Australian National University

14 UD Tank Opening Report

#130

21st January – 1st April 2019

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Contents

1 Reason for tank opening

This tank opening was scheduled maintenance operation but forced due to concerns about the maximum achievable terminal voltage due to beam loading (isolated to the high enery mid-section region). There were two main goals:

- reinstall the gas stripper system with the new NEC backing manifold and
- install the new high-energy mid-section foil stripper housing which has a new electrode/aperture configuration.

2 Summary of work

2.1 Tank opening #130

2.1.1 21/1/19 Monday

- 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.

2.1.2 22/1/19 Tuesday

- There were problems with the Department's GMI PS200 gas detector (zero failure on the O_2 sensor), which delayed entry in the tank. An alternate gas detector was sourced from Romeo from Facilities and Services.
- Gas tests showed the atmosphere within the 14UD was OK and compliant with the Confined Space regulations and was safe to enter.
- Platform was deployed and tool and lighting setup loaded on.
  Performed initial 10kV HV entry test using the Megger only. A number of issues were found in unit 13, tube 1 and 4, unit 14, tube 2 and unit 20, tube 2 and 4.

2.1.3 23/1/19 Wednesday

- Wiped down column using RBS solution.
- Ran chains to examine condition
    - Chain 1 was OK with no serious whip. Chain 1 had a 40 second run down time.
    - Chain 2 was OK with no serious whip, but ran a little louder than Chian 1. Chain 2 had a 44 second run down time.
    - Chain 3 was noisier than the other two, which is what we have come to expect. Chain 3 had approximately a 33 second run down time.
- Ran Shaft to examine condition
    - High energy shaft is very quiet and in good order.
    - Low energy shaft is very quiet and in good order.
- Looked at resistor issues in units 13 and 14. Most resistors were within specification. However gap 1 on unit 13 post D leaked 1.5µA/3.38GΩ@5kV and gap 13 on post B leaked 2µA/2.53GΩ@5kV. Both these posts were installed new in TO 129. As these issues do not rely on the vacuum space in the acceleration tube, they can be looked at later.
- The tank cup was inoperative during the last period. An air line was connected to avoid releasing SF_6 into the tank and the tank cup was tested. It works fine.

However, there is a possible leak upstream of the hand valves near the solenoid (the section beyond this was isolated and tested and it seems to hold pressure). We're unsure if the leak is from the jimmied airline or from the actual copper lines.
- Entered the bottom of the tank to install the portable O_2 sensor.

2.1.4 24/1/19 Thursday

- Continued resistor troubleshooting in unit 20. The issue was found to be because some column resistors (with the burnt ends) that are meant to be associated with an 8-gap tube section were incorrectly installed opposite an 11-gap tube section, and vice-versa with the 11-gap column resistors. These were swapped back to the correct positions and unsurprisingly, this solved the issue.
- Removed come casting covers in preparation for moving the terminal spinnings
- Opened the terminal
- Ran a quick sweep of the terminal with the radiation detector. Nothing above 1µSv/h was found even at point previously marked with a high reading.
- Inspected the shield box that normally contains the gas stripper leak valve controller to see if we can mount the box in a fixed position on the back of the shielded box. It looks possible with some small modifications. This will allow us to do away with the flexible bellows and install fixed gas lines (and hence have more confidence in their ability to withstand 100psia of SF_6.

2.1.5 25/1/19 Friday

- Installed new corona needle assembly
- Reconnected SF_6 bottle to the line for the tank cup and tested cup operation. It appears to work fine. Isolated the cup hand valves and the bottle to see if the line retains pressure and it does, at least over a period of hours.
- Fabricated a bracket and mounted the gas stripper valve control box directly to the back of the shielded box in the terminal. It fits! Some tidying up will have to happen when all the hard gas lines are installed.

2.1.6 28/1/19 Monday

- Straya day holiday

2.1.7 29/1/19 Tuesday

- We were light on staff so not much happened today.
- Bent tubes for run from gas stripper box to the inside wall of the shielded box.
- Ordered high purity N_2 gas bottle (and regulator) to use for venting the terminal foil stripper section.

2.1.8 30/1/19 Wednesday

- Ran mains power to terminal
- Vented terminal foil stripper
    - Set up Hi-Cube system to terminal foil valve
    - Pumped up to valve and vented to air
    - Removed Hi-Cube
- Examined removable piece in terminal plate and decided it can be removed. Will leave sandwich plate on one side just to be on the safe side. A brace is being made

up to take any weight on the bracket that stabilises the terminal vacuum tubes. Hole boring can then be done outside on a proper machine.
- Various frigging around venting LE tube
- Turbo flanges mainly unbolted ready for removal. We realise we are lacking the studs to fit them, vague recollection of them being too short and that they were taken away to make new and have not done so.
- Brace completed and installed, does not appear to be for any vertical load bearing, lateral only. The brace is unlikely to do much then but can't hurt.
- Emailed NEC regarding removal of that slot piece in the terminal.
- Slow day due to lack of staff.

2.1.9 31/1/19 Thursday

- Read out chain/shaft charging system hours on meters in control room console.
- Today we took a step back to assess our plans for the installation of the new gas stripper backing manifold. Specifically, our plans to drill a hole in the terminal support plate. There were plans to remove the insert plate, but no one was confident that this would not compromise the column structure. The best option may be to use the mag drill, but the fixing system will have to be well thought out. We also did a sanity check on the dimensions of the manifold and looks like the extension brace plate will nicely interfere with the terminal support plate. This means we need a big hole.

2.1.10 1/2/19 Friday

- After more investigations and thought, we returned to the idea of removing the plates from the machine to cut the hole.
    - Removal was slow and careful, with a set up of levels and dial gauges used to make sure there were no great movements when bolts were released.
    - Initial loosening of the bolts showed some movement and the bridge installed to support the acceleration tube was removed and a longer one installed to move the load toward the edge of the circular plate. After this, there was minimal movement (maybe a 0.15 mm drop).
    - The center plate required some coaxing as it was pinched by the four post brackets.
    - By the afternoon, all three plates were out. A temporary plate was fixed to the gap to as a safeguard for over the weekend.

2.1.11 4/2/19 Monday

2.1.12 5/2/19 Tuesday

- Refitted plate from terminal. Installation was much easier than removal, but still required the use of clamps.
- Cut 64 studs for terminal turbos
- Remounted terminal turbos. Have nipped up the bolts, but have not fully tightened them. Will install the manifold first.

2.1.13 7/2/19 Wednesday

- Decided against installing gas stripper backing manifold. It will be installed last thing before tube pump down to reduce the time exposed to atmosphere.

- Stripped rings and plates from unit 19 and surrounding area to allow for removal of the high-energy foil stripper.

2.1.14 8/2/19 Thursday

- Vented the high energy end of the acceleration tube
- Opened the Weisser valve
- Removed the high energy foil stripper changer mechanism.
- Disconnected feed through and ion pump that connects to foil stripper body.
- Fitted tube jack into unit 18. Will be able to jack from the top flange of tube 4 (8 gap).
- Loosened terminal bellows and compressed with zip ties. Terminal faraday cup has been jacked up and chocked to give some space.

2.1.15 9/2/19 Friday

- Loosened the tube nuts on unit 19, acceleration tube 2, jacked up the tubes from unit 18 and then removed tube 2 from unit 19.
- Lifted out the high-energy foil stripper body.
- All parts were tested with the radiation meter and none were above 2µSv/h.

2.1.16 11/2/19 Monday

- There was some investigation of the high energy stripper assembly and discussion of why there is (as there was the last time it was removed during TO 125) a halo around the top aperture, at the top of the bottom aperture and underneath one of the middle apertures. These halo are also about 2 – 3 mm off the axis of the aperture.
- The process of re-magnetising the horse show magnet in the high energy stripper assembly began.
- A problem was found with the high-energy stripper foil changer mechanism. At some points, motion is not smooth and the poles of the magnets skip. A bearing failure could be possible and the mechanism will be disassembled.

2.1.17 12/2/19 Tuesday

- Installed new rigid pipework from the gas stripper control box to internal wall of the shielded box. VCR connections have been tightened as per spec.
- N_2 stripper bottle has been recharged to 0.XXX barg and reinstalled into the terminal, along with the pipework from the bottle to the port on the shielded box.
- All bearings in the high-energy foil stripper changer mechanism have perished and the entire assembly should be rebuilt. New bearings should arrive tomorrow.
- A measurement of the magnetic field of the stripper magnet revealed half the expected field of 100G. The field was measured at a distance of 3/4in from the flat edge of the magnet's poles and read ~50G. The field close to the surface of the poles was ~350Gs.
- In an attempt to re-magnetise the magnet an electromagnet was fashioned from a piece of mild steel bar which fit across the poles of the magnet. Using a lathe with a large four jaw chuck to hold the steel the chuck was hand operated to wind ~200 turns around the middle of the bar. Applying 6A (~20V) through the winding with a bench supply yielded about 700Gs of field measured close to the surface of the poles. This field was applied to the magnet to permanently re-align its magnetic domains. This method did not yield any increase in field for the magnet. Another

attempt to re-magnetise was done by rubbing powerful Neodymium type magnets along the magnet starting from the centre out toward the poles making sure to use the correct polarity for each half of the magnet. This also yielded no discernible increase in magnetic field in the magnet.

2.1.18 13/2/19 Wednesday

- Alignment work on the accelerator began.
    - A view through the machine from the low-energy end with a target at the tank base showed that the gas stripper canal was misaligned 0.7mm toward post D and 0.4mm toward post A.
    - Correction of this misalignment involved tightening casting jack screws on the post D side and the post A side. Correction of the post D axis misalignment required tightening of jack screws from about unit 7 all the way down to unit 27.
- Colin Dedman suggested that to re-magnetise Alnico magnets like these required very large peak power machines and could not easily be done here. He also suggested a better approach would be to use Neodymium magnets and simply build a frame or holder for them. By experiment it was quite easy to place two small magnets to reproduce a 100G+ field approximately ¾" from them. However the working temperature of these common Neodymium magnets is quite low ~80deg C which could possibly be exceeded in its environment. Some other magnets have been ordered which have much higher working temperatures. Some Neodymium type magnets with working temperatures up to 150°C and some Samarium Cobalt magnets with working temperatures up to 300°C were ordered.

2.1.19 14/2/19 Thursday

- Checked the alignment of the acceleration tube just below the high energy stripper using a cross wire method. The tube appeared to be misaligned 0.XX mm, but it is unclear if this is as a result of changing the jack tension yesterday or simply due to the removal of the tubes above.

2.1.20 15/2/19 Friday

- The fail-safe frame had a misbehaving IR detector replaced and it now should be reliable.

2.1.21 18/2/19 Monday

- Apertures in high energy stripper body were aligned using a rod jig thing.
- HV feed through connection was tested using the mini-Megger and was OK

2.1.22 19/2/19 Tuesday

- Installed high energy stripper body into accelerator. Bolts have been torqued up to 6Nm (needs to be tighter).
- Spoke system below the high energy stripper system was reinstalled.

2.1.23 20/2/19 Wednesday

- Reinstalled unit 19 tube 2 (above stripper assembly) and torqued bolts up to 3Nm, then 6Nm.
- Lowered the tube jack to mate the top flange of unit 19 tube 2 with the bottom flange of tube 1. There was some misalignment and twist, which was mostly removed by individually tweaking the bolts on the tube jack. By the way, the tube jack “walks” (rotates) if you turn all three bolts at the same time. We managed to get the bolts in and the jack was lowered all the way and removed. The bolts were torqued to 3Nm, then 6Nm.
- With the tube back together, the bolts on the three flanges that had been undone were torqued to 8Nm, then to their specified torque of 9.6Nm (85in•lb).
- The high energy stripper is now ready for alignment.

2.1.24 21/2/19 Thursday

- Had to make up an alignment target for the lower aperture of the high-energy stripper assembly. This is an aluminium target with the front face painted white. It was lit using a small LED torch positioned using a retort stand.
- The stripper body was aligned by looking though the telescope at the low-energy end. The misalignment was 0.7mm on one of the axes. The other axes was centred. This isn’t bad considering the spoke system was completely released to fit the stripper.
- Connected high energy midsection ion pump to stripper assembly body.

2.1.25 22/2/19 Friday

- Closed Weisser valve and reinstalled terminal stripper foil changer
- Reinstalled terminal bellows
- Reinstalled high energy stripper foil changer

2.1.26 25/2/19 Monday

- I don’t remember

2.1.27 26/2/19 Tuesday

- Low energy sublimer vacuum pump was baked

2.1.28 27/2/19 Wednesday

- Attempted to fit the new NEC gas stripper backing manifold and found that the tee section that is meant to connect to the acceleration tube is about 1 inch too short. The upside was is that the mistake was not ours and the manifold was simply not made according to the dimensions on the approved drawing.
- Brent is making a 1 inch "extension" piece to bridge the gap.
- Aside from that, all preparations were made to be ready to pump down the acceleration tube.

2.1.29 28/2/19 Thursday

- Manufacture of the 1 inch stainless steel spacer continued

2.1.30 1/3/19 Friday

- The gas stripper backing manifold was installed with the new spacer attached.
- The gas feed pipework that attaches to the backing manifold was installed.
- Everything was tightened up and pump down of the acceleration tubes began

2.1.31 4/3/19 Monday

- Set up for leak chasing of the acceleration tubes
- Wanted to evacuate the gas stripper pipework and did so up to the leak valve, but then realised that we can't evacuate the N_2 bottle side. Had to power up the terminal from mains while disabling the ion pumps and bypassing the fibre to the high energy mid-section. Couldn't get control of the terminal until we jiggled some fibre cables under the tank (outside).

2.1.32 5/3/19 Tuesday

- Pumped down the gas stripper pipework with the leak valve at 70% open (EPICS reading). Vacsorb vacuum reading was about 100mTorr, with gas stripper vacuum output at about 330mTorr. Gas stripper leak valve was closed and vacuum side of the pipework opened to the accelerator tubes. No major vacuum excursions were observed.
- Checked current reading from terminal faraday cup and tank faraday cup. Both read correctly, including both positive and negative polarities on the terminal cup.
- Attempted some leak testing. Shut the low-energy ball valve, the tank 300l/s ion pump and the high energy sublimer. Began with a base leak rate of 5×10^{-9}mbar•l/s before closing valves/switching off pumps, which then deteriorated quickly to 2×10^{-8}mbar•l/s and then 8×10^{-8}mbar•l/s some ten minutes later. High energy vacuum made it as high as 1.5×10^{-4}Torr up from low 10^{-6} range. Quickly sprayed for leaks inside, looking for gross leaks, but nothing was found. Switched the pumps back on and let the vacuum recover.
- Attempted to start the terminal ion pumps (two 60l/s and one 20l/s). That started and maxed out their current at ~14mA. Everything looked OK but then the high energy

vacuum started creeping up to 1.5×10^{-5}Torr, so the terminal ion pumps were switched off.

2.1.33 6/3/19 Wednesday

- Began clean and close procedure on unencumbered units at the top of the machine. Completed units 1 through 10.
  - Unit 1 required replacement of a ball ended resistor lead
  - Unit 3 had a bad ring screw
  - Unit 9 post gap 2 resistor pair showed a lot of activity on the spark gaps. These were replaced with a new pair.
  - Unit 10 required replacement of a number of ring screws.
- There was some debate whether the solid copper resistor leads on the post in unit 4 should be changed back to braid.
- Unit 10 post C also showed a few arc marks across the gaps. They look bad, but current leakage at 5kV was less than 2nA.
- Clean and close continued from unit 11 through to unit 18 in units that were available.
- Switched on gas stripper backing trap heater late in the day to start bake out.

2.1.34 7/3/19 Thursday

- Wiped down all three chains with acetone.
- Continued attempting to bake out the gas stripper manifold trap. This was cycle of turning the heater on and off and monitoring the vacuums.

2.1.35 8/3/19 Friday

- Same same

2.1.36 11/3/19 Monday

- Happy birthday Canberra

2.1.37 12/3/19 Tuesday

- Continued with the struggle to re-establish vacuum in the acceleration tube.

2.1.38 13/3/19 Wednesday

- Same same

2.1.39 14/3/19 Thursday

- Clean and close on units 20 and 22 tough to 28
- Quick vacuum inside exposed castings
- Replaced solid copper leads in unit 4 post resistors with traditional braided lead. I think the experiment with solid leads is over. They seem to place too much lateral; load on the resistors and there is otherwise no benefit.

2.1.40 15/3/19 Friday

- The high energy sublimer died overnight. It is being replaced with a refurbished spare.

2.1.41 18/3/19 Monday

- Tested for a short on the high energy midsection ion pump by applying +1kV to pump using Megger. Resistance came back a >3TΩ, so it looks good.
- Checked wiring from high energy foil stripper suppressor and looks like it should be negative, as is desired.

2.1.42 19/3/19 Tuesday

- Leak tested the acceleration tube from a base leak rate of 8.2×10^{-9}mbar•l/s. No reaction was observed. May repeat tomorrow if the vacuum is significantly better.
- Measured the high energy stripper suppressor output using a 1000:1 probe. It appears to be -3.6kV but have to confirm calibration of probe (meant to be -5kV). Also measured the ion pump power supply at -3.9kV with the same probe.

2.1.43 20/3/19 Wednesday

- Began rebuilding the deck that builds up the high energy mid-section in unit 19.
- Tested the high energy mid-section foil stripper motor and it appears that the system doesn't actually reset to zero when you ask it to. It will just carry on from where it was. So, the dodgy way to "fix" this is to just manually match the motor controller counter with the mechanical counter and move on.

2.1.44 21/3/19 Thursday

- Finished rebuilding the deck that builds up the high energy mid-section in unit 19.
- Re-rung units 19, 20 and 21.

2.1.45 22/3/19 Friday

- Disassembled unit 19 to gain access to the ion pump.
- Attached Terranova ion pump controller to high energy stripper ion pump in attempt to "jump start" it.

2.1.46 25/3/19 Monday

- Continued efforts to restart ion in-tank pumps

2.1.47 26/3/19 Tuesday

- Continued efforts to restart ion in-tank pumps. All pumps were deemed operational and normal work could continue.

2.1.48 27/3/19 Wednesday

- Closed the terminal
- Completed clean and close procedure on remaining units.

2.1.49 28/3/19 Thursday

- Performed 10kV high voltage tests with the new Megger. No issues were observed.
- Wiped down the terminal with water.
- Unloaded platform.
- Performed charging system and terminal operation tests. All was OK, with breakdown occurring at no less than 7kV.
- Checked charging current meters. All was OK.
- Removed under platform lights.
- Were traversing up the column to the low energy end in preparation for parking the e platform when a problem was noticed with the high energy shaft. The bottom bearing assembly in unit 26 was noisy (even though we'd run the shafts recently with no issue). Removed the assembly to find that the lower bearing in the assembly was slipping. This carrier was a newer one that had been replaced TO121. The upper bearing was the noisy one however.

2.1.50 29/3/19 Friday

- Reinstalled bearing into unit 26, re-rung unit and rested 10kV HV performance of unit 26 and unit 27 in case anything was disturbed.
- Moved to platform to level 4 to begin parking procedure.
- Closed the port hole doors.

2.1.51 1/4/19 Monday

- Began gas up of tank

3 Re-establishing vacuum in the acceleration tube

4 RGA scans for SF_6 in the accelerator tube

5 RGA tests of gas stripper N_2 cylinder

There were suspicions that SF_6 was somehow entering the gas stripper N_2 gas cylinder. Whilst the cylinder was removed from the 14UD, RGA scans were performed to check this idea and to test how many pump purge cycles were required to completely remove the SF_6.

These tests were performed on 30th January 2019.

The cylinder was removed during TO #129 and traces of SF_6 were measured using the hand-held halogen detector. The RGA previously installed at the high energy end of the machine was removed and shifted to the LINAC test area.

The sketch of setup is shown in Figure 1. It was discovered that RGA was not tuned properly to measure SF_6. SF_6 gas supplied from the recovery system SF_6 bag and cylinder showed no traces of SF_6 detected on the RGA. This explains why no SF_6 was measured at the high energy end of the 14UD during tank opening 129.

The RGA was tuned to He according to the manual and to SF_6 (peak 127) by increasing to maximum width and shifting the peak position. Unfortunately this tune affected the correct position of medium masses (Ar, O, N). Nevertheless the detection of SF_6 was good. This new tune was locked for this RGA. At any time it could be unlocked and reset to the factory setting. However, at factory settings it loses detection of He and Ar.

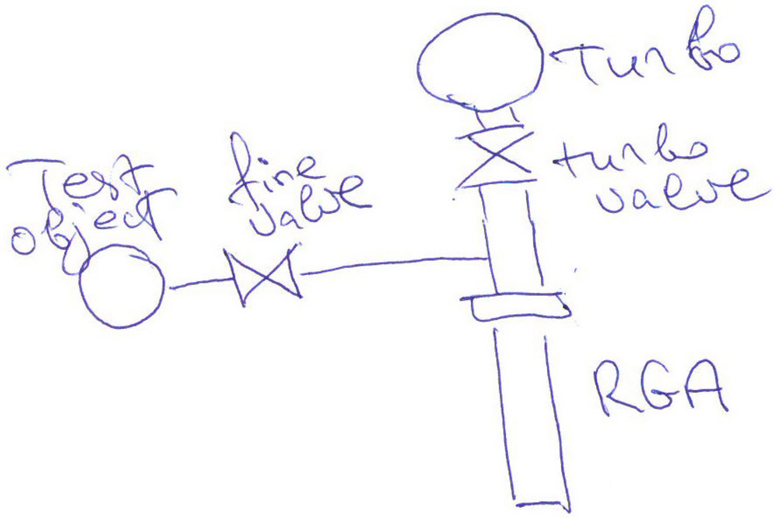

Figure 1 Sketch of setup used to test for presence of SF_6 in the gas stripper N2 cylinder using an RGA.

With the retuned RGA, it was confirmed that there was SF_6 in the cylinder, as shown in the trace in Figure 2. The SF_6 trace did not disappear after 1 cycle of pumping to 40 micron and backfill with gaseous N_2, as shown in Figure 3. After 3 more pump purge cycles, the SF_6 trace disappears from the RGA trace and was not detected with halogen detector, as shown in Figure 4.

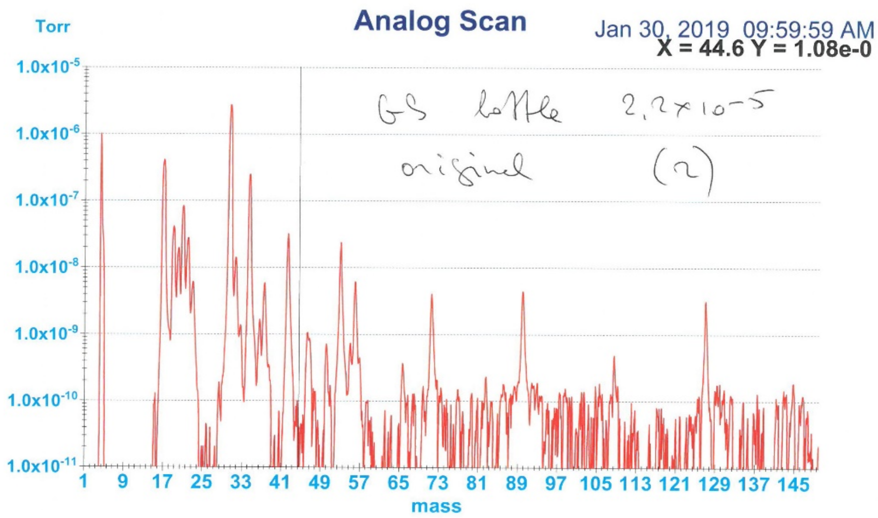

Figure 2 First RGA scan shown presence of SF_6 in N_2 gas cylinder.

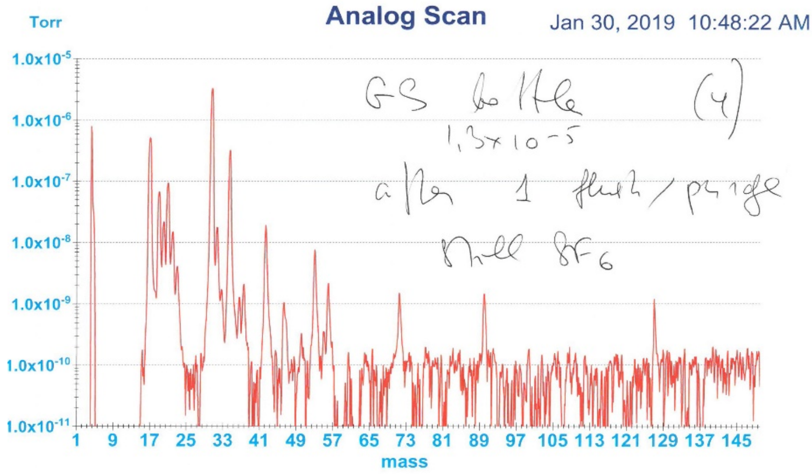

Figure 3 Second RGA scan shown presence of SF_6 in N_2 gas cylinder even after a pump purge cycle down to 40 micron and backfilled with gaseous N_2.

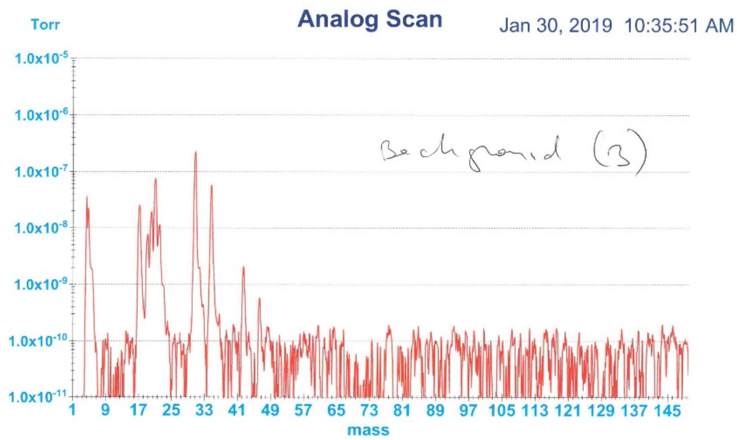

Figure 4 Final RGA scan showing no presence of SF_6 in N_2 gas cylinder after three pump purge cycles.

Hence, three pump purge cycles are sufficient. Both the RGA and halogen detector seem to produce similar conclusions.

6 Installation of gas stripper manifold

The main motivation for this tank opening was the reinstallation of the gas stripper components that were removed during tank opening 129. The main component to be installed was the new backing manifold. This is shown in Figure 5 and unlike the old manifold, this has a single trap that uses alumina beads (instead of micromaze traps, which for some reasons are no longer available).

Installation of the new manifold required a hole to be cut into a plate in the terminal. After a number of days of discussing how this should be done, it was removed from the machine and the hole/slot machined in the workshop. Removal of the plate required the use of trigger clamps to slowly push the plate out.

The other challenge was the supplied manifold was not consistent with the approved drawing, with the tee section that connects to the accelerator tube being 1 inch too short. Hence, a stainless steel extension piece had to be fabricated.

Figure 5 New gas stripper backing manifold with slot cut in terminal plate and extension piece to connect to the acceleration tube.

7 Shoring rod system safety upgrade

During this tank opening, a ball valve was fitted between the tank end-cap and the shorting rod clutch housing at both high energy and the low energy ends. The ball valve will allow operators to quickly isolate the tank SF_6 inventory during most types of non-standard shorting rod events.

There are two most probable shorting rod events. First, a nylon shorting rod or nylon shorting rod stud can break inside the tank, which is sometimes due to spark damage. A broken rod or stud becomes suddenly apparent when there is a burst of SF_6 as the unanticipated broken shorting rod is pulled from the machine. Second, the operator can mistakenly remove the last shorting rod. The last shorting rod is marked on the end with an annular groove, which is painted red or black. Failure to look for this shorting rod end mark, together with failing to keep track of shorting rod numbers withdrawn, can result in a sudden burst of SF_6. The 3/4" (19mm) diameter hole allows the full pressure, usually 100 psia, SF_6 to escape.

The previous safety system required the operator to push a dummy nylon shorting rod into the clutch thus sealing the hole. Operator skill and fortitude enabled several of these events to be coped with. However, this system relied too heavily on skill, a calm presence of mind and on imagined and simulated training.

In light of this, a new ball valve idea was conceived. The ball valve gives operators a faster and easier way to close off the flow of gas during an emergency.

8 Installation of high-energy stripper body

The new high energy stripper was designed to reduce (and hopefully eliminate) loading caused by electron backstreaming, which was reducing the maximum terminal voltage of the accelerator. The first and biggest change was made to the aperture and bias arrangement. The existing stripper had a small (12.7mm) top aperture which was negatively biased, encouraging backstreaming when the beam hit it. The new stripper had a larger top aperture (25.4mm) which allowed the beam to go through to the second smaller aperture (12.7mm) and any secondary electrons were suppressed by the –ve bias on the larger top aperture. Secondly a change was made to the magnet. The existing magnet measured ~60G on axis, down from the nominal designed strength of 100G. After some initial trouble with re-magnetising the existing magnet, a new magnet (of slightly different geometry) with a strength of 150G on axis was fitted. The third change was a foil catcher, a disc at the bottom of the stripper designed to stop any broken foils from entering the tube below and again becoming a source for secondary electrons. Finally, the new stripper has a fresh housing and all new apertures to eliminate contaminated/activated surfaces.

The old stripper was removed as per steps and method used during tank opening 125, as outline in tank opening report 125, section 4.

Figure 6 Installation of the new high energy stripper assembly

Alignment was achieved by tweaking the spokes that are attached to the top flange of the acceleration tube below the stripper assembly

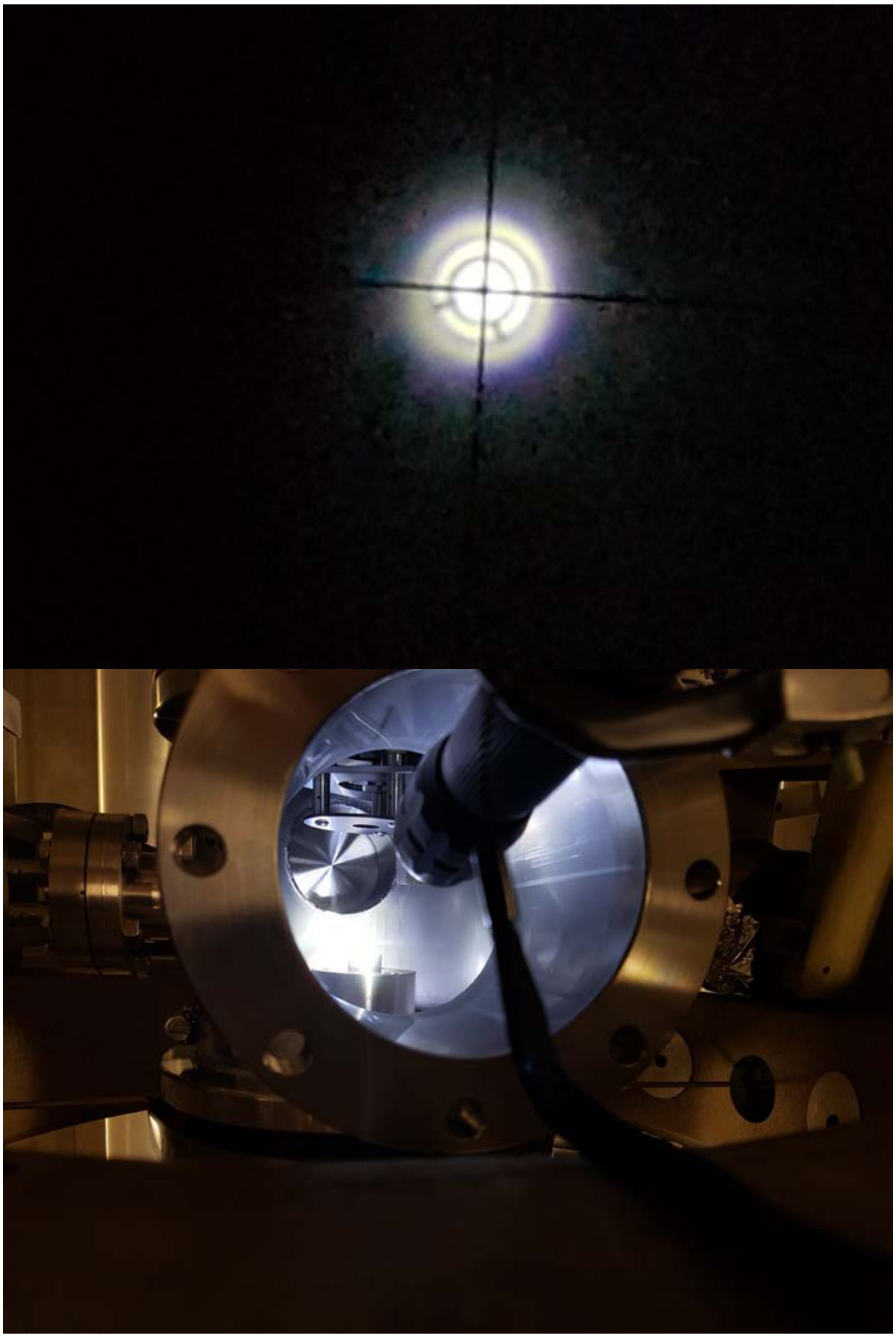

Figure 7 Alignment of the new high energy stripper assembly.

9 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
6	Post gap 9	New unused resistors installed on both top and bottom, showing 18µA @ 20kV (lower than 19µA nominal).	Keep track of current as resistors age	Yes
14	Post gap 18	Current leakage of 0.02µA	Restest, as current leakage after test on immediate entry was much higher.	Yes
14	Post A gap 1	Current leakage of 0.2µA@5kV		Yes
10	Post C, gaps 6, 8, 13 and 19	Visible spark marks across gaps		Yes
7	Spring contact upper	Flat section, a bit gnarly	Check on next TO	Yes
8	Spring contact lower	Ugly coil form	Check on next TO	Yes

10 Tube ceramic insulator current leakage

The current state of shorted tube ceramic gaps is shown in Table 2

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

Unit	Tube	Gap	Leakage though insulator @5kV (µA)		Discovery	Comment	Repair
			TO #123	TO #129			
3	2	2	8	8.8	TO #121		Dummy resistors top and bottom, dummy on post gap ????
6	1	2	1.1	1.2	TO #123		Dummy resistors top and bottom, dummy on post gap 5, top
6	1	3	60	80	TO#128		Dummy resistors top and bottom, dummy on post gap 4, top
7	3	10	12	14	TO #120		Dummy resistors top and bottom, dummy on post gap 10, top
12	1	1		32	TO #129		Dummy resistors top and bottom
12	1	2	0.25	43	TO #123		Dummy resistors top and bottom, dummy on post gap 5, top
12	1	3		4	TO #129		Dummy resistors top and bottom
12	1	4		73	TO #129		Dummy resistors top and bottom
12	1	9		7.2	TO #129		Dummy resistors top and bottom
13	1	10	0	0	TO #120	Suspicious arc mark across gap	Dummy resistors top and bottom, dummy on post gap 3, top
13	2	1	0.05	0.02	TO #120		Unshorted TO#129, deemed too small. Monitor.
13	2	2		95	TO #129	Short moved from U13 T2 G1	Dummy resistors top and bottom, dummy on post gap 8, top
24	3	10		18	TO #129		Dummy resistors top and bottom, dummy on post gap 14, top
25	3	10	7	7.2	TO #120		Dummy resistors top and bottom, dummy on post gap 16, top
26	3	5	0.15	>100	TO #123		Dummy resistors top and bottom, dummy on post gap 12, bottom
26	3	9		0.25	TO #129		Dummy resistors top and bottom,
26	3	10	0.01	>100	TO # 123	shorted TO129	Dummy resistors top and bottom,
26	3	11	2.5	16	TO # 123		Dummy resistors top and bottom,

							dummy on post gap 14, bottom
28	3	1	0.01		TO # 123		None, deemed too small. Monitor
28	3	5	0.47		TO # 123		Dummy resistors top and bottom, dummy on post gap 12, top
28	3	7	0.1		TO # 123		Dummy resistors top and bottom, dummy on post gap 13, top
28	3	9	0.02		TO # 123		None, deemed too small. Monitor
28	3	10	0.05		TO # 123		None, deemed too small. Monitor
28	3	11	0.28		TO # 123		Dummy resistors top and bottom, dummy on post gap 14, top

11 Machine hour meter readings

Table 3 Machine hour meter readings

Date compiled	31 01 19					
Team member(s)	PL					
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	44817	44740	44904	66572	66564	41173
Previous reading (TO #126)	43108	43031	43195	64705	64698	39833
Change in hours	1709	1709	1709	1867	1866	1340
Previous total hours	21576	21499	26005			
Current total hours	23285	23208	27714			

Note that we know about a problem with the charging volts meter. We are judging charging volts from calculations in section 12.

12 Terminal voltage distribution for period of service

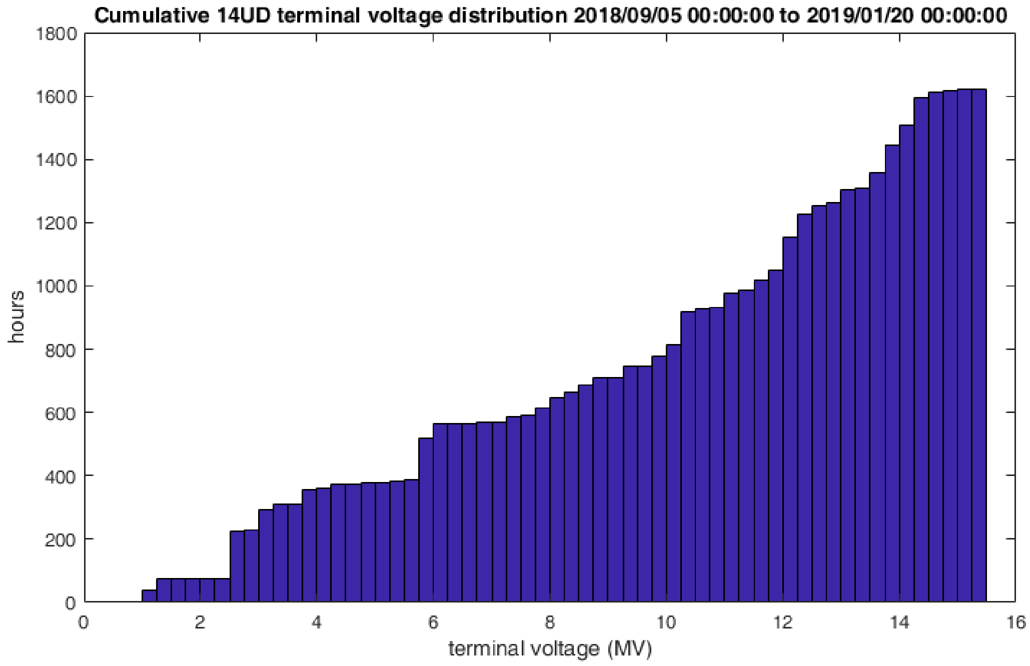

Figure 8 Cumulative terminal voltage distribution for period of operation from the end of tank opening 129 to the start of tank opening 130 (including any time spent conditioning the machine)

The total hours with voltage on the terminal was 1617 hrs, which gives a utilization of 49% assuming a twenty-four hour, seven-day maximum.

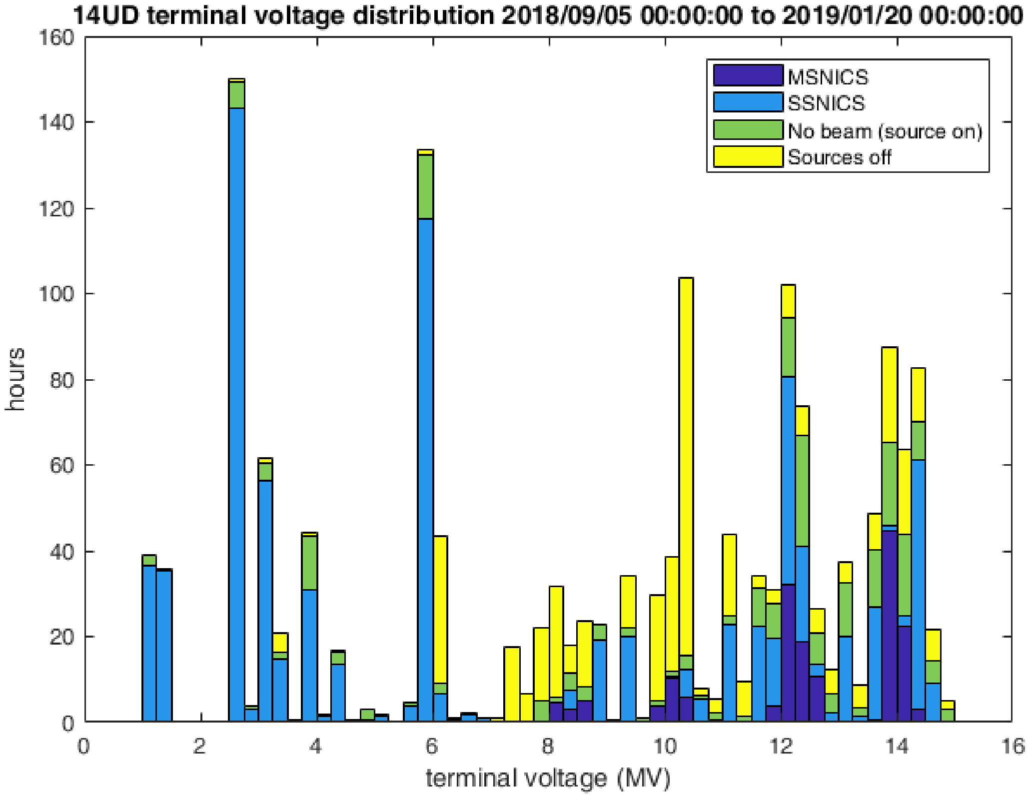

Figure 9 Terminal voltage distribution for period of operation from the end of tank opening 129 to the start of tank opening 130 with breakdown in type of usage.