ANU HIAF status report

Nikolai Lobanov on behalf of HIAF TEAM

SNEAP 21 May 2021
Outline

• Past and present HIAF upgrades
• 14UD performance over the years
• Known problems and issues
• Summary of vital developments
• Plan of action
14UD/linac and its instruments:

Tube entrance lens control NIMB 421 (2018) and NIMA 767 (2014)
L5 major upgrade and new He⁻ ion source Linardakis talk
Entire inventory of posts and tubes ordered from NEC
(new e magnetic suppression- ondulator) Tunningley talk
New target area, and beam lines under investigation
NP Department 3-6-9 years development plan has been updated
Upgraded SNICS and McSNIC for reliability NIM B 415 (2018)
Linac beam pulse width monitor, tunes with srf phase detector
Linac resonators upgrade 2 x PRST AB 9 (2006), and PRST AB 10 (2007)
14UD tubes: 50 years of hard work...

Linardakis HIAT19 talk
Ion sources: still a lot of surprise

Recent rebuild
Bunching and chopping:

Fast chopper upgrade
HE normal conducting buncher and acceleration modules and 10 kW amplifier
(work in progress)
LE buncher and HE chopper upgrades 2 x NIMA (2021)

Beam lines:

8.5T solenoid- mechanical suspension and commissioning NIMA (2020)
ANU neutron shielding- few beamlines upgraded
Supere line 6 upgrades
AMS cycling system NIMB (2015)
Space irradiation beam line

Operation:

TO#132 detailed TOR available PRST AB 18 (2015)
Linac#29 Cryo crew training in operation and compressor maintenance
14UD operation up to 14.5 MV
Sulphur and Fluorine decease treated successfully work in progress
Outline

• 14UD performance over the years
• Known problems and issues
• Investigation of tube Ti electrodes
• Plan of action
• Summary of vital developments
14UD performance (2001 to 2013)
14UD performance recent years
Dear Nikolai,

We are sorry to hear of your continuing problem with failed posts in the 14UD. Greg is out of the office, however I have checked with others at NEC concerning your questions.

1. Optimum SF6 pressure: There probably is no hard limit or firm optimum pressure. According to old-timers here, posts have been run in pressures as high as 120psi, and certainly 95-105 psi is commonplace. Increased pressure obviously strengthens the spark gaps and potentially could shift spark energy to the ceramics, but the ceramic voltage holding capability also increases with SF6 pressure.

   This is true for surface voltage gradient. However the volume breakdown does not depend on SF$_6$ pressure.

Electrical Breakdown Strength of Al$_2$O$_3$ $\sim$100 kV/mm
Effects limiting HV performance

• Insulator surface exposed to vacuum or SF$_6$

• Triple junction
  – Microscopic void with E enhancement $\sim$ 9
  – Foil protruded with sharp edge causes FE and hairline tracks

• Total-Voltage Effects
  – $E_{\text{breakdown}} \sim \text{SQRT}(\text{Gap Length})$
Damaged 14UD posts

Spark Damage Triggered at Triple Junction

The stress during sparks can still be too much even for graded assemblies

Broken post due to mechanical stress

Two posts removed during TO#122
Replaced with least “worst spares”
### 14UD evolution & factory specs

<table>
<thead>
<tr>
<th>Year</th>
<th>Age</th>
<th>$U_T$, MV</th>
<th>$SF_6$, PSI</th>
<th>$\Delta_T$ LE, %</th>
<th>$\Delta_P$ LE, %</th>
<th>$\Delta_T$ HE, %</th>
<th>$\Delta_P$ HE, %</th>
<th>scaled by $SF_6$ and $\Delta$</th>
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<tbody>
<tr>
<td>1973</td>
<td>0</td>
<td>18.1</td>
<td>115</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>18.1</td>
</tr>
<tr>
<td>1975</td>
<td>2</td>
<td>14</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15.74</td>
</tr>
<tr>
<td>1985</td>
<td>12</td>
<td>13.67</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>-2.4</td>
<td>-2.4</td>
<td>15.4</td>
</tr>
<tr>
<td>87-88</td>
<td>15</td>
<td>15.5</td>
<td>102</td>
<td>12</td>
<td>-4.1</td>
<td>9.6</td>
<td>-6.5</td>
<td>15.01</td>
</tr>
<tr>
<td>1989</td>
<td>16</td>
<td>15.5</td>
<td>102</td>
<td>12</td>
<td>-4.1</td>
<td>9.6</td>
<td>-6.5</td>
<td>15.01</td>
</tr>
<tr>
<td>2018</td>
<td>45</td>
<td>14.5</td>
<td>100</td>
<td>10.6</td>
<td>-5.5</td>
<td>8.4</td>
<td>-7.7</td>
<td>14.53</td>
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</table>

* $-4.1\%$ post reduction to match 8 gappers

$\Delta$ represents change of effective ceramic length

From TO 61 1988

We didn’t want to test the column at pressures as high as as 104 p.s.i.a., let alone 115 p.s.i.a., since ceramics in posts had cracked when the machine operated at 104 p.s.i.a.

### 14UD specs under stress: 15.0 MV, 102 PSI, with shorted ceramic gaps 14.5 MV

Relaxed specs $\sim$0.5 MV lower
Outline

• 14UD performance over the years

• Known problems and issues
  – Watch list of faulty items
  – “HV rush” in 80th and excessive SF$_6$ pressure
  – SF$_6$ leaks and SF$_6$/O$_2$ as GS gas
  – “bad” beams
  – “evil” Users
  – “ruthless” accelerator
“HV rush” in 80th and excessive SF6 pressure

SNEAP’88

RESISTOR DEVELOPMENT FOR N.E.C. ACCELERATORS

D.C. Weisser

WEISSER: I make no case that this is a minimum solution. It is conceivable that this is overkill, but I want these to operate in an 18 MV 14UD, and I do not want to worry about sparks. This is an efficient way to make them. I

RESISTOR IMPROVEMENTS FOR A NEC PELLETRON

DR D.C. WEISSER

Department of Nuclear Physics, Research School of Physical Sciences, Australian National University, Canberra, ACT 2601, Australia

At SNEAP 89, ANU1 reported the design, installation and early improvements in resistor assemblies for the 14UD Pelletron Accelerator. The 3000 resistor assemblies have now successfully logged 6644 hours of operation at terminal voltages up to 16.6 MV and have experienced many terminal sparks. There have been no resistor failures other than infinitesimal ones associated with 0.1% manufacturing flaws. These have been rectified under warranty by Welwyn.
“HV rush” in 80\textsuperscript{th} and excessive SF\textsubscript{6} pressure

Nuclear Instruments and Methods in Physics Research A287 (1990) 64–0

NEC ACCELERATOR TUBE UPGRADE: 16.7 MV IN A 14U

D.C. WEISSER and M.D. MALEV

The starting point for the improvement program was the accelerator performing experiments at up to 13.7 MV or 2.4 MV/m across each tube ceramic insulator. The pinnacle voltage performance for experiments was 14.8 MV in 1981 with a consistent deterioration subsequently.

The machine continued to condition well. Fig. 4 shows low values of continuous X-ray rate of \(\sim 1000\) Hz, vigorous pulsed conditioning and a peak terminal voltage of 16.6 MV. The machine subsequently achieved 16.7 MV.

with compressed tubes
In his 1974 review paper [35], Allan Bromley stated, “Looking further into the future, electrostatic accelerator technology has now advanced to the point where it becomes reasonable to at least consider designs for tandem electrostatic accelerators in the 50–60 MV range”. This prediction reflected the optimistic view of many in the field of electrostatics at that time. It was also a period of generous funding fueled by the advances in nuclear-structure research. The explosion of ideas in this field called for ever-greater energies.

<table>
<thead>
<tr>
<th>Accelerator</th>
<th>Gain, MV</th>
<th>Stored Energy, J</th>
<th>SE/G J/MV</th>
</tr>
</thead>
<tbody>
<tr>
<td>14UD</td>
<td>30</td>
<td>42000</td>
<td>1400</td>
</tr>
<tr>
<td>Linac SLR</td>
<td>0.7</td>
<td>0.5</td>
<td>0.7</td>
</tr>
</tbody>
</table>

14UD at 15.5 MV

High stored energy is main limiting factor in electrostatic accelerators.
Dreadful SF$_6$ in tubes

SNEAP 82  JAERI report

It is believed that there were two small SF$_6$ leaks in the accelerating tube for a long period of time. These leaks were not observed by the mass spectrometer at the base of the column because the column pumps removed the SF$_6$.

In addition, these leaks did not affect the base pressure of the accelerating tube. However, even these very small leaks were enough to have a strongly adverse affect on the voltage holding capability of the accelerator.

Norton: I guess a lot of us had always thought that SF$_6$ leaks were poison, but this was fairly dramatic. The leaks were extremely small, but the behavior of the machine after they were gone was phenomenal. If I can, I would like to say a little about Munich, which has an MP with N.E.C. tubes. I was there a few weeks ago. Their machine was behaving, from what they said, as I remember this machine was behaving with SF$_6$ leaks. And indeed, they had a pressure sensitive leak in the terminal and were not too concerned about it because they do not see it on the mass spectrometer at the base of the machine when the column pumps were on. We didn’t either. But, there was a situation when they could condition the tube up to 13 MV, have a small spark, and they were deconditioned. They were back to running beam around 12 to 12.5 MV.

Hurley: Any time we have had an SF$_6$ leak there has been a very sharp deterioration in voltage performance.

A lot more on SF$_6$ has been reported at SNEAP/HIAT in 80$^{th}$
“Evil” Users

• unexperienced users
  • due to high turnover of staff

• bad practices
  • operation in manual mode instead of auto
  • operation with tank slits fully open
  • Operation with poor tuned beam (high loading)
“Bad” beam experience was reported when running with Sulphur beams at BNL facility up to the point to abandon Sulphur runs.

More likely the scale of this phenomenon depends on voltage gradient in the machine and beam intensity. Another consideration is tubes electron suppression efficiency. NEC tubes suppression is not as good as in inclined geometry tubes. The energy of electrons could be up to 300 keV and weird chemistry could be enhanced under such conditions. For instance Ti fluorides, sulphides etc may be formed activating emission sites which are difficult to eliminate.

However, ANSTO did not reported any issues with HV running SF6 as a gas stripper medium.

Nikolai

In the past and present days we regular run F⁻, S⁻, with increased use of ZrF₅⁻, CaF₃⁻ etc.
“Ruthless” accelerator

- S.R. system
  - non-flexible and slow
  - Min safe number of S.R. is TWO

- Terminal Q-selector was not supplied initially
  - Excessive charge loading in HE

- Maintenance platform
  - limited compliance

- Voltage grading resistors are great BUT
  - poor visual, weak banana interface and multi-wire link

- NEC tube
  - e- suppression does not work on beam axis
Ceramic/Ti: partial or full replacement?
• Finally, the summary of vital developments
Major Technical developments

- UT
- TO#
- linac#

- 14UD commissioning
- HE stripper
- compressed tubes, resistors
- NCRIS upgrades
- GC, LEB, fast AMS, 3FB, vac
- linac
- SB
- TEL
- Ilrif, Dressler
- 3 Eng Exc Awards
- alpha
6-9 years and beyond

Accelerator development aspirations

- New beam lines
- New Linac 4× higher field gradient
- New Linac injector
  ✓ Parallel operation of 14UD and Linac

Cost

- Staged as funding available
- Prepared for new NCRIS infrastructure program

State of the art cryomodules

- 2 fit present Linac footprint
  ✓ Two give 35 MV boost
  ✓ 5 times present Linac
  ✓ USD $4M each
Alternatively

State of the art stand-alone cryomodule based on Nb QWR (RadiaBeam Systems and ANL)

- 2 fit present Linac footprint
  - One gives 2 MV boost
  - 3 replace present Linac
  - USD $1M each
  - Cryoplant and cryo crew are not required

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Dimensions</td>
<td>Ø40” x 88.5” Length</td>
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<tr>
<td>Frequency</td>
<td>72.75 MHz</td>
</tr>
<tr>
<td>Beta</td>
<td>0.07 – 0.12</td>
</tr>
<tr>
<td>Voltage per cavity</td>
<td>Up to 2.0 MV</td>
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<tr>
<td>Static 4.5 K load</td>
<td>1.94W</td>
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<tr>
<td>Dynamic 4.5K load</td>
<td>4.58W</td>
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<tr>
<td>Number of cryoheads</td>
<td>1-3</td>
</tr>
<tr>
<td>Cryogenic capacity</td>
<td>5-12W</td>
</tr>
<tr>
<td>Helium tank capacity</td>
<td>100 L</td>
</tr>
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</table>
Concerns

• unsecure long term funding model which should include depreciation component
• lack of formal on-call and after hours support
• diminishing support from Uni and growing bureaucracy in all aspects: purchasing, staff promotion, WHS, AL/LSL threshold etc

• COVID related delays, Uni/Dept restructure
Accelerator staff the key to excellence

No unplanned TO since 2013
Questions ?