK, but should retest on Monday.

2.13 1-6-14 Monday

- Began retesting gas stripper box and piping for leaks. The He leak tester had been pumping all weekend and reached a case measurement of 4.7×10^{-11} mbar·l/s.
- There was a reaction at the last Swagelok connection to the leak detector, but it was pointed out that by Alan (Synchrotron) that we were spraying close to the He leak detector exhaust. So, we moved the leak detector down to the next terminal level away from the region to be tested.
- Tried to mount the “lightened” stainless steel CPO electrodes, but there was a lot of run-out. Took it away to investigate, but not much we can do about it. The other, new stainless steel electrode had a UNC thread?!
- Leak tested the gas stripper system from a base reading of 8×10^{-11} mbar·l/s and had no response. Just as a check, sprayed helium near the leak testers exhaust valve and in a couple of minutes, the reading went up to 8×10^{-9} mbar·l/s. So, new rule: Keep the leak tester as far away from the area under test as is practical!
- Evacuated gas stripper system with the fine valve at 40% using the leak detector. Closed fine valve at 0.17 mT.
- Pumped on foil interspace using leak detector (it’s dry and the base pressure is ~3 mT). The pressure went up when the valve was first opened.
- Opened the Wessier valve.

2.14 2-6-14 Tuesday

- Preparing to close the terminal
- Found that the chain 1 downside inductor was laterally too close to the chain. Readjusted and ready to go.
- Checked fine valve position visually to see if correlates to the position reported by EPICS. It’s good.

- Closed up boxes in the terminal.
- Removed gas stripper valve handles.
- Resinated cap over the Weisser valve.
- Installed new saddle clamp over gas stripper pipework
- Tested insulation resistance of terminal pulley shafts to terminal. All resistance were greater than 100 MΩ.
- Installed second new stainless steel CPO electrode
- Began terminal operations checklist to prepare for closing, but aborted when the gas stripper pressure (as read on the convectron via EPICS) shot up as soon as the valve on the N_2 bottle was cracked open. We valved of the bottle off again quickly! After isolating the stripper canal, we watched the stripper pressure continue to climb. Clearly, the fine valve was not actually closed, even though it was on the limit switch at a read back of ~7%. So, we kept driving it shut by moving the limit switch and altering software limits in EPICS. The pressure stopped climbing at a valve position read back of about -0.5%. The valve then did not open again until about 12%, and then did not close until 8%. It will all be checked gain, but what we may just be seeing the effect of “recalibration requirement” mentioned in the manual after the valve has been exercised to its fully open position (as it was to enable argon flow during welding). We all agreed that this must be the mechanical equivalent of turning it off and then turning it back on again.

2.15 3-6-14 Wednesday

- Operated fine valve a few times to gauge consistency of opening point (while pumping on it with the leak detector). Opening point was between 13.5 and 14.2%. Interestingly, the fully closed position isn’t until about 11%.
- Repeated the above with gas stripper system open to tube and gain, the opening point was about 14.2%, with fully closed registering at 11.5%. This satisfied us that all was OK.
- Reset the fine valve close limit switch. Minimum position according to EPICS read back is now about 6.1% (was at ~7.5%).
- Rechecked N_2 gas bottle pressure. It is 0.25 barg and left as is. Much effort was made to measure the bottle pressure without deliberate contamination of the N_2 gas, which included evacuation of the dead space between the bottle valve and the pressure meter.
- Blew down and wiped terminal, then proceeded to terminal operations checklist (with shafts running). All was OK.
- The rest of the afternoon was devoted to learning from Cooper about alignment of components in the terminal.

2.16 4-6-14 Thursday

- Closed terminal using a combination of the platform and the hand crank at level 2. This meant that we had a nice, soft lift and drop of each of the terminal spinnings.
- The rest of the day was used for another round of low-voltage tests

2.17 5-6-14 Friday

- Started open-clean-inspect rundown starting form unit 1 and finishing at unit 15. Issues found and rectified were:

    - Unit 1 shorting rod contact housing was loose and noted that gauze gasket was missing. New housing, gasket and spring installed after clean-up of casting surface.
    - Replaced unit 2, tube 1, gap 9, replace resistor lead.
    - Replaced unit 4, tube 1, gap 1, replace resistor lead.
    - Replaced unit 12, tube 1, gap 1, replace resistor lead. Also one resistor in pair had and oversized spark gap electrode. New spark electrode was fitted. Other resistor in pair was loose in its shield.
    - Unit 13, tube 1, gap 6 top resistor had green dust on it (reminiscent of eroded shield a few tank openings ago). Resistor was disassembled and checked, but nothing was obviously wrong. A spare was installed in its place just as a precaution.
    - Unit 13, tube 2, gap 11, top resistor had misaligned spark gap. New spark electrode was fitted during alignment.
    - Unit 15, tube 1, gap 1, replace resistor lead
    - Unit 15 post resistor, gap 7, top resistor shield had stripped thread. Replaced with spare.
- Check watch list item for unit 6. There is increased discoloration as compared to last time, but there is no current leakage at 6 kV across the gap, and only this gap.

2.18 8-6-14 Monday

- Queen's Birthday public holiday

2.19 9-6-14 Tuesday

- Recommenced open-clean-inspect rundown for unit 15 through unit 28. Issues found and rectified were:
    - Unit 17, post resistor, gap 4, both ends of resistor lead charred with marks on resistor spark gaps. Resistors replaced with spares and good lead fitted.
    - One of the unit 19/high-energy midsection top grounding loop rivet attachments on a post had come loose. There was insufficient material to re-rivet, so clamp attachment based on resistor mounting (similar to that described in section 5 of tank opening report 120)
    - Unit 20, post end of stringer two rivet mounting was loose. The suspicion was that we had tried to just tighten this previously, but now decided on permanent fix. Used a resistor-type clamp as just described for unit 19/high-energy midsection.
    - Unit 23 tube end of stinger 2 had a loose screw. Replaced with "new-style" radiused socket head screws (see section 5 of tank opening report 119).
- All idler high-energy end idler petals (aside from those already cleaned unit 19) removed for cleaning.

2.20 10-6-14 Wednesday

- Refitted all high-energy end idler petals.
- Hand oiled chains from open unit 26.
- Re-rung all open units.
- Performed compressed air blowdown of column.

- Vacuumed platform
- Refit casting covers that had been removed for terminal opening.
- Performed 30 kV high-voltage exit test. All OK.
- Re-measured some low-voltage test values for unit 27 and unit 28.
- Wiped down column.
- Unloaded all unnecessary items from service platform and vacuumed again.
- Parked platform to enable entry to bottom of the tank in anticipation of inoperable platform tomorrow.

2.21 11-6-14 Thursday

- Cleaned the bottom of the tank and checked inductor spacings. Also took the opportunity to fish out various items that had been dropped during the tank opening.
- Topped up all chain oiler reservoirs.
- Checked suppressor electrode connection to chains
- Vacuumed in tank bottom.
- Ran through closing procedure and associated tests.
- Platform was raised, with final part of travel performed by hand crank for more control and a softer docking.
- Closed port holes and started pump out.

2.22 12-6-14 Friday

- Gassed up tank.

3 CPO electrodes

As discussed in tank opening report 123, one stainless steel CPO electrode had been installed. During this tank opening, there was some concern that the weight of the electrodes were placing undue stress on the tank feed throughs

The already installed stainless steel electrode was removed and sent for modification to reduce its weight. The modifications entailed removal of as much material as possible from the back side of the electrode. A second new, “light” stainless steel electrode was also produced and installed. Note that due to a mix up, the thread on the two CPO electrodes is not the same. One is UNF and the other is UNC.

Mounting of one of the electrodes is shown in Figure 1.

Figure 1 Second stainless steel CPO electrode

4 Gas stripper reconfiguration

The gas stripper was rebuilt due to various issues reported over a number of tank openings. It was felt that there was a leak into the stripper system and that previous attempts to address this by changing the valves to welded-body Swagelok type valves had not fixed the problem. It was also felt that O_2 stripper gas was detrimental the conditioning of the acceleration tube and that a change to N_2 was required.

The objective was to eliminate all Swagelok compression-type connections from the entire gas striper, replacing them with welded components or VCR-gasketed connections where necessary. The entire system from the storage volume to the turbo backing manifold was upgraded or replaced.

At the gas storage volume, the fitting was changed from a NPT pipe fitting sealed by tape/sealant into a fully welded connection. The screwed fitting was removed and machined to remove the trapped volume in the thread area and bored out. An intermediate stub fitting was machined from solid stainless steel and hand TIG welded (Ross Tranter) into the modified screwed fitting on the internal side, then that welded assembly was welded into the gas volume. The resultant protruding stub was fitted with a VCR connection via an orbital weld (Dane Kelly / NP techs).

The turbo backing manifold side had two Swagelok fittings entering at the middle section. VCR adapters were modified to fit into the Swagelok connectors (sans nuts/olives) and hand TIG welded into place (Ross Tranter). Both gas volume and backing manifold were then leak tested using helium at atmospheric pressure and proven good.

The next stage centred on the system inside the shielded box in the terminal. The bellows leading to and from the box had their Swagelok ends cut off and prepared for orbital-weld type VCR fittings. Bulkhead fittings into the box were changed for VCR items necessitating enlarging of the holes in the box. All of the pipework and Swagelok fittings within the box were removed and replaced with new orbital-weld type fittings and clean Swagelok tubing. The variable leak valve similarly had its Swagelok fittings cut off and replaced with VCR orbital-weld fittings. Some rearrangement of the box internals were necessary but the end result saw all joints done either by orbital-welded fittings, mini-conflat (convectron gauge) or VCR joint.

Back inside the terminal, new tubulation was constructed using clean Swagelok tubing, orbital-welded fittings and 4 new VCR valves (SS-4BK-V51 type). All components were leak tested both on the bench were possible and also in the system once it was assembled. The chosen VCR gasket material was Stainless Steel. A problem was encountered with the leak detector when it was placed close to the leak testing area whereby helium was back streaming through the pump and showing up as a false leak. This was resolved by placing the leak detector lower down in the terminal away from the area being tested. A gas ballast system might be beneficial on this leak detector.

The gas volume was charged with N_2 and the leak valve was tested. A shift in the opening and closing points was observed compared to previous numbers but the leak valve operated correctly and, after a number of cycles, the points were repeatable. The “fully closed” position is now less than 6.5% and the point at which a pressure reaction is observed is now about 14% (previously about 16%). Any changes in this over time need to be noted.

Figure 2 Gas stripper system with new VCR connections

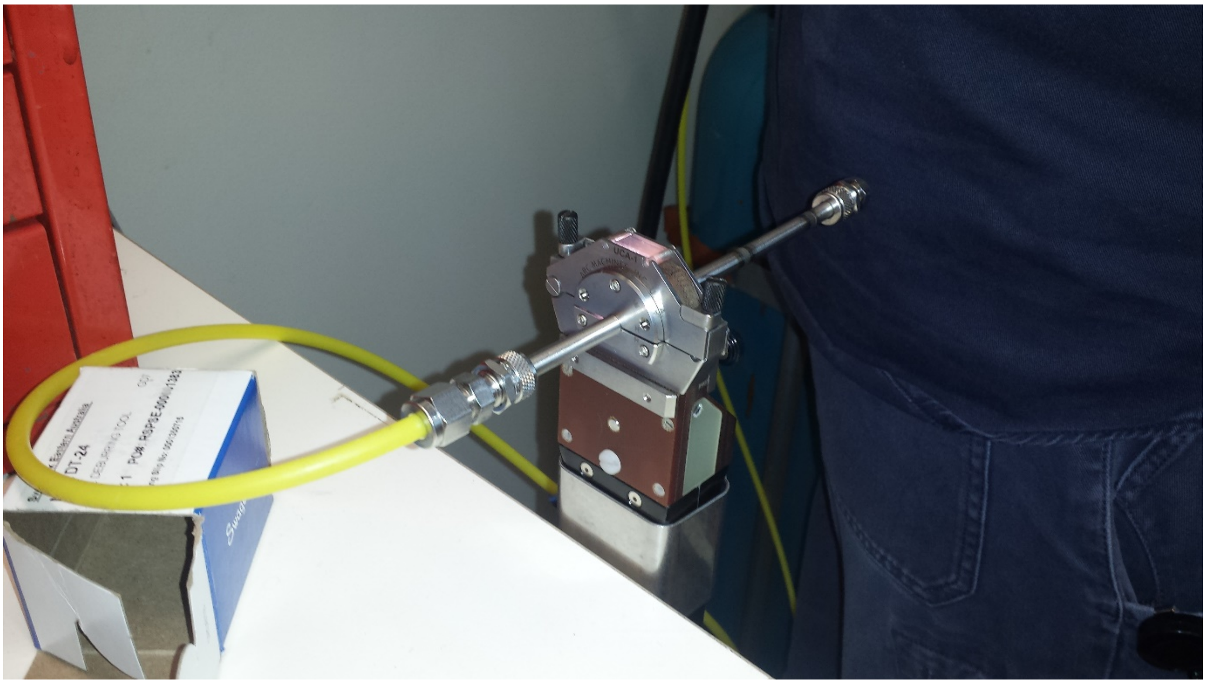

Figure 3 Orbital welder in use

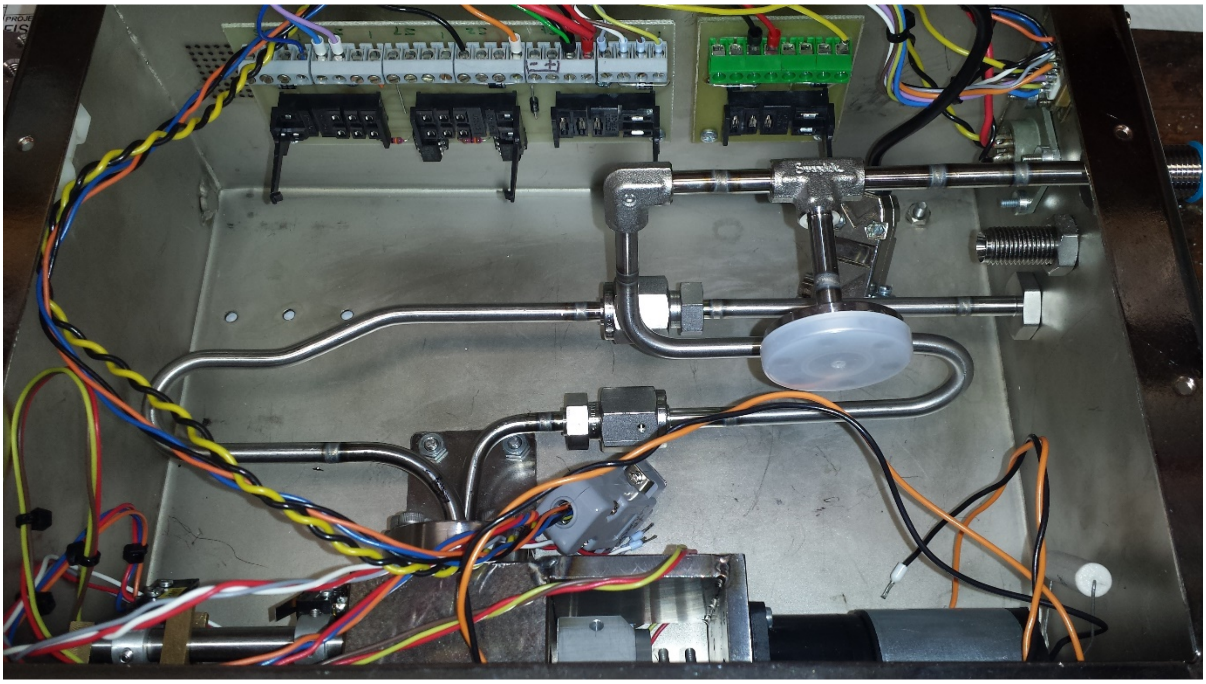

Figure 4 New welded and VCR connections inside gas stripper control box

5 Stringer/wire attachment to posts

There were two instances in this tank opening requiring reattachment of stinger or wire to posts. These are shown in Figure 2 and Figure 3 and are based on thoughts discussed in section 5 of tank opening report 120. In both cases, we had previously tried repairs such as re-riveting the existing clamps, but the deterioration of the rivet holes on the post meant that we had to do better this time and fix both once and for all. The attachments are simply resistor end clamps that have been turned down to a reasonable diameter.

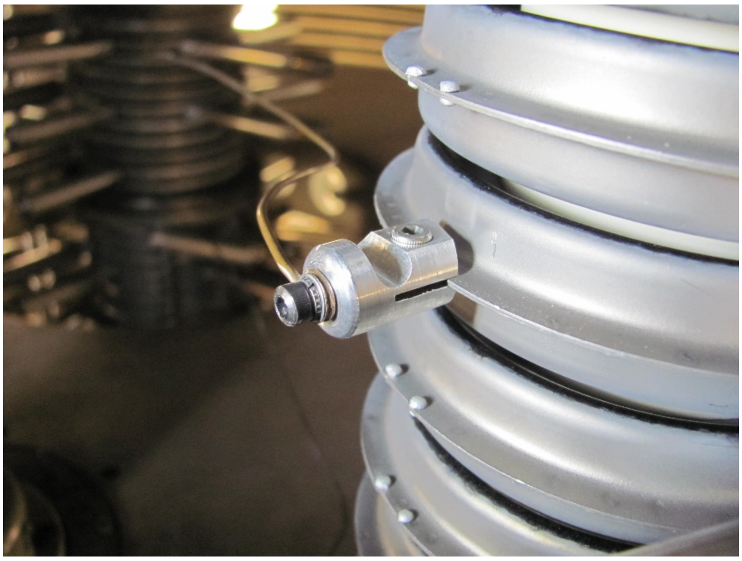

Figure 5 Unit 20 stringer two attachment using a turned down resistor end clamp

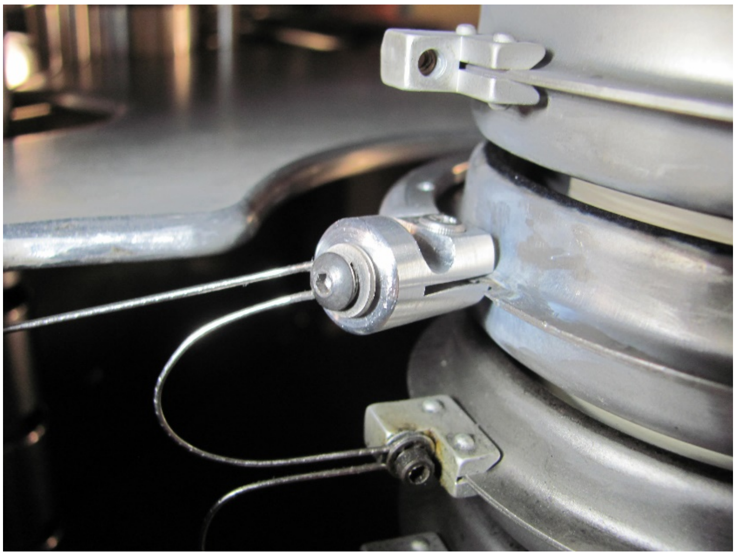

Figure 6 Unit 19/high-energy midsection grounding loop attachment

6 Charging system standoff reconfiguration

During the initial inspection at the bottom of the tank, shards of nylon were found littered about as shown in Figure 2.

Figure 7 Nylon shards littering the bottom of the tank from exploded charging system standoff

Closer inspection showed that the nylon debris was due to an "up" charging system standoff insulator "exploding". The "down" charging system insulator standoff was also damaged to a lesser extent. The failure was not shown up by initial electrical testing as both damaged insulators maintained enough structural integrity to keep the aluminium caps insulated and in place (see Figure 8).

The damage appeared to be caused by sparking from the aluminium mounting collar, through the nylon to the aluminium cap. In line with standard insulator protection, it was decided to introduce a metal to metal spark gap (of approx. 3mm). For the new standoff, existing caps were utilised along with a new nylon spacer and new aluminium mounting bracket. This is shown in Figure 9.

It was also decided that the arrangement be rewired. For both the "up" and "down", the wiring now comes up from the "mushroom" on the bottom of the tank to an intermediate standoff then to the new spark-gapped standoff where it is then distributed to the 3 "up" or "down" inductors. This minimises the number of standoffs required and is simpler to follow than the old daisy chained arrangement.

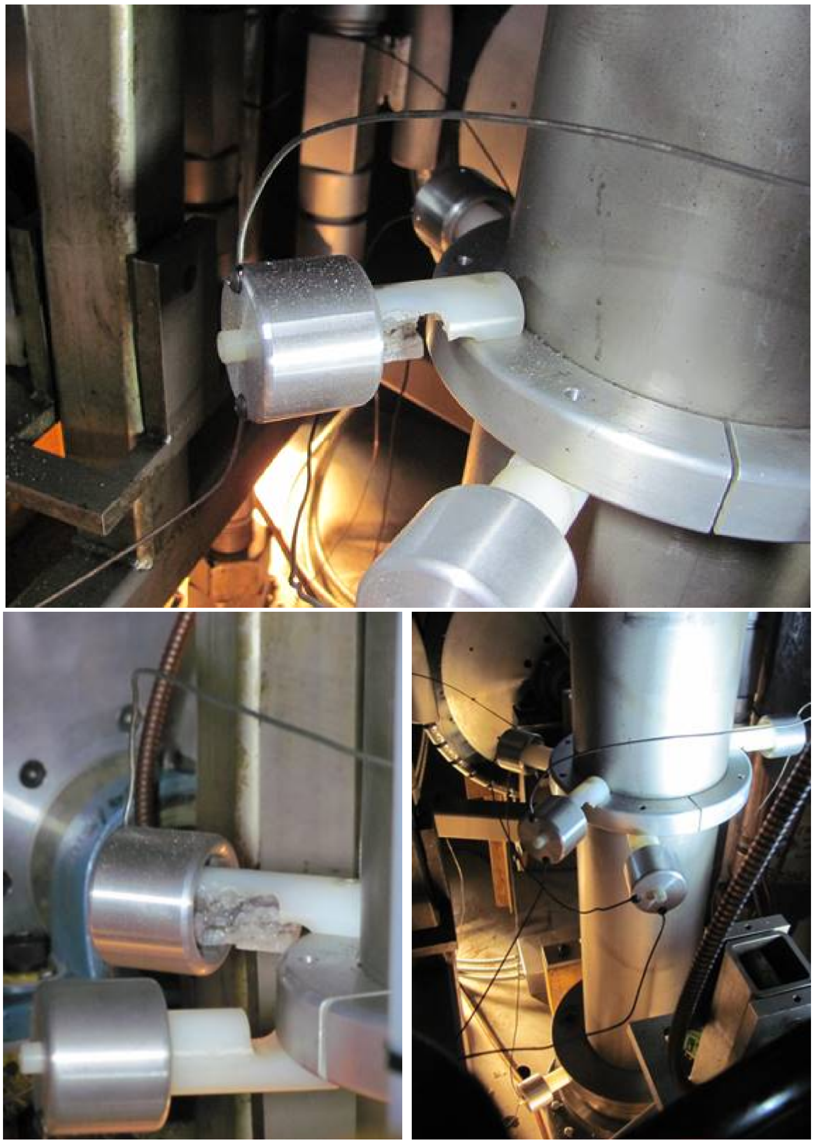

Figure 8 Damage to nylon charging system standoff

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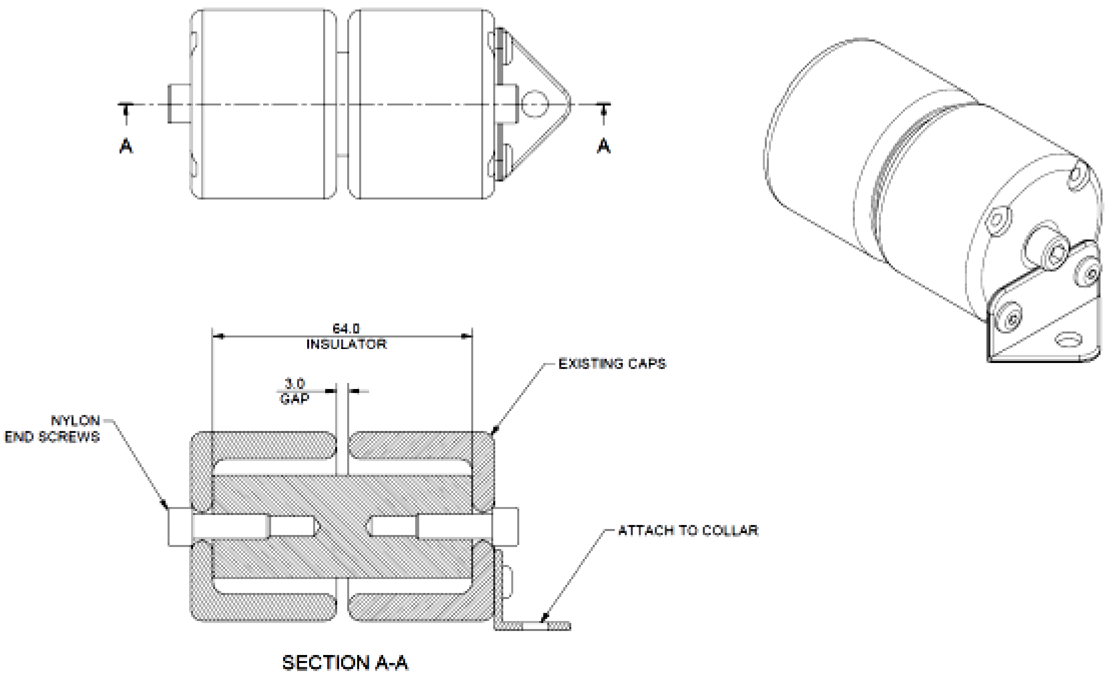

Figure 9 Modified charging system standoff with spark gap

7 Watch list

Table 1 Watch list of suspect items for review next tank opening

Unit	Component	Description	Condition/ Resolution	Retain watch
6	Post C, gap 10	May have small subtle cracks in ceramic	Increased discoloration, no current leak at 6 kV	Yes
22	Post C, gaps 7 and 10	May be a small subtle crack, but also what may be two, small, surface divots at a “nine o’clock” position	No deterioration	Yes
28	Post B, gap 12	Marks including metallic deposits	No deterioration	Yes
28	Shaft bearing	Determined to be OK	No deterioration	No

8 Tube ceramic insulator current leakage

The current state of shorted tube ceramic gaps is shown in Table 1

Table 2 Summary of tube ceramic current leakage in the 14UD

Unit	Tube	Gap	Leakage though insulator @5kV (TO #123)	Discovery	Comment	Repair
3	2	2	8 µA	TO #121		Dummy resistors top and bottom, dummy on post gap ????
6	1	2	1.1 µA	TO #123		Dummy resistors top and bottom, dummy on post gap 5, top
7	3	10	12 µA	TO #120		Dummy resistors top and bottom, dummy on post gap 10, top
12	1	2	0.25 µA	TO #123		Dummy resistors top and bottom, dummy on post gap 5, top
13	1	10	0 µA	TO #120	Suspicious arc mark across gap	Dummy resistors top and bottom, dummy on post gap 3, top
13	2	1	0.05 µA	TO #120		Dummy resistors top and bottom, dummy on post gap 8, top
25	3	10	7 µA	TO #120		Dummy resistors top and bottom, dummy on post gap 16, top
26	3	5	0.15 µA	TO # 123		Dummy resistors top and bottom, dummy on post gap 12, bottom
26	3	10	0.01 µA	TO # 123		None, deemed to small. Monitor.
26	3	11	2.5 µA	TO # 123		Dummy resistors top and bottom, dummy on post gap 14, bottom
28	3	1	0.01 µA	TO # 123		None, deemed to small. Monitor
28	3	5	0.47 µA	TO # 123		Dummy resistors top and bottom, dummy on post gap 12, top
28	3	7	0.1 µA	TO # 123		Dummy resistors top and bottom, dummy on post gap 13, top
28	3	9	0.02 µA	TO # 123		None, deemed to small. Monitor
28	3	10	0.05 µA	TO # 123		None, deemed to small. Monitor
28	3	11	0.28 µA	TO # 123		Dummy resistors top and bottom, dummy on post gap 14, top

9 Machine hour meter readings

Table 3 Machine hour meter readings

Date compiled	25/05/2015					
Team member(s)	PL/TT					
Reading	Chain #1 (1O)	Chain #2 (2N)	Chain #3 (3P)	LE shaft	HE shaft	Ch. volts
Notes	New @TO121	New @TO121	New @TO118			
Current reading	26965	26904	27052	45462	45460	28520
Previous reading (TO #123)	23001	23001	23001	40640	40639	24898
Change in hours	3964	3903	4051	4822	4821	3622
Previous total hours	1469	1469	5811			
Current total hours	5433	5372	9862			

10 Terminal voltage distribution for period of service

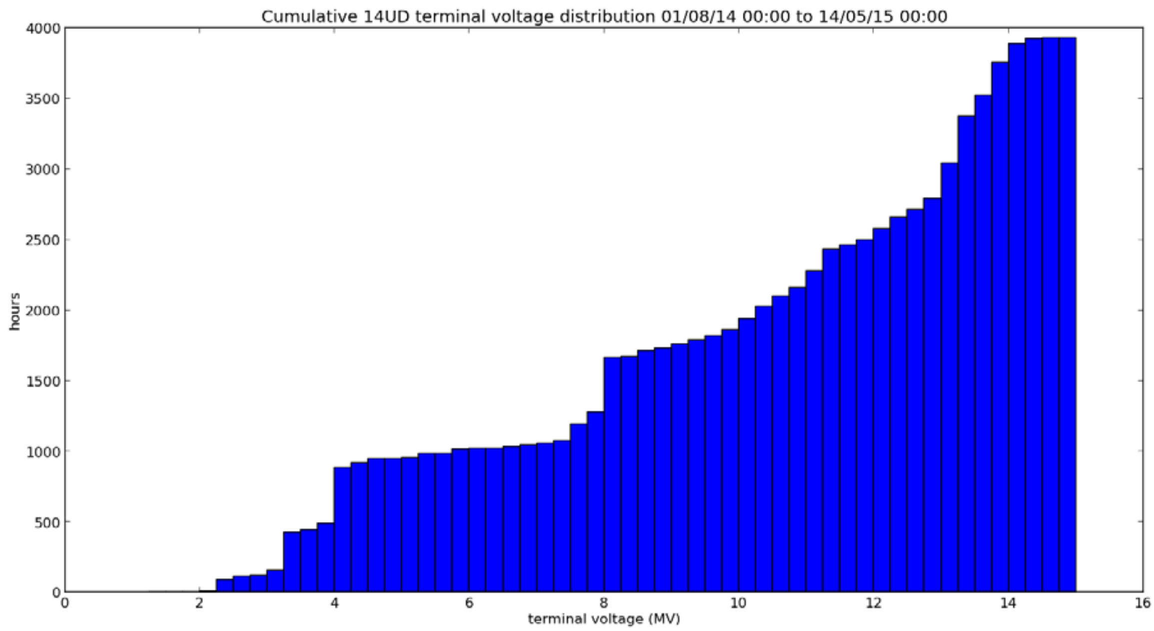

Figure 10 Cumulative terminal voltage distribution for period of operation from the end of tank opening 123 to the start of tank opening 124

Total hours with voltage on terminal was 3926 hrs, which gives a utilization of 60% assuming a twenty-four hour, seven-day maximum.

11 Initial performance

11.1 Gas stripper base pressure

Figure 11 and Figure 12 compare the gas stripper system base pressures over time (shaft alternators on and gas valve fully shut) from before any work was done on the gas stripper system to after the system was reconfigured to use welded and VCR pipe joins. This shows that performance is as good or better. That is, the process was a success!

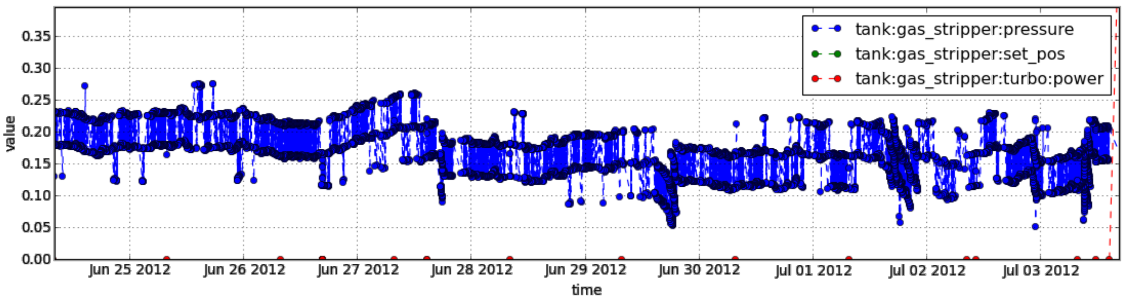

Figure 11 Gas stripper base pressure before tank opening 117 (untouched system)

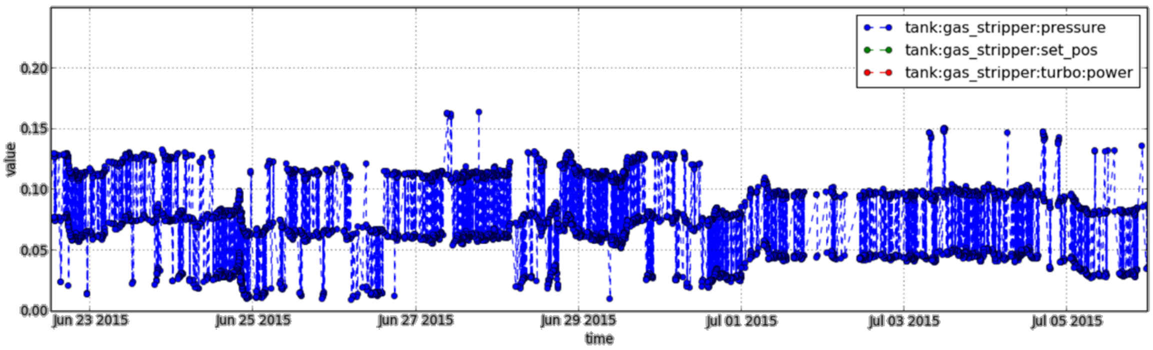

Figure 12 Gas stripper base pressure after tank opening 124 (VCR and welded system)

11.2 SF_6 ingress into acceleration tube

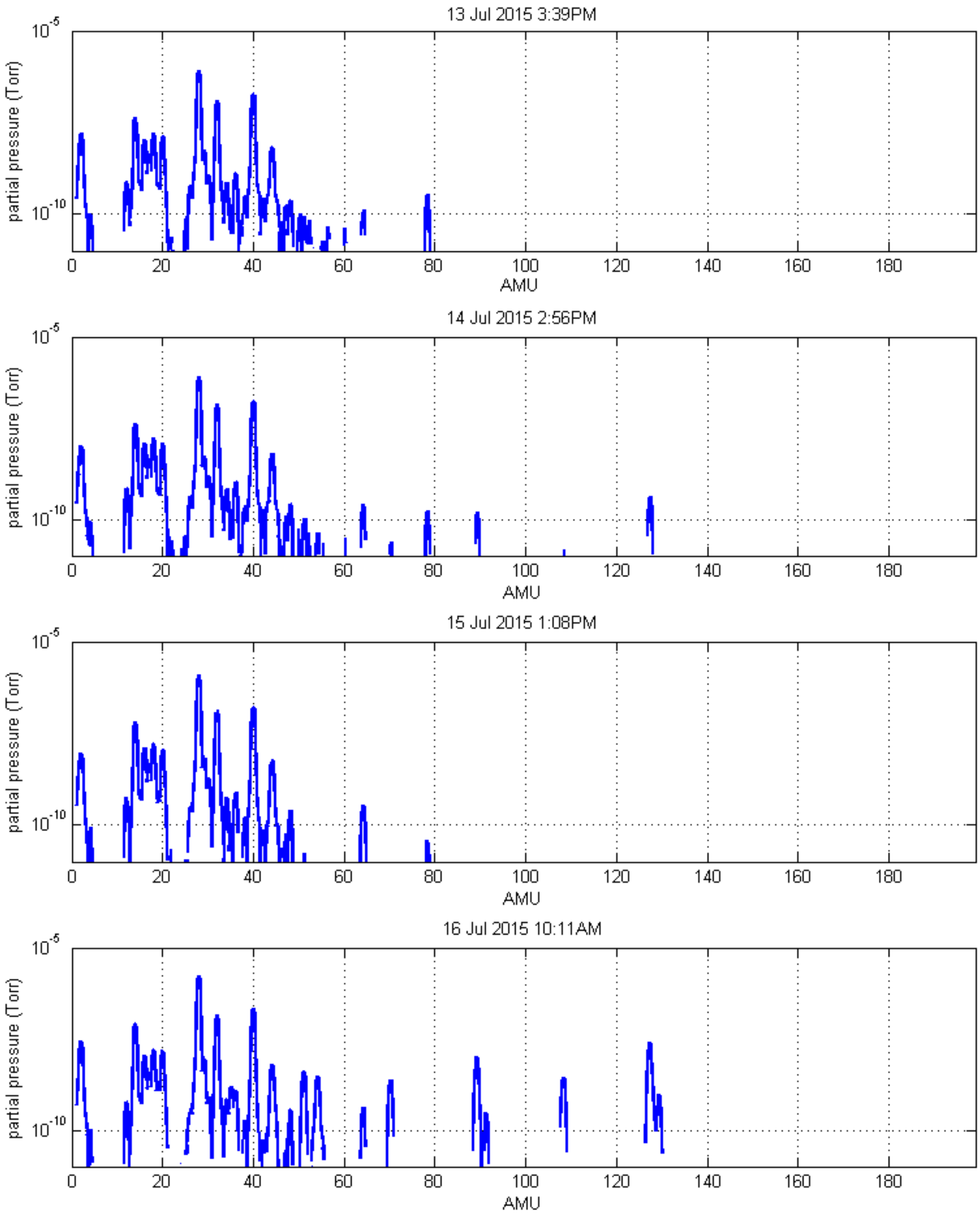

Figure 13 RGA scans taken after TO 124. A round of conditioning was performed between the 15th and 16th of July. In all traces, the shafts were off (no pumping in the terminal) overnight and the 300l/s ion pump at the low-energy end was switched off for at least two hours to allow any gasses in the terminal to reach the position of the RGA at the low-energy end.