Australian National University

14 UD Tank Opening Report

#134

27th April 2023 – 29th of May 2023

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Reason for tank opening

This was a scheduled opening for general maintenance. There are no emergency repairs required, but given the long period between tank opening, some capabilities were slowly compromised. For example:

- The 150kV low-energy beam focus sparks at the tank feedthrough above about 120kV. This compromises runs where a low terminal voltage is required since that is when the effect of the beam focus is more noticeable.
- The gas stripper leak valve also will not shut on occasion, so this will need to be inspected.
- Terminal stripper foils will be restocked.
- High-energy vacuum gauges have failed and need to be replaced.

Summary of work

Tank opening #134

27/4/23 Thursday

- The SF_6 was pumped from the 14UD into the storage vessel.
- The porthole doors were opened however the fresh air ventilation could not be operated. The suspicion is that there are some wiring issues after the late 2021 electrical distribution board upgrade

28/4/23 Friday

- Daniel identified that there is no neutral wire connected from the level 4 distribution board to the contactor box that runs the ventilation fan. The motor itself is a three-phase motor and doesn't need a neutral, but the control circuit to operate the relay (through the switch on the entry hole and the control box) requires one to supply 240VAC.
- The relay for the motor was changed to a 24VDC actuated Schneider unit. A 24VDC power supply was also installed and hey presto, it works.
- The tank is now being ventilated over the weekend.

1/5/23 Monday

- 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. No major outliers detected, which is good and bad as there are no major issues but nothing to explain decreased performance over the last couple of months.
- Column was wiped down with RBS solution.

2/5/23 Tuesday

- Mechanical tests were performed
    - Shaft bearings sounded all OK
    - The shafts in units 6 and 17 need to be inspected as they look like they have a bit of runout.

    - All chain idlers will need to be checked, especially the unit 25 down idler, which seems to be “clapping” a little.
    - Chain 3 seems to have a little more whip than the other two.
- Removed casting covers necessary to open terminal.
- Entered the bottom of the tank for a first look.
- Refilled the chain oilers which were nowhere near empty.
- Removed the charging system standoffs. One nylon insulator was slightly damaged and the “double” spark gaps are marked with spark damage and need to be polished up.
- Static chain leg clearances were 64, 63, 78mm for chain 1, 2 and 3 respectively

3/5/23 Wednesday

- Removed the shafts in units 6 and 17 for inspection and repair. They are appear to be bowed and the best solution is to machine up new blanks and install them.
- Polished charging system standoffs to removed spark marks and then refitted into bottom of the tank.
- The platform was locked out for a bit as someone from Facilities and Services was fitting new fluorescent tubes into the tower. It was pretty dark in there.
- There is ongoing work outside the tank:
    - Various joints in the SF_6 recirculation system are being renewed
    - Work to move motion of the corona needles into EPICS (wiring etc.)
    - Inspection of the nylon feedthrough of the 150kV beam focus feed through.

4/5/23 Thursday

- Opened the terminal
- Met with a contractor who inspected the platform motor and will be designing a system for greater safety and control over platform speed.
- There was an attempt to remove the terminal foil stripper assembly but this resulted in an adventure to find a working HiCube pumping station. After a few pump purge cycles, a new out-of-the-box unit managed to pump down. It’s now running overnight and we’ll vent the foil section in the morning.

5/5/23 Friday

- HiCube pumping system ran well overnight and allowed venting of the stripper section. It was vented to air at no faster than 1 Torr per second.
- Stripper foil mechanism was removed for repopulation.
- Began trouble shooting the gas stripper issues where the valve would not close. Early thoughts are that it is an electronics problem as there is no voltage on the motor when the valve is asked to close. There are relays that actuate and a pulse-width modulation motor control, so lots of electronics to go wrong.
- From this point the tank was handed over for the purposes of a photo shoot. A few techs strutted the platform giving their best “blue steel” looks.

8/5/23 Monday

- Checked isolation between terminal wheels and terminal (inserting insulator between carbon brush). There are no shorts and resistance at 1kV ranged from 880MΩ to about 500GΩ.
- Terminal up idler on chain 3 seems to be slipping a bit and needed to be readjusted.
- Examined terminal cup polarity switching and found that no 12VDC was making it to the dual-polarity amplifier. This is likely due to a damaged AQV253H PhotoMOS relay of which we do not have any spares. An order has been placed with Mouser.

- Examined all idler pulleys and there are definitely some issues.
    - Chain 3 unit 19 up idler needed new bearings
    - Chain 1 unit 22 down idler bearing is clicking. Removed to replace bearing but new bearings were not a snug fit, which indicates the wheel bore diameter has increased for some reason. Only fix here is a new wheel.
    - Chain 1 unit 22 up idler is seized and wheel outer damaged. Replaced with new wheel.
    - Chain 1 unit 25 up idler wheel is breaking apart. It was replaced with a new wheel.
- There are seven NEC 2DA01120 idler wheels left and we should order more.

9/5/23 Tuesday

- There is a lot of working outside but associated with the tank. There are few remaining bodies for work inside the tank.
- Even so, managed to start a clean and close on unit 1
- Attempted to finish off Perspex shafts for reinstallation into units 6 and 17. We used the NEC supplied Perspex blanks and had them machined in the MWS. Tunningley noticed a discrepancy between the keyway depth on the drawing and the actuals shafts. Trying to investigate.
- Venting the high-energy end of the machine to replace the vacuum gauges on the high energy manifold.

10/5/23 Wednesday

- Shaft for unit 6 came back from the MWS. It was refitted and clocked. Seems fine.
- Ditto for unit 17 shaft.
- Also noticed some backlash in the high energy alternator shaft and isolated it to near the alternator. We were hoping it was not due to a bearing in the actual alternator and after a professional second opinion from Battisson, we determined it was a loose grub screw on the alternator keyway. A bit of Loctite 222 was added and the grub screw tightened.
- Low-energy shorting rod clutch was serviced (which means disassembled, cleaned, new o-rings and vacuum grease and reassembled – see 942-001 for assembly model).
- Rewiring is complete on corona needle insertion motor and EPICS testing is underway.
- Entire tank-side corona needle assembly was removed in preparation for servicing the system seals.

11/5/23 Thursday

- Removed triode main assembly for service. It was completely disassembled and cleaned, although there are some marks about halfway down the inner bore. This is probably form sparking from the low point of the inner rod and it was not possible to remove the marks. All o-rings were replaced and the assembly reinstalled.
  Tech Files\030 TANK\TRIODE 14 UD\TRIODE MAIN ASSEMBLY was used as the reference model.
- Refit triode needle assembly and then proceeded to fit the new needles from inside the tank. Used new EPICS control to move the needles in, so we've moved one step closer to the 21st century.
- Began pumping down the high-energy end of the machine from the multi-cup box

12/5/23 Friday

- High-energy tube vacuum was good and in the low 10^{-8} Torr.
- Reinstalled fully populated stripper foil mechanism and pumped down the space using the HiCube. Did you know you can turn off the turbo and just run the backing pump? Setting [P:023] from memory. You can't change the vacuum readout from hectopascals though. SI units all the way.
- Installed four new relays into the gas stripper control box. It now opens and closes freely.
- Installed new AQV253H PhotoMOS relay for the terminal faraday cup. Tested with a test current box and it seems to work.
- Replaced ethernet to fibre media converter for terminal foil camera/microphone and it's all back operational. May need to tweak position to see foil counter in the terminal but that can be done later.

15/5/23 Monday

- Measured the pressure inside the gas stripper N_2 bottle in the terminal and it was 0.28 barg. It's well down from the last tank opening but expected given the issues with the gas stripper valve not closing. As there is plenty of N_2 left, the bottle was left as is.
- I've made a terrible mistake. Turns out, evacuating the pipework upstream of the gas stripper leak valve while the Weisser valve is open is not a good idea. Tripped both ball valves and ended up at 10^{-2} Torr in the acceleration tubes, according to the gauge at the high energy end. Played it safe by closing the Weisser valve and working on either end. Forced open the low-energy ball valve and let the ion source pump this down. Same with the high-energy end, but the multicup box turbo did the pumping. Both ends slowly recovered vacuum and managed to start all the ion pumps. The terminal foil stripper was removed again to make sure the vacuum accident hadn't made shiny confetti. It hadn't, but the carousel was removed for a closer look and a new gasket. So, a lesson to all you students memeing these reports, understand your vacuum system.
- At some point in the last few days Tunningley serviced the high-energy shorting rod clutch (so now both ends are done)
- What a horrible day.

16/5/23 Tuesday

- The morning was given over to a film crew to take footage for a short film related to the HIAF 50th celebrations in August. Some of the technical staff now need agents.
- No foils were damaged after yesterday's vacuum excursion. A new gasket was fitted and the carousel reinstalled into the terminal. The space was slowly pumped down at about 1 Torr per second. At about mid 10^{-2} Torr, the main valve was opened with the turbo running.
- While this was pumped down, the 150 kV beam focus feedthrough in-tank assembly was refitted. The nylon insulator is a very tight fit but everything is now back together. The "air side" still needs reassembly.
- Back at the terminal, the stripper interspace had reached low 10^{-4} Torr, so the Weisser valve could be opened. No issues today and all blanks and covers were refitted and the HiCube system removed from the tank.

17/5/23 Wednesday

- Cleaned the terminal and checked inductors spacing. An inductor on chain 3 was out slightly. There is also a bit of wheel material around, which is the stuff that is conductive and difficult to clean off.
- Cleaned all three chains. Chains 1 and 3 had a rivet or two that was obviously one of the ones we installed. From some angles, it looks like the pellet itself is deformed. Chain 3 had a lot of pellet lip to lip spark damage.
- Updated firmware on acceleration tube and high energy Inficon VGC503s
- Continued work on updated charging system power supplies. Need to address issue of ultimate terminal voltage cut out feature.

18/5/23 Thursday

- Clean and close began and we reached and completed up to unit 10. No major issues but:
    - Two resistor leads replaced in unit 5
    - There was a nice discharge pattern on the lower casting of unit 8 with two nearby resistor leads showing damage. These were replaced.
    - There was the tiniest amount of debris sitting on the lower casting of unit 9, around which there was a purple halo pattern that could only bee seen at a high incidence angle. The debris wasn't completely solid but didn't feel like wheel material.
    - Replaced a post resistor pair in units 9 and 10 that had marked spark gaps.
- With the terminal covering unit 11 and below, it's time to think about closing the terminal. Performed terminal tests with the terminal powered from mains. Everything is OK, even the gas stripper valve. With that, transformers and power leads were removed in preparation for closing the terminal.

19/5/23 Friday

- The terminal was closed successfully.

22/5/23 Monday

- Continued clean and close on units 11 through 14:
    - Stringer was loose on unit 11 stringer 3 at the post end
    - Three blackened banana plugs on resistor leads in unit 13
    - Blackened posts resistor leads changed in unit 14
    - Stringer 1 on the post in unit 14 required tightening
- Measure distance from fully retracted needle mushroom to terminal and it is approximately 2250mm.
- Wiped terminal and removed spark marks and the normal corona needle staining
- Opened unit 16 and depopulated resistors on tubes 1 though 3 and the matching post gaps in preparation for fitting of new toolless resistor housing design for testing.

23/5/23 Tuesday

- Continued clean and close in units 15 through 28 (excluding unit 16):
    - Stringer 2 in unit 18 was loose at the post mount. Recompressed rivets to tighten.
    - Stringer 1 in unit 19 was loose at the post mount. Recompressed rivets to tighten and tightened screw.

    - There were track marks found on the top end of the Perspex alternator shaft in unit 20. These were polished off in place.
    - More track marks found on the bottom end of the Perspex alternator shaft in unit 21. Again, these were polished off in place.
- Cleaned and reinstalled casting covers (aside from unit 16).

24/5/23 Wednesday

- Installed new "tool-less" resistors into unit 16. Some finagling required on "non-standard" flanges, such as the tabs on the tube flanges. The posts resistors are a more susceptible to misalignment of the spark gaps. Reinstalled rings and casting covers, which completes the clean and close shuffle.
- Blow down of the column completed.
- 10kV high voltage tests complete. All tested OK.

25/5/23 Thursday

- Wiped down the column
- Continued with tank closing preparations, such as unloaded the platform and vacuuming.
- Tests all passed, with some delays after figuring out some EPICS issues.

26/5/23 Friday

- Left button-up until today so that no mistakes were made in a last-minute rush.
- Platform unladed at top of tank and then proceeded with some platform tests at the top and bottom. At both ends of the tank, *the unloaded platform wants to move up* if the brake is off. Friction stops it from running away completely, but if there is momentum, it will go.
- Parked the platform and bolted the port holes closed.
- Today is a good day.

29/5/23 Monday

- ACT Public Holiday
- Started Kinney and evacuation of tank

30/5/23 Tuesday

- Started and finished gassing up with SF_6 to about 100 psia
- Tentatively fired up the machine and brought the terminal volts up to 6MV without issue. EPICS control of the charging volts and the corona needle distance works. Let's see if it survives a full spark at 14MV.

Toolless resistor install

Background

In preparation for the ceramic upgrade, toolless resistors have been developed. The idea is to eliminate the issues associated with installing (and removing) the current design. Given the 3000 odd resistors that will need to be replaced, it was thought this would be a worthwhile

investment. The new design allows the resistors to be slid into position and the body rotated to tighten onto the electrode, negating the need for a tool.

The two assemblies used are:

- 955-027 TT (TOOLESS TIGHTENING) RESISTOR ASSY – TUBE
- 955-025 TT (TOOLESS TIGHTENING) RESISTOR ASSY – POST

Models and drawings for these can be found in Tech Files\030 TANK\RESISTORS.

Unit 16 was identified as a good location for testing the new assemblies. This unit should be under high electrical stress so should give a good, harsh test.

Installation

The old resistor positions were documented then the process of removing them began. Removal, like installation, was frustrating and difficult. Trying to loosen the clamping screws at arm's length with small Allen keys with no visual sighting reminded us of the need for this upgrade.

Installation of the new resistors was, for the most part, easy, and a valuable exercise as we were able to identify some issues which can be addressed for future installations:

- Setting the clamp. When assembling the resistors, the clamps need to be firm to install the spark gaps, however this can close the clamps slightly making them difficult to get onto the electrodes. A simple tool can be developed to maintain the slot dimension while assembling the resistors
- Setting the spark gap. A tolerance build-up can mean the resistor ends are not entirely concentric with the end of the tubes. A bigger hole on the spark gap will allow the gaps to be consistent and independent (to a degree) of the trueness of the resistor. This method was also used with the old resistors.
- Post end resistors. The final electrode, top and bottom, on each post has a slightly different arrangement which requires a step cut out on the end flange. This step means the resistors don't fit, as the angled ferule contacts the flange. Special stepped ferules are required for these locations. The old resistors used special squared off clamps in these locations.
- Tabbed mounting. Tabs are used when connecting the last resistors, top and bottom, to the tube flanges. These tabs are nominally 1.2mm, which is larger than the 0.9mm of the electrode skirts. The clamps can be opened wider to accommodate this, however a nicer solution would be to use thinner tabs.
- Identifying feature. The difference between the post and tube electrodes (1.2mm vs. 0.9mm) requires different clamps. It is difficult to distinguish the small difference in size, so another identifying feature would be good to easily tell them apart.

Testing

The Megger exit test was performed and the results for unit 16 were in line with the other comparable units. Time will tell if these resistors will remain good electrically as well as hang on mechanically…

Repair of 150kV beam focus feed through

The 150kV low-energy beam focus was sparking above about 120kV. During the tank opening, the entire feed though assembly was removed and inspected. Silicon grease had been used

during its installation during TO #117 in August of 2012 to fill the gap between the nylon insulator and the HV cable on the air side of the assembly.

This grease was heavily blacked as can be seen in Figure 1 through Figure 3. Most of this cleaned off relatively easily but some evidence of damage and activity remained. Figure 4 shows spark marks on the "can" cover, suggesting the sparking was occurring through the grease and grounded on the can at the level where the nylon feed though ends.

Remediation consisted of

- Removing all grease
- Shortening the HV cable to remove any damaged length
- Cleaning the inner bore of the can cover
- Reaming the inner bore of the nylon feed through to remove surface damage (there was no evidence of damage in the bulk).
- Reinstalling *without any grease*

The tank side assembly was also removed and inspected. The usual spark marks observed on the spark gaps were cleaned off. The resistor was measured and found to be 11kΩ (low-voltage multi-meter measurement) compared to the specification of 25kΩ±10%. This was assumed to be a faulty resistor until a new spare resistor measured 32kΩ. The new high value resistor was used and measurements will be made during future tank openings to determine if the resistance value degrades or if they are all really that far out of tolerance.

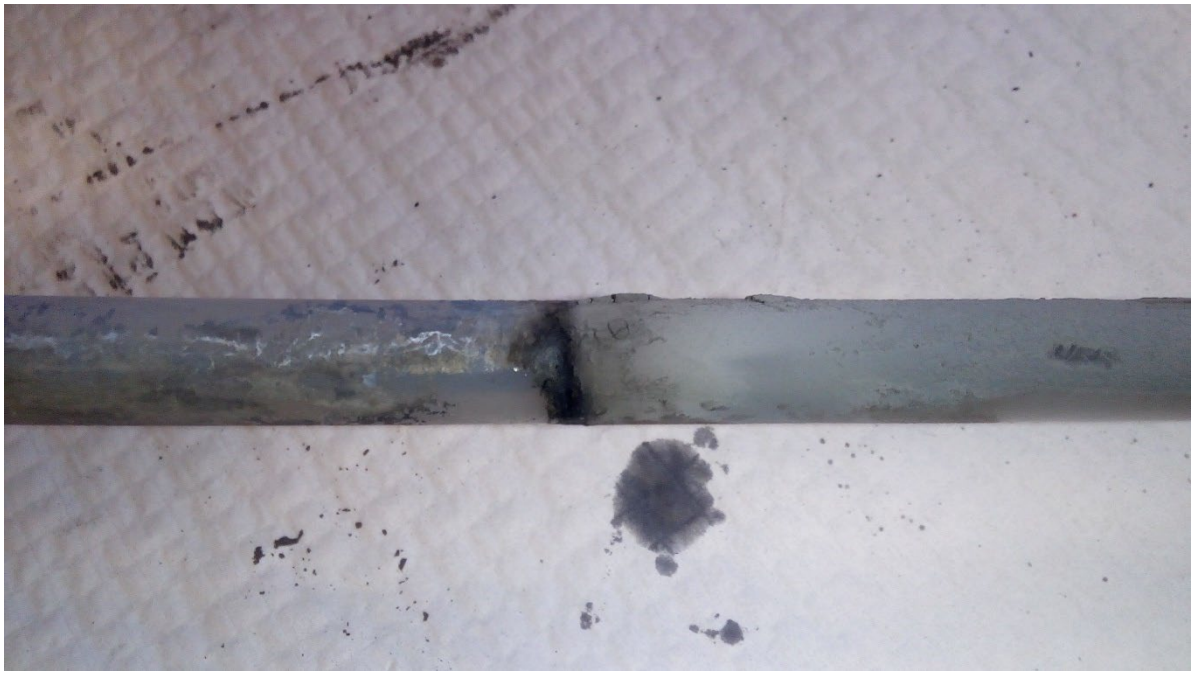

Figure 1 150kV beam focus HV cable (air side) showing blackened grease

Figure 2 150kV beam focus nylon feed through (air side) showing blackened grease

Figure 3 150kV beam focus nylon feed through HV cable (air side) showing blackened grease down bore

Figure 4 150kV beam focus cover “can” (air side) showing spark marks

Recirculator servicing and issues

SF6 leaks

Several small leaks in the dryer pipework had been identified when at SF6 pressure. V4, V8 and filter housing fittings were repaired and will be tested when the 14UD is at pressure again.

Dryer Re-activation

- Gas dryer vessel was evacuated during pump-out of 14UD.
- Nitrogen flow was started through the dryer vessel and exhausted outside the tower.
- The dryer heating element was switched on. Temperature monitored throughout the day.
- Achieved +300°F by 11.30am and was still at baking temperature at 4pm.
- Next morning heater was off and had tripped circuit breaker at DB.
- After several days delay finding an electrician to test the circuit and reset the breaker it was deemed ok to run again.
- Heater operated from 12pm to 4pm when it was found tripped again
- Again circuit was tested and CB reset by electrician.
- Heater was on from 10am to 11.30am before tripping again.
- At this stage a minimum of 10 hours at drying temperature had been achieved so it was decided to stop heat cycle and move to evacuate the vessel.
- Started vacuum pump. Pressure started at 1000 microns and improved to 500 microns over approx. a week of pumping.

Continued evacuation of dryer until 14UD gas-up.

Final leak chase of pipework

Leak chase after 14UD gas up with recirculator pipework at tank pressure found leaks were successfully fixed. No response with new gas detector.

Note for next tank opening

Gas dryer heater circuit will need electrician to diagnosis and fix before operating. Fault is thought to be new more sensitive RCD's in the new DB's.

Post opening tasks

1. Order a large stock of NEC 2DA01120 idler wheels
2. Order three new pellet chains

Tube ceramic insulator current leakage

The current state of shorted tube ceramic gaps is shown in Table 1. No new shorts were added in this tank opening.

Table 1 Summary of tube ceramic current leakage in the 14UD

Unit	Tube	Gap	Leakage though insulator @5kV (μA)				Discovery	Repair
			TO #123	TO #129	TO #132	TO #134		
3	2	2	8	8.8			TO #121	Dummy resistors top and bottom, dummy on post gap ????
6	1	2	1.1	1.2		1.1	TO #123	Dummy resistors top and bottom, dummy on post gap 5, top
6	1	3	60	80		430	TO#128	Dummy resistors top and bottom, dummy on post gap 4, top
7	3	10	12	14		8.7	TO #120	Dummy resistors top and bottom, dummy on post gap 10, top
12	1	1		32	10		TO #129	Dummy resistors top and bottom
12	1	2	0.25	43	13		TO #123	Dummy resistors top and bottom, dummy on post gap 5, top

12	1	3		4	0.02		TO #129	Dummy resistors top and bottom
12	1	4		73	4		TO #129	Dummy resistors top and bottom
12	1	9		7.2	1		TO #129	Dummy resistors top and bottom
13	1	10	0	0			TO #120	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	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	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

Machine hour meter readings

Table 2 Machine hour meter readings

Date compiled	9/03/2021					
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	58834	58756	56910	82648	82677	
Previous reading (TO #132)	53150	53073	53093	76043	76014	47343
Change in hours	5684	5683	3817	6605	6663	
Previous total hours	32573	32496	36858			
Current total hours	38257	38179	40675			

There appears to be an issue with the chain 3 meter or we have in fact, not been running chain 3 as much.

Note: the charging volt meter was removed completely to remove 240VAC from the control console and charging hours can be inferred from the terminal voltage hours below.

Terminal voltage distribution for period of service

The total hours with voltage on the terminal was at least 5702 hrs. This is consistent with the chain hours in the previous section (aside from chain 3)

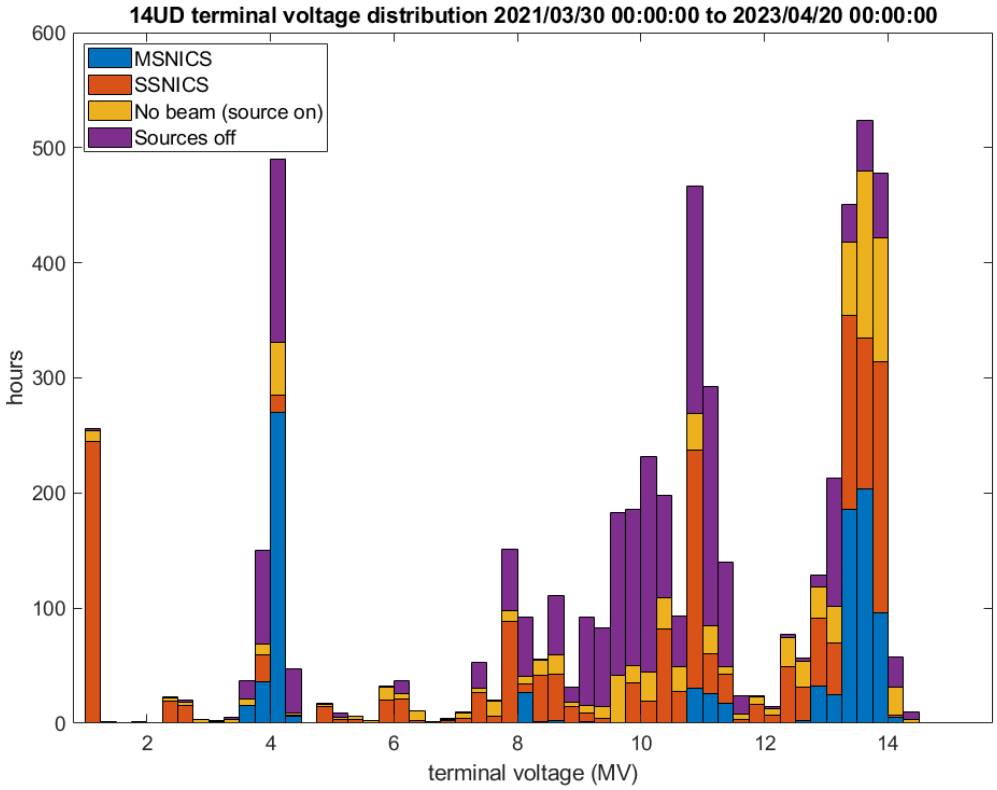

Figure 5 Terminal voltage distribution for period of operation from the end of tank opening 132 to the start of tank opening 134 with breakdown in type of usage (tank opening 133 was not a full tank opening and there was no entry into the tank). Note that facility was in a shutdown for electrical distribution board upgrades from about June 2021, followed by a COVID shutdown from about mid-August 2021 to at least late November 2021.

Initial performance

The machine ran for a Masters student run that wasn't terribly challenging voltage wise. However, over the King's birthday, there was an order of magnitude increase in tube vacuums over a six-minute period. Head on over to tank opening report 135, but the short of it is: SF_6.