AUSTRALIAN NATIONAL UNIVERSITY

DEPARTMENT OF NUCLEAR PHYSICS

14 UD TANK OPENING REPORT # 111

21st August to 11th September 2009

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REASON FOR TANK OPENING

This was an unscheduled opening due to the accelerator having a failure of the chain charging system during the night of August 20. The experimenters reported not being able to get voltage on the terminal and that the charging meter current was very unstable following some calamitous event that generated a lot of noise from the accelerator.
We quickly found that there was a short to ground of the suppressor (+ve), chain charging circuit within the accelerator.

This tank opening would now include the tasks forecast for the planned opening later in the year.

- Test the emergency lights
- Perform electrical and mechanical tests and inspect all idlers, chains, pulleys, bearings, shafts and resistors.
- Perform initial 30kV insulation test of the column.

- Wipe down column
- Implement improvements to shorting rod seals. ANU Second Design.
- Assess feasibility of applying a sealant in the gap of the top flange of the pressure vessel to eliminate the small leak that exists.
- Assess potential installation of better pressure and temperature readouts of the pressure vessel.
- Check reference voltage of the Gas Stripper Valve Motor power supply for a dip when operating. The same supply voltage is used for read back via a potentiometer of the position of the gas valve opening.
- The Terminal Stripper requires a top-up of foils.
- Change in two sets of four refurbished column post

DIAGNOSIS OF FAILURE 21-08-09

The charging system was drawing a high current indicating a short to ground. With the power supplies disconnected from the HV feed throughs located at the bottom of the tank, we found there was a short circuit to ground of the feedthrough conductor or the attached charging system within the 14UD.
It was also discovered that the in series, 50kohm spark protection resistor had failed and was open circuit.

- It was decided to commence manufacture of a new nylon feedthrough insulator in anticipation of finding this to have sparked through as previously seen in TO#108 4-08.

PUMP OUT 21-08-09

- The partial pump out was done on the Friday immediately following the breakdown of Thursday evening.

"Sods Law" was with us but we were ready! The complete contents of the storage vessel had been pumped into the accelerator so the scheduled maintenance of the storage vessel pressure relief valve could be done. This valve had been recently discovered to have a small leak. We understood this situation would leave us exposed in the event of needing to pump out the 14UD.
Fortunately a plan was ready to cap the PRV port and have the storage vessel back in service incorporating a relief valve in another part of the pipe work.

PUMP OUT 24-08-09

- The final pumping out was completed.
- The entry ports were opened for ventilating the tank overnight
- The platform cable/sealing fasteners were released ready for deploying the platform the following day.

SUMMARY OF WORK: 25-08-09 to 11-10-09

25-09-09 Tuesday

- An oxygen monitor was used to check air quality before entering the machine.
- The platform was deployed. The emergency lighting and the platform safety lights were tested and found to be operating.
- The initial cruise down the column found the machine no more dusty than usual. When the high energy end of the column came into view, Chain #2 was noted to be missing.
- Chain#2 is **broken!** Chain pieces ranging from small pieces of nylon to several pellets were found in U17, U19, U20, U21, U22, U27
- Disconnected the wire from the charging system HV mushroom inside the tank and with HV tester found the feedthrough out to the supplies to be good up to 7kV (in air).
- Removed rings to open units to recover the chain pieces.
- Removed the collected chain from the tank floor.

26-09-09 Wednesday

- Closed the units previously opened for the chain cleanup so we could do our usual 30 kV High Voltage gap tests. All was normal and work could begin.
- Wipe down the column with detergent and water.
- Opened U15 and U16 to clean prior to lowering the lower terminal spinning over these units.
- Chain # 2 inductor stack, 1/2" nylon stud was broken from the steel pillar top during the chain failure event.
- We retrieved our spare chain from storage to prepare it for installation. This is chain 2K with 13.7kHrs. It was "retired" from service in 1992 (TOR #77) due to concerns about the link pin hole elongation in the pellet.
- Contacted NEC for a quote to supply new chain and chain wheel sheaves.

27-09-09 Thursday

- Cleaned U17, U18, U19,
- Cleaned U20. The chain idlers are fitted to the underside of U19 that is the top of U20. We found on the idler petals of Ch #1 down side one petal that had significant spark marks with a raised peak of aluminium in this feature. These were polished off.
- U22 Tube 3 Gap 8 resistor lead deformed during chain breakage event. Straightened up OK.
- U22 up side idler wheel edges chipping away and bearing poor.

- U22 down side idler petal slightly damaged by chain impact. This polished out OK
- Made a sketch of the geometry of the internal gap in the large top flange of the accelerator with the view to applying a sealant in this gap.
- Removed chain #2 lower inductor stacks from the machine
- Opened upper terminal spinning's to access the stripper assembly.
- Started heat regeneration of the mini roughing, vacsorb system used during stripper assembly removal.

28-09-09 Friday
- The Terminal Stripper was removed. (000) Foils were at #183.
- The repopulated Terminal Stripper was refitted after lunch and vacuum re-established.
- The order for one new chain and a pair of chain wheel sheaves was dispatched.
- Completed the installation of a sealed tubulation in the SF^6 recirculation blower inlet pipe. A temperature measurement device will be fitted into this shortly.

31-09-09 Monday
- Chain #1 U22 down idler pair was badly worn concave and edges brittle. Swap in idler pair from U22, Chain#2 down.
- Changed out resistor leads that were bent too sharply in U25 column #3, #7, #9 and #18.
- Chain #1, worn idler, U19 upside (single) was replaced with idler from Chain#2.
- Cleared obstructions including grounding straps from the underside of the top flange. Cleaned the surfaces of the flange's internal gap ready for applying sealant.

1-10-09 Tuesday
- Applied sealant to internal gap of the 14UD top flange.
- Removed Chain#2 upper chain wheel.
- Measured the vertical load imposed by the drive motor and its support arm that tension apply to Chain #2

2-10-09 Wednesday
- Removed Chain#2 U16 idlers.
- Replaced Chain#1 U16 upside single idler with serviceable unit from chain#2.
- Refitted flat grounding straps to underside side of the top flange following sealing operation.

- Fitted the new charging system feedthrough insulator into the hole in the bottom of the tank. Re-cut and smoothed the external edge radius of both feedthrough holes.

3-10-09 Thursday

- Removed Chain #2 lower wheel. Found to have very bad inner bearing.
- Removed Chain#2 oiler and plumbing.
- Removed from the underside of U28 and the tank floor all redundant SF6 gas control pipe work no longer required.
- Commence installation of refurbished posts in U6.
- A pair of new chain wheels, axles and bearings were assembled in the workshop ready for the fitting with the new wheel sheaves.
- Deepened the fastener countersink detail on a single idler petal per position to accommodate new c/sunk screws superior and more durable larger hex recess.

4-10-09 Friday

- Tested the terminal gas stripper turbo pump power supplies. The wave forms were both OK and recorded.
- Tested terminal Ion Pumps
- Tested the terminal gas stripper power supply voltage drop during operation.
- Installed a refurbished post in position B of U16 and refitted the resistors.

7-10-09 Monday

- Fitted the chain wheel locating fixture to Chain #2 chain wheel before removing the wheel.
- Installed a pair of plumb bobs to the locating fixture in the terminal.
- Chain#2 terminal chain wheel carbon contact brush was removed and cleaned as it was sticking.
- The new chain and chain wheel sheaves arrived from NEC USA.
- The two new chain subassemblies where joined using riveted pins. We retained three screw secured pellets including the joiner ends. This provided for the expected initial shortening.

8-10-09 Tuesday

- Tested the operation of the HE and LE shafts. Both sounded good and smooth.
- Cleaned and closed the terminal mid and upper sections.
- Commence installation of refurbished posts in U11. The post in position D required some filing of the holes in the casting to permit easy installation of end flange screws.

- New ring screws were fitted to U11. One of the posts top and bottom titanium elements contacting the end flanges is made up with three thicknesses of sheet and thus the ring screw slots in these positions required widening.
- The application of the Bostik Seal n Flex 1 polyurethane sealant applied to the top flange gap looked a bit messy but satisfactory from a sealing point of view.

9-10-09 Wednesday

- Machining detail was completed on the new chain wheel sheaves for Chain #2 by the main workshop.
- Fitted the upper chain wheel. The reference positions from the locating fixture were essentially discarded as the fixture required loosening to fit the new larger diameter chain wheel.
- Adjusted terminal chain wheel position so as string line of the plumb bob was centred about the machined chain holes in the immediate casting below. Other measured references agreed with this.
- Fitted the lower chain wheel. Broke the carbon contact brush in this process. Suitable replacement brush (Bosch part #2604321090) from a power tool spares supplier was used as a replacement.
- Loaded the new chain from the terminal and joined the ends. Noted there was significant twist in the free hanging chain of about 80 degrees.
- The positioning of the lower chain wheel required offsetting from the plumb bob axis to conform with the shaft contact brush and it's mount.

10-10-09 Thursday

- Removed one pellet from chain #2 following overnight stretching. Motor stop leg measured 75mm to tank floor.
- Chain #2 lower chain charging inductor stack assemblies were installed and set with the gauge.
- Remade the broken grounding connection at the tank floor. This was from Chain #2 pivoting inductor support arm. The soldered joint failed and a new screw type lug was made.
- Installed a complete set of new casting idlers to chain #2. Except U16.
- Installed the casting idler petals including one in each location with the new countersunk socket head screws. The new screws head diameter is larger and required machining to suit the deeper countersunk holes in the petals.
- Chain #2 terminal chain wheel inductors were installed and set with the gauge. This included the grounded inductors.
- Raised the lower terminal spinning to close the terminal.

- Installed new idlers in U16 which were now accessible following the raising of the lower spinning.
- Opened, cleaned and closed U23 to U28.
- U25 repaired a loose stringer on Tube 3, column end.
- U25, we noted the resistor assemblies and leads had more oily deposits on them than was typical. These were cleaned.
- Operated chain #2 overnight.

11-10-09 Friday

- Chain #2 was shortened by removing two pellets. The overnight running had the motor stop leg measuring ~28mm. This reset the leg to ~87mm.
- Observed whilst Chain #2 was separated for shortening, the free hanging up side would now only relax with about a 45° twist clockwise.
- Using a strobe light we assessed the chain slippage of the three chains.
- Cooper assembled the three pellets removed from the new Chain #2 to assess if the twist was evident in this small sample.
- Chain#2, it was thought we should photograph the residual twist seen earlier this day. We removed a pellet pin and allowing one side of the chain to hang freely from the terminal to Unit28. We still had a twist of approx 45°.
- The casting covers were fitted and then the column was blown down using high pressure breathable air.
- The column was wiped using RBS and water.
- The 30 kV gap test was done and no problems were found.
- The charging and metering tests were performed and the machine was closed.

COLUMN POSTS

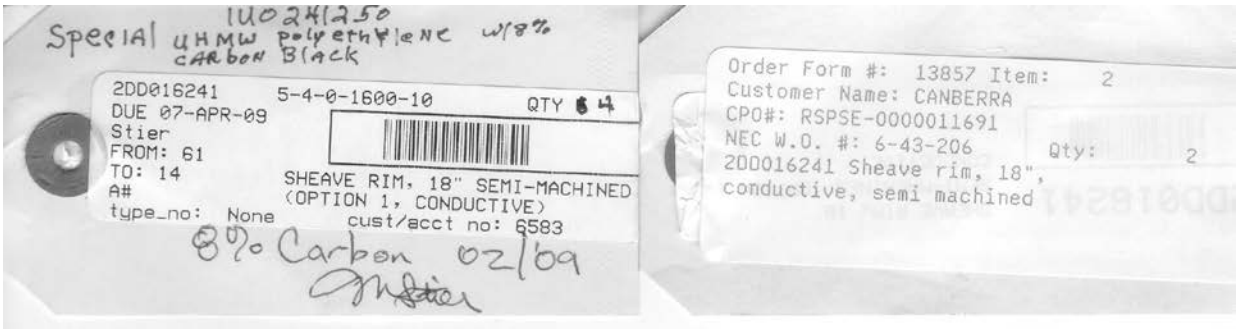
Two sets of refurbished column posts were available for this opening.
Units six and eleven were selected for replacement.
The installation of post D in U16 required some elongation of the holes in the casting to allow the alignment of its fasteners.

CHAIN WHEELS AND SHEAVES

We purchased a pair of new chain wheel sheaves for position #2 to run with the new chain. The ID tag for these parts from NEC reads

IU0241250 UHMW POLYETHYLENE
W/8% CARBON BLACK.

These require mounting on the aluminium wheels and axle assemblies before final detail machining of the radius to match the chain pellets.



We had new spare chain wheels and axles ready and these were put into service in this location.
We found when we removed the existing lower chain wheel that the inner bearing was in quite poor condition. Very grumbly.

CHAINS
Chain #2 had failed.
The total hours on this chain was 69khrs. It would appear it had sustained a catastrophic spark event that fractured a nylon link.

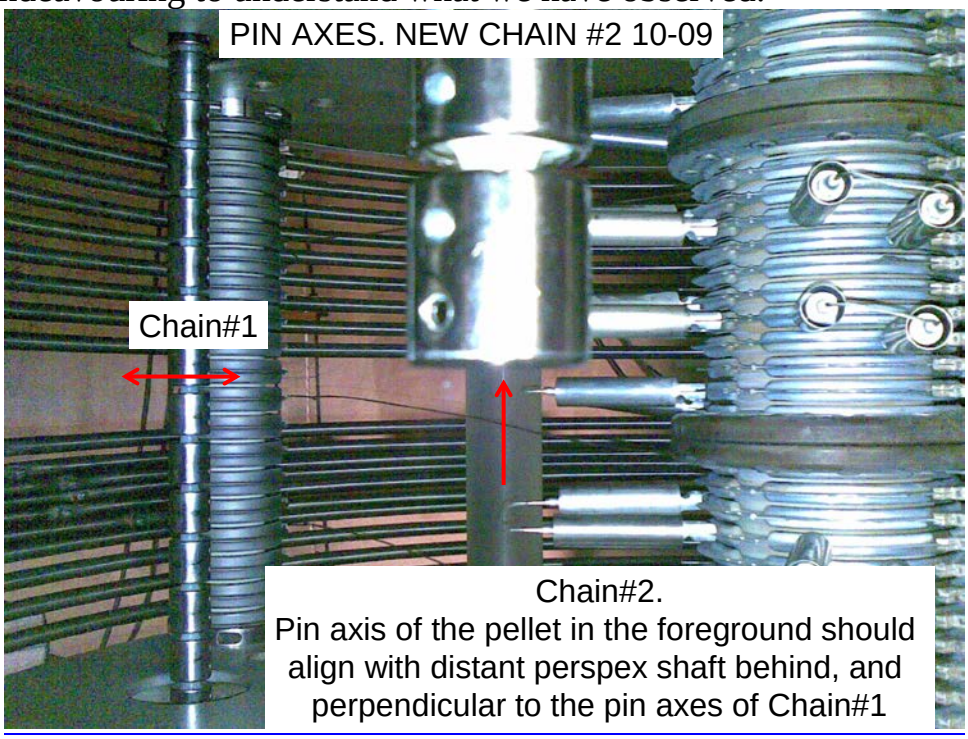
Many pieces of broken chain were found down the column with the bulk in one piece laying in the tank bottom. The smaller pieces ranged from fragments of nylon links, pins with bushes, three and four pellet sections of chain.
The nylon stud of the up side charging inductor in the terminal was broken at the steel pedestal. Inductors top and bottom had sustained chain pellet impacts and these were dressed off smooth
Fortunately there was very little collateral damage to other infrastructure.

NEW CHAIN #2 AND RELATED HARDWARE.
There was much conjecture as to the serviceability of our one spare chain 2K. Though low hours, it has many worn pin pivot holes in the metal pellets attributed to the pellets being made of lighter gauge steel. It was decided late in week 1 of the opening to order a new standard chain.
It was promptly delivered from NEC for position #2.

When it arrived we were surprised that NEC was now nickel plating the chain pellets. The plated pellet surface looked to be smoother than our last new chain that had chrome plating on the pellets. Some sections of pellets appeared to have a fine polished surface as if spun on axis in a lathe. Others sections were mill finish tube with plating.
We replaced all the screwed pin joins in this chain with riveted pins. Our new chains have 545 pellets. To bed this chain in and incur some of the usual initial stretching the chain was operated for two nights prior to closing. One pellet was removed following the first night and two following the second.
During the initial installation of the new chain there was a right handed twist of about 80 degrees in the free hanging drop from the terminal. This is evident in the assembled small sample of the three pellets removed to shorten this chain.

Images show pin axes (drill bits fitted) misaligned. Light rotational force applied then relaxed in both directions taking up the pin to hole clearances.

NEC is endeavouring to understand what we have observed.



The residual twist after two night's operation was assessed. With the removal of a pellet pin and allowing one side of the chain to hang freely from the terminal there was approximately 45 degrees residual twist.

The chain oiler was removed from this location #2.
The Chain #3 oiler is the only SF6 gas driven function requiring plumbing to operate. The redundant copper plumbing laying across the tank floor was removed including the cooper to plastic transition bulkhead plate in the underside of the very last casting (bottom U28).

CHAIN #2 IDLERS
We made the decision to fit out position #2 with a complete set of new casting idlers to run with the other new hardware. Some of the removed though still serviceable wheels were fitted in other locations during this opening.

CHAIN #1
This chain was inspected during the opening but required no other attention other than cleaning the inductors and checking their setup with the gauge.
This chain is run dry and the dust associated with this was thought not to be significant. Our experience with this dry operation is growing and particularly now with two dry chains in operation.

CHAIN #3
This chain was wiped clean and required no other attention other than cleaning the inductors and checking their setup with the gauge.

CHAIN CHARGING SYSTEM
NYLON FEED THROUGH
The following image and text in *Italics* is an extract from TO#108.
This incorrectly reports the spark through of the nylon *to be adjacent to the sharpish outer edge of the hole in the tank wall*. The spark through was actually within the length of hole in the tank wall. The outer edge of the hole is actually aligned with the brown stain below the spark damage.
The positive side 1” diameter nylon feed through had been sparked through between the central conductor and the tank wall.
The conductor is ¼” diameter steel rod.

During our disassembly of the feed throughs we decided to further improve the finish of the radius of the holes in the tank external wall. The previous radius work was found to leave room for improvement though hasn't been a source of spark damaging activity. We re-cut the radius with the same specially made tool but with some adjustment. The re-cutting was smoother and we paid greater attention to polishing the radius. We neglected to clean up the swarf and dust from this exercise and it caused problems later. See Initial Performance.
The in series 50Mohm resistor was found to be open circuit was replaced with a 25Mohm unit from NEC.
The new nylon insulator was fitted to the suppressor feed through.

Radius detail done during TO#108.

Refinishing done this opening.

CHAIN TENSIONING
We measured the load applied to the chains using a spring balance and a sling arrangement hanging from the platform to the motor drive shaft. Without any chain, in position #2, the pivot arm was set horizontal and the weight taken up. This measured to be 50-53kg.

CHAIN SLIPPAGE MEASURMENT
We also used a strobe to assess slippage of the chain on the pulleys. The motors spin at 580rpm and can set the strobe to view the chain as stationary and we could

see the relative slippage of the chain drive wheel. We timed how long it took to slip by one revolution.
Chain #1 = 15sec Chain#2 = 4-5sec Chain#3 =4-5sec.
Increasing or reducing the chain tension made very little change.

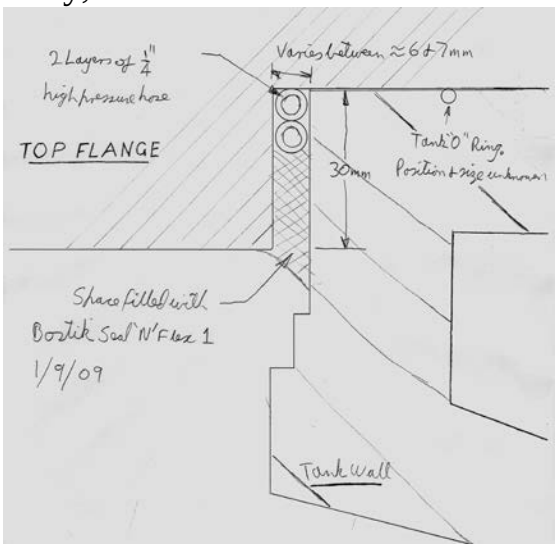
SF6 GAS LOSS REPORTING
We have a responsibility to report SF6 loses to a group within the ANU who subsequently report to government as part of the Greenhouse and Energy Reporting Act. SF6 is included as a reportable gas.

The calculated average loss over the past 4.73 years is in the order of 89kg per year.
Pumping losses per year are calculated to be 20kg (10kg x 2 openings per year).
We have two known leaks: the pressure relief valve on the storage vessel and the second leak from the 14UD tank top flange.
The relief valve leak rate was 0.19 l/min or 23 kg during 2 weeks of tank opening, which is the typical opening period in one year. This leak was eliminated in September 2009 by refurbishing and re-calibrating the relief valve.
The remaining 46kg loss can be attributed to the leak at 14UD tank top flange.
An attempt to eliminate or at least reduce this was made during this opening.

The precise calculation of our gas inventory requires us to improve the pressure and temperature measurement hardware. A new thermometer bulb well was fitted into the gas recirculator's inlet pipe ready for the selected new hardware.
A new pressure transducer to monitor tank pressure will be fitted also.

SEALING THE 14UD TOP FLANGE.
We applied Bostik Seal N Flex 1, polyurethane sealant to the tank top flange in an attempt to eliminate a small SF6 gas leak. This material is used in the construction industry and was selected for its tolerance to cyclic expansion and compression properties (±25%).
We have known of a SF6 gas leak on the top flange of the 14UD for some time.
The leak rate is not easily quantifiable and it is believed to be leaking past the o-ring.
The investigation and repair of an o-ring leak would require significant effort and disturbance to the facility. It had been considered often and reluctantly accepted by all parties to live with this leak.
The nagging unacceptability of this leak and the recent meeting to report our gas losses provoked the proposal of an interesting solution.

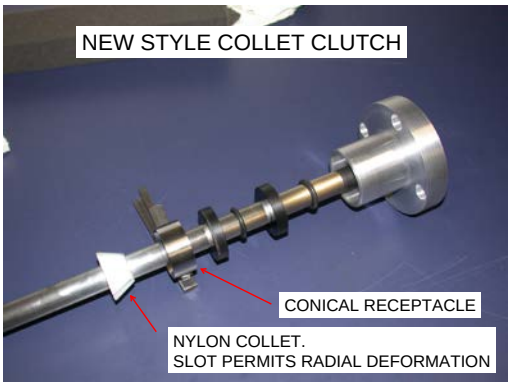
It was proposed that a curable sealant could be applied to the internal gap formed by the top flange and the mating flanged neck at the top of the tank to eliminate the gas leak.
Details of the gap at the top of the tank were gathered and it was decided to insert two pieces of nylon tubing before applying the sealant. The tube reduced the volume of the sealant required and also in the event of needing to cut the sealant away, we had a defined interface at which the materials change.



The two layers of 1/4" hose were inserted and the sealant applied and smoothed.

SHORTING ROD CLUTCH/SEAL

Experimenters are requiring more frequent shorting rod changes. This is causing greater wear of the o-rings within the clutch and sealing mechanism. This is evident with rubber pieces on the shorting rods. More lubricating oil can lead to the clutch function not resisting the force of the gas pushing against the rod.
Cooper had a plan that included hardware to restrain the shorting rod to permit the removal of the clutch pack o-rings and compression discs without pumping out the accelerator.
This plan would rely on the one fixed position, primary gas seal o-ring below the clutch pack to still perform well enough to execute the clutch pack servicing.
Now with the tank open we had access to all the seals and clutch system. This made the implementation of modifications and the testing of the servicing procedure much easier.



A redesign of a significant nature was undertaken. It involved the removal of two o-rings and their compression discs to be replaced with a conical stainless steel receptacle of (50º inclusive angle) and a mating slotted nylon cone or collet that radially compresses to grip the shorting rods when the axial force is applied by the over centre clamp.
A slot in the cone allows oil lubrication to pass to the remaining o-rings below.

This is providing superior resistance to the displacement of the rods by the gas pressure with very free movement, in or out of the rods when the axial clamping force is released.

MACHINE HOUR METERS 24-08-09 AGM

CHAIN 1	CHAIN 2	CHAIN 3	LE SHAFT	HE SHAFT	CH VOLTS
9341	9341	9342	17754	17753	10312

TOTAL HOURS

CHAIN 1 (1N)	CHAIN 2 (2l)	CHAIN 3 (3L)
18.5 K	69.2 K	61.5 K

TOURS
This opening saw many more staff and visitors have a look at the inside of the machine and were given a brief description of how it works.
Groups from our School Machine Shop, ANU Environmental Accounting, ANU Facilities and Services, PhD Students (Nuclear Physics and other) and interested person from the Supercomputer facility toured the machine.

INITIAL PERFORMANCE
The first attempt to operate the accelerator found the chain charging system was drawing high currents when voltages above 10kV were applied. Investigations found there was leakage to the grounded shielding of the coax cable between the supply and the tank feedthrough. The charging system tests before the tank

closure are limited to around 8 to 9kV when the spark protection discharges. Thus this failure was not evident until we had closed and gassed up the tank.
We had neglected to clean up the metal swarf and abrasive particulates in the external enclosure covering the charging system feedthrough assembly. Different personnel had placed the lids on these enclosures unaware of this need.
The mushroom shaped end that the coax connects with on the end of the series resistor had attracted at least one piece of the metal swarf, sitting perpendicular pointing at ground. This obviously was our next source of breakdown of the circuit. The coax itself was OK. This was cleaned up and all was working as per normal.

The accelerator sparked at 8.7 MV, 14.0 and 14.1 during conditioning to 14.4 MV over 3 days. The machine has sparked at 14.4 two more times to date.
The care in our routine cleaning of the machine during this opening again appears to have paid off handsomely with the easy attainment of 14.4MV.
The operational voltage is limited to around 14.8 MV at the current tank SF6 pressure of 100 PSIA.