ANU HIAF 14UD LABORATORY REPORT FOR ATF2014 – ACTIVITY PERIOD OF JULY 2012 TO APRIL 2014

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Recent years have seen significant upgrades to the 14UD hardware and to the experimental capabilities of the facility.

The programme of upgrades for atomic mass spectroscopy (AMS) applications has seen the in-house fabrication and installation of a custom multi-Faraday cup chamber and associated hardware. Along with this hardware, a new magnet box manufactured by Buckley Systems (New Zealand) was installed. This new magnet box allows for the passage of multiple particle beam trajectories through the analysing magnet. The installation was a major engineering effort, requiring a carefully controlled partial separation of the magnet iron, removal of the existing magnet box and insertion of the new box, all while maintaining the alignment integrity of the beam lines.

Additional hardware to allow fast beam cycling for AMS has also been acquired and installed. This includes a Trek 10/10B-HS high-speed, high-voltage, power amplifier (±10 kV) in series with the box volts, which allows a fast beam energy change. Six more of these power amplifiers have been purchased and will be replacing existing Glassman power supplies that feed an electrostatic triplet lens at the entrance to the acceleration tube. An NEC isotope sequencer will form the core component of the AMS upgrade via interconnection with the ion source and triplet power supplies.

Recent months have seen significant progress on the installation of a new superconducting solenoid in one of the 14UD's target areas. After early problems with the solenoid quenching at less than the required field, it has now been received from Oxford Instruments in the United Kingdom. The iron return yoke required for completion of the solenoid was manufactured in-house by the Research School of Physics and Engineering workshop from over six tonne of iron forgings. The formal commissioning procedure is currently underway and the system is expected to be operational by the end of 2014.

A number of other major capability upgrades have been achieved across the facility, from control systems to maintenance processes.

In the area of control and computer hardware, the accelerator control system has been fully ported to EPICS; a new user interface written in Python 2.7 based on wxPython and PyEpics libraries has been deployed and achieved user acceptance; and an upgrade to the central data acquisition (DAQ) system has commenced. A prototype DAQ unit has been installed with ongoing work on a new web-based monitoring and control interface. Following user acceptance, a second phase of DAQ development will focus on fundamental improvements to the design, such as removing existing limitations of sixteen slots per experiment and sixteen channels per slot.

The increase in the cost of SF_6 insulation gas due to the carbon tax has forced a review of inventory and handling procedures. A NATA accredited independent lab test of an SF_6 sample from inside the 14UD tank showed air content below four percent. New fast SF_6

containment valves were installed at the low- and high-energy ends of the acceleration tube. SF_6 extraction and testing gear has also been purchased. This consists of a Rapidox 3100C IR SF_6 multi-gas analyser, a Rapidox gas recovery bag and an ENERVAC GRU-4 SF_6 gas recovery unit.

Pulsed beam capabilities of the facility have also received upgrades, with major upgrades still in progress. The 5 MHz slow chopper has been upgraded and a high-energy chopper phase stabilization system has been deployed. A high-energy normal-conducting buncher has been designed and in the process of fabrication. Associated hardware for this includes a 10 kW 150 MHz amplifier from Amplifier Research, which has been installed with additional associated infrastructure such as a radiofrequency switch-frame and safety interlocks. A new three-frequency, low-energy bunching system with removable electrodes is also approaching bench testing phase.

A subtle but effective upgrade was the installation of an acceleration tube entrance lens control system using a Glassman 150 kV high-voltage power supply. This is fully operational and has reduced dependence on shorting rods for lower terminal voltages[1].

Other devices have also been purchased but are yet to be commissioned. One is a NEC terminal potential stabilizer (TPS) v6.0, which has been tested for non-pulsed beams but requires further investigation of CPO signals and operation for pulsed beams. Its performance is not yet adequate for the range of experiments performed using the 14UD. Another is a Drusch nuclear magnetic resonance (NMR) probe for use in the analysing magnet. It is not operational due to design problems and has been sent back to Drusch for hardware and firmware upgrades that intend to address the issues that were identified.

Recent periods have also seen a busy schedule of maintenance activities. There have been six tank openings in the reporting period dealt with in this report. These were for:

1. major component upgrades and thorough cleaning (tank opening #117);
2. a broken high-hour nickel-plated chain (unscheduled tank opening #118);
3. the rectification of sparking activity observed in two units (unscheduled tank opening #119);
4. the rectification of limited terminal voltage attributed to poor performance in a single unit (tank opening #120);
5. the installation of new hardware – including two new chrome plated chains – and the rectification of a small but sudden increase in the base pressure of the terminal gas stripper system (tank opening #121); and
6. another attempt at rectification of the leak in the gas stripper system (unscheduled tank opening #122).

From these tank openings, the three major issues to emerge are:

- the reintroduction of oilers to combat wide distribution of black particulate material thought to be chain pulley wheel sheave material;

[1] See M. De Cesare *et al.* "A novel beam focus control at the entrance to the ANU 14UD accelerator", EPJ Web of Conferences, Vol. 63, 2013.

- current leakage across tube and post spark gaps, with a correlation between leakage and cracks in the ceramic insulator (at least in posts);
- an increase in the failure rate of the ceramic insulators in posts, whether they be detected via current leakage or by scattered debris.

Oilers have been reintroduced into the 14UD, even though conducting tyres are still are used on the main chain pulleys. This was seen as necessary due to the significant amount of black dust and particulates observed in the high-energy end during a tank opening after operation for about nine months. Significant accumulations were mostly on the underside of the castings of the “down” side of the chains and largely at the castings with chain stabilising idlers. There were also accumulated deposits on the up DC idlers, the inductors and the high-energy rings. The black dust was determined to be chain wheel sheave plastic that was abraded and mobilised by the three chains. This dust was believed to be destabilising and limiting the maximum operating voltage of the accelerator and the chain oilers were reinstalled with the view that lubrication should prevent the abrasion and generation of particulates and, if any dust was produced, it may be trapped and not distributed as widely. Since the reinstallation of the oilers, and after a thorough cleaning of the 14UD internals, this has proven true.

During operation after tank opening #118, the attainable terminal voltage stability was not ideal, with small sparks and occasional recoverable drop-outs reducing the voltage to 13.3 – 13.7 MV with long reconditioning times. A detailed investigation over the next two tank openings revealed current leakage through a tube insulation gap and a worrying arc trace on another gap. Having nor spares, nor the time to install a new tube section, two insulation gaps in this unit were shorted. Every single insulation gap in the 14UD was then examined, on both posts and the tubes. In total, five gaps (of 1036) were shorted throughout the machine. One of these leaking gaps was on a post gap and furthermore, one where no issue was found during routine high-voltage tests upon entry into the tank. Close visual inspection revealed two small cracks in the ceramic insulation.

A consistent pattern is emerging amongst posts removed from the 14UD. This is that any post insulation gap that exhibits current leakage will have some sort of crack in the ceramic. The most distressing aspect is the increasing rate of detection of leakage currents or even outright mechanical failure of ceramic insulators in posts, with another seven detected during tank openings #121 and #122, with a handful more placed on a watch list.

It is not yet known what leakage is tolerable while the machine operates at high terminal voltages and what contribution, if any, the leakages make to voltage stability. At the time of writing, the machine was capable of sustaining 14.4 MV, even though ceramic insulators with small leakage currents are known to be in use in the machine. However, it must be remembered that posts form a structural component of the column in the 14UD and therefore, the possible failure of posts is a very serious issue.

A proper failure analysis is yet to be performed and it is not known which, if any, failure modes correspond to electrical punch through in the bulk of the ceramic. By visual inspection, there are four distinct types of flaws or failure in the ceramic. These are:

- single hairline cracks from electrode to electrode (parallel to post axis), sometimes darkened by arcing activity;

- flaking of the top 2 mm (approximately) of ceramic material with no evidence of arcing activity;
- complete failure of sections of the insulator, which is accompanied by scattered debris; or
- a criss-crossing of surface cracks.

Judging by historical routine high-voltage test results, it is highly likely that ceramic insulators with some level of current leakage have gone undetected over the past decade. However, the problem has not been seen to this extent since 1986, when the machine still used corona points to deliver a voltage gradient and SF_6 breakdown products were problematic.

Two final points should be noted regarding ceramic insulators. First, there is no definitive pattern to the location of flawed or failed insulators in the column and second; the relationship between cracks and leakage current is not mutual. That is, ceramic insulation gaps with obvious cracking do not always exhibit a detectable leakage current.

Discussion of other maintenance tasks and issues can found in our detailed tank opening reports available at http://physics.anu.edu.au/nuclear/tor.php.