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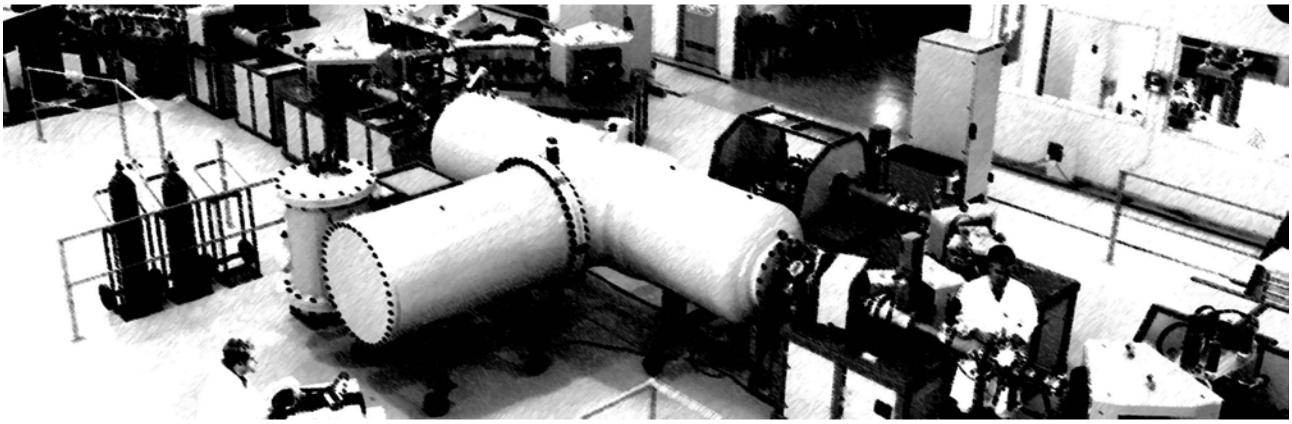

COMMISSIONING and FINAL INSTALLATION REPORT

for the

STAR ACCELERATOR FACILITY

Prepared by David Garton

Institute for Nuclear Geophysiology
Australian Nuclear Science and Technology Organisation

September 2005

Commissioning Report for the STAR Accelerator Facility

1. SCOPE

This document describes the commissioning phases, management, safety and approvals systems used during the installation of the STAR Accelerator Facility. It is also intended as a historical account of changes to the engineering specification and the necessary modifications that were made to meet local and national standards.

2. INTRODUCTION

AINSE, Australian Universities and ANSTO have acquired a new HVEE 2 MV Tandetron accelerator with significant funding from the Australian Research Council (ARC). The new accelerator replaces a 40 year old Van de Graaff accelerator and will be used across a very wide range applications utilising Ion Beam Analysis (IBA) and Accelerator Mass Spectrometry (AMS) techniques.

The procurement stage began with a comprehensive consultative approach to selecting an accelerator that would best meet the current and future scientific demands. During mid 2000, a final decision was made to purchase a new 2 million volt tandem (Tandetron) accelerator from High Voltage Engineering Europa, Holland. A contract was signed on the 13th December 2000 to supply, install and commission the accelerator and provide a warrantee period of 12 months from the final acceptance. HVEE was the sole supplier of the accelerator and components and took responsibility for the design, installation and training.

The accelerator was pre-assembled and tested in the company's factory at Amersfoort, Holland to verify that the mechanical and electrical integrity conformed to the tendered specification and international standards where applicable. The HVEE accelerator and beam line components as supplied, represent approximately 75 percent of the accelerator facility with ANSTO's beam lines and support infrastructure making up the difference.

The construction phase of the project started in October 2002 and was immediately followed by a commissioning phase starting in May 2004. HVEE completed extensive operational performance tests and undertook final acceptance tests in the presence of ANSTO staff in June/July 2004 marking the completion of HVEE's commissioning phase. During the late construction phase ANSTO was able to begin the construction and testing of it's specialised IBA beam lines and end stations. The -30° beam line was completed and commissioned in October 2004 followed by the +10° beam line in December 2004. The whole project took a total of 26 months.

ANSTO's contracted contribution to the project was detailed in a document produced by HVEE called Installation Requirements and Recommendations, A-4-35-175-0006-51079 and was supplied to ANSTO preceding the receipt of the shipped accelerator and components from Holland. Generally, ANSTO was responsible for providing assistance to the HVEE engineers and the preparation of the site and integrated services. ANSTO was also responsible for supplying volatile consumables, bulk consumable compressed gases, assistant labour and some tools and equipment. To complete the project ANSTO designed and installed two IBA beam lines and scattering chambers.

All installation, commissioning work and acceptance tests provided by HVEE as specified in the contract have now been completed. HVEE's physical involvement at

ANSTO has now ceased but support provided under warrantee will continue for a period of 12 months from the completion of the acceptance tests. This is estimated to be the end of July 2005.

This report will briefly describe the installation and commissioning process for both the HVEE and ANSTO components of work. This report will not discuss the detail of the acceptance tests as these have been detailed elsewhere.

3. DEFINITIONS

Accelerator	All components including the high voltage generator, associated beam lines, magnets and other diagnostic and beam shaping elements, control systems and vacuum systems and electrical and signal wiring
Accelerator Operations	The group that manages the operation and maintenance of the ANSTO accelerators. It is attached to Institute of Nuclear Geophysiology
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
Engineering Services	ANSTO Engineering Services
HVEE	High Voltage Engineering Europa
HVG	High Voltage Generator – accelerator pressure vessel
Institute of Nuclear Geophysiology	Former ANSTO Environment
OEM	Original Equipment Manufacturer
STAR	Small Tandem for Applied Research
Tandetron	Commercial name owned by HVEE, representing the charging system used in the high voltage generator

4. LICENCING

A Licence to Site and Construct the accelerator and components was issued by ARPANSA on the 5th July 2002 under application F0134. This enabled all site works, mechanical, electrical installations and the connection of services to be completed in preparedness for the commissioning phase. This work was completed in March 2004. A Licence to Operate the Facility was issued on 24th December 2003 prior to the completion of the construction phase to allow smooth transition into the testing and commissioning phase.

5. DESCRIPTION OF THE FACILITY

5.1 Location

The accelerator facility is located on the lower floor at the western end of building 22 at ANSTO, Lucas Heights. It occupies an area of approximately 250 m^2, including control room, personnel access paths, barriers, storage of OEM and ANSTO supplied parts but not including support laboratories and additional plant, which in some cases supports the general infrastructure for the whole building.

5.2 Accelerator

The "accelerator" is the term given to all parts connected to the high voltage generator by the adjoining beam lines and the control system, including the control room and control devices. In general terms the accelerator consists of a 2MV Tandem style high voltage generator, two ion sources, an Accelerator Mass Spectrometry (AMS) beamline for C14 measurement, two ANSTO designed and constructed beamlines consisting of scattering chambers and beam lines with associated diagnostics and beam shaping components.

6. DIVISION OF WORK

Three main bodies were involved in the installation and commissioning of the overall project.

6.1 High Voltage Engineering Europa

HVEE was contracted to supply, install and commission the accelerator as supplied by them. An acceptance test with parameters agreed to by ANSTO and HVEE was performed after commissioning to allow HVEE to demonstrate to ANSTO that the contracted specification had been achieved. This represented the end of the HVEE installation and commissioning requirements.

6.2 Institute for Geophysiology

Institute for Geophysiology supplied technical management, supervision and direct technical engineering support and various site resources to the HVEE engineers. This came from the core of accelerator expertise already established at ANSTO. The budget for the installation was managed through Institute for Geophysiology on behalf of AINSE.

6.3 Engineering Services

Engineering Services provided resources and supervision and arranged for contract labour to undertake the majority of the civil works. They also provided assistance in the structural design of the concrete support pad and services to the accelerator.

7. QUALITY ASSURANCE

Institute for Geophysiology and Engineering Services maintain quality certification to the ISO 9001:2000 quality standard for their management system. Institute for Geophysiology 's certificate number is QEC12839-08. No specific audits were completed during the installation of the new accelerator however internal audits continued on the Institute for Geophysiology management processes. Compliance with the quality management system was maintained during the process of constructing and commissioning the accelerator. Management of the completed STAR accelerator was included in the Institute for Geophysiology quality procedure ENV-P-076, "Management of the ANSTO Accelerators" from the time that the acceptance tests begun.

8. SAFETY ANALYSIS

A comprehensive Safety Analysis Report, SAC 1677/04 for the STAR Accelerator has been produced and approved by the Safety and Radiation Science, Safety Assessment Committee on the 7th February 2005. It provides details on operational limits and safety design features. It is valid for 3 years or until there is a change or modification that will impact on safety in the facility.

9. CERTIFICATIONS

WorkCover NSW has issued a Plant Design Registration certificate, no. PV 6-57599/03, for the High Voltage Generator pressure vessel under the terms of the regulation for OH&S 2001. An application to have the portable Dilo SF_6 gas handling plant registered is currently being prepared in conjunction with ANSTO Engineering Services Quality Control group. They are responsible for coordinating the periodical inspections of pressure vessels at ANSTO. The HVG pressure vessel was last inspected in March 2005 and certification reissued on the 14-03-05, valid for two years.

10. ENGINEERING DRAWINGS AND DESIGN

HVEE supplied a fully designed accelerator system that required no modification at the site other than adjustments, which are accepted as necessary for fine tuning and to meet local safety regulations.

ANSTO approved the conceptual facility “layout” engineering drawings provided by HVEE on the 20th November 2001. This showed the location and general configuration of the accelerator relative to the building floor plan. A signed copy was posted back to HVEE.

HVEE supplied conceptual drawings (D-9-33-018) of the concrete pad showing external dimensions and integral trench locations. These drawings were provided by HVEE as a guide to meet the requirements as specified in section 5, Accelerator Site in the Installation Requirements and Recommendations manual FR51079 AINSE. Engineering Services contracted Forbes Rigby P/L in Wollongong to provide a structural design based on HVEE’s drawing. HVEE was kept informed of design progress and provided further advice on our requests.

Two copies of all other design drawings for the accelerator have been supplied by HVEE. A review of all electrical drawings has been completed by Engineering Services and a number of anomalies were found. HVEE is responsible for ensuring drawing amendments are completed and copies are re-issued to ANSTO.

Drawings prepared by Engineering Services and Institute for Geophysiology have been drawn to Australian Standards. Copies of drawings prepared by Engineering Services are filed in Engineering Records and Information Services (ERIS). Copies of Institute for Geophysiology internally produced drawings for the STAR accelerator are filed electronically on an Institute for Geophysiology network server.

11. CONSTRUCTION PHASE

A layout of the accelerator can be seen in Appendix 2.

11.1 Shipment and Storage of Accelerator

The accelerator was shipped to ANSTO from HVEE in Holland inside of three 40 foot long shipping containers. ANSTO was responsible for removing the parts from the containers and storing them in building 22, in a "clean and dry environment". On inspecting the shipping container's contents, only one box containing the recombinator was damaged. HVEE engineers later assessed the damage and made repairs and adjustments.

11.2 Concrete Support Base to HVEE Design

To achieve the best results from the accelerator the hardware requires precision alignment and stability. HVEE specified a design for a single cast concrete pad with integral channels cast into it for the services and control lines. Forbes Rigby P/L in Wollongong was contracted to provide the engineering design for the concrete pad and ANSTO Engineering Services provided the supervision of the construction.

The area in building 22 chosen for the new accelerator was previously used as the target area for the 3MV Van de Graaff accelerator beam lines and radiation shielding. The original floor was made up of individual concrete pads approximately 4 x 8 metres in size. The weights varied from less than 500 kg to over 2700 kg. Due to the substantial weight of the shielding and equipment on the floor, the original floor pads had moved and in some cases cracked. Two exploratory holes were made through the concrete floor to determine the footing structure beneath the slab. The findings showed coarse packed rubble over bed rock ranging between one quarter to one half metres deep. The rubble was unevenly compacted across the length of the proposed slab. The structural design provided by Forbes Rigby P/L made allowances for the insufficient footing material by incorporating piers beneath the new pad, to the stable rock under the rubble.

The finished new pad measures approximately 15 x 10 metres, formed in a tee shape, and is flat to within ± 2 mm per 3 metres (from end to end the tolerance remains at ±2 mm). This is better than the specified requirement of ±2 mm per metre. The concrete was cured for 6 weeks and the dryness monitored prior to sealing the floor with grey floor paint.

11.3 Electrical Power and Earthing System for the Accelerator

The earthing system designed by HVEE for the Tandetron accelerator incorporates two separate earth lines for electrical isolation between the accelerator as supplied by HVEE and it's control system. It functions to protect the computer control system and sensitive electronics from high voltage transients that may occur from electrical breakdown within the accelerator's high voltage generator. The hard-wired earth point for both systems physically joins at a substation over 50 metres away from the accelerator. The computer control system uses the building earth, which was upgraded to provide a lower resistance path to earth and has additional earth points, established less than 5 metres away. The length of the earth run from the accelerator back to the substation provides a suitable inductance, which serves to earth high frequency transients.

To isolate the earthing systems HVEE requested that the transformer was not earthed, effectively separating the primary and secondary circuits. To guard against this electrical hazard, the transformer is surrounded by a metal housing, which is linked to the accelerator earth. In this wiring configuration the unearthed transformer does not comply with Australian wiring rules. To overcome this, a Residual Current Device (RCD) has been connected to the primary supply of the transformer in the distribution board. As well, a circuit breaker has been installed to limit the short circuit current.

Administrative controls have been put in place to ensure the two earths are not inadvertently connected together. Labels have been placed at distribution points and notes inserted on key drawings to indicate the differences. A sign has been placed in the supply transformer's housing to warn against reconnecting the earth. Technical staff working in the area have been cautioned about cross connecting portable equipment between earths.

11.4 Reticulated Cooling Water System

The cooling water system specified by HVEE for the new accelerator was an open drain type. ANSTO submitted a proposal to HVEE for a closed loop system that recycles water without exposure to air thus eliminating problems associated with algae. HVEE's main concern with the closed loop system is that to achieve a high enough flow for satisfactory cooling rates the pressure difference between the supply and return lines would be too high for the equipment being cooled leading to possible bursting damage. The pressure difference for the supply line stays the same, but the return line has a raised pressure of about 200kpa meaning that the supply pressure to atmosphere is raised by that amount as well.

ANSTO purchased a closed loop cooling system as recommended by a consultant engineer that would meet the cooling requirements for the accelerator and equipment. The unit chosen meets the cooling capacity specified by HVEE but operates at the higher end of the pressure supply/return differential. The higher continuos load has not created any apparent problems as all fittings used have a substantially higher pressure rating.

HVEE has specified water conductivity levels below 10 µS/cm for the main power supplies based on the manufacturer's specifications and between 100 – 150 µS/cm for all other equipment. Sydney tap water varies from 125 µS/cm upwards and would be considered acceptable for "other" equipment but since there is no distinction in the reticulation system to all equipment so the lowest achievable conductivity is required. This has been achieved by using a conductivity lowing filtration system. The lowering of the conductivity raises the pH of the water so a chemical treatment is used to reduce the pH to neutral value close to 7 or slightly above.

11.5 Supply of reticulated compressed air and gases

Compressed gases and air are used within the facility for a variety of functions. Compressed air is used to operate electro-pneumatically actuated gate valves. Nitrogen and argon gases are used to charge vacuum systems when cycling the pressure from negative to atmospheric values. To eliminate the use of gas cylinders located around the facility a separate gas handling bay has been established outside of the building with the a gas reticulation system installed to pipe the gas to specific user points around the facility. Pressure relief valves are provided at the point of distribution in the gas handling bay and also at some crucial points around the user beam lines. Air pressure regulators are located at points of distribution around the beam lines.

11.6 Sulphur Hexafluoride (SF_6)

SF_6 is used inside of the high voltage generator to increase the insulation between the high voltage terminals and the inside wall of the vessel. Up to 600 kg of SF_6 is stored in either the STAR HVG or the DILO portable gas handling and storage plant. The gas is not toxic however it is an asphyxiant. Oxygen depletion monitors have been strategically located below the ducts in the immediate vicinity of the accelerator to provide warning if there is an SF_6 leak. Leaking SF_6 gas, which is five times heavier than air will displace oxygen thus lowering the concentration which will trip the alarm system. As well, hand held halide detectors have been used to survey for leaks during installation and testing. There have been no recorded leaks of SF_6.

11.7 High Voltage Generator

The resonant frequency used in the oscillator circuit of the high voltage power supply was found to be un-balanced. The capacitance was changed to re-tune the resonant frequency back to the centre of the bandwidth.

12. TESTING AND INSPECTION PROCEDURES/APPROVALS

12.1 Installation and testing of HVEE supplied components was carried out by or supervised directly by, HVEE engineers. The procedures used are those established by HVEE. ANSTO received no information regarding the formal testing methods and/or techniques used during commissioning. ANSTO did however, jointly agree with HVEE on the specification for the acceptance tests used on the fully commissioned accelerator.

12.2 Two sets of acceptance tests were performed by HVEE engineers and directly witnessed by ANSTO staff. As agreed in the contract there was a System Function test and a System Performance test for both the AMS and IBA facilities provided.

13. SAFETY HAZARDS AND MONITORING

Occupational hazards during commissioning included radiation, high voltages, process gases and air under pressure, bump and trip hazards, movement of heavy items.

13.1 Hand held gamma and neutron monitors were used throughout the commissioning of the accelerator. Radiation surveys were carried out under different operational conditions. These were reported to Risk and Reliability section for the risk assessment. A record of surveys is kept for new experimental conditions or when there has been a change. See Appendix 4 for radiation survey information.

13.2 Fixed gamma-ray type radiation monitors were strategically located around the accelerator before the acceptance tests begun. At the high energy end of the accelerator, near the switch magnet there is also a neutron monitor.

13.3 Protection from high voltages has been provided by HVEE. All user accessible systems are engineered with interlocks to isolate power if there is indiscriminate entry. All high voltages were monitored and logged in the control computer during commissioning.

13.4 Safety Events during Commissioning

Both events below were reported to ARPANSA in quarterly reports.

13.4.1 One incidence of excess dust and exhaust fumes occurred during the preparation of the floor in building 22. The original concrete floor was wet cut to minimise dust. To assist in the removal of the cut floor a small excavator was driven into the building to lift the concrete pieces. The building ventilation was not adequate to remove the fumes and dust. Work was stopped while additional ventilation was provided. Safety and Radiation Science monitored the fumes and gave clearance when it was safe to resume work.

13.4.2 During the commissioning of the high voltage generator an internal fault led to external high voltage breakdown on the vessel. Barricades and signs were placed around the vessel to restrict access while fault finding continued. The HVEE engineers made some repairs to the inside of the vessel and external vessel flanges, it was then returned to normal operation. The fault has not returned. ANSTO provided additional earthing to the vessel to improve safety.

14. FACILITY MANAGEMENT

14.1 The operation and maintenance of the STAR accelerator is managed by Institute for Geophysiology through Accelerator Operations in the Accelerator Science project.

14.2 The management system is documented in quality procedure ENV-P-076, “Management of the ANSTO Accelerators”. It is the same system as that used for the other two accelerators.

15. MAINTENANCE PROGRAMS

15.1 Accelerator Operations provides a structured maintenance system based on information and training provided by HVEE. The program is based on preventative maintenance and “improvement actions” that are raised for non-conforming operational issues.

16. SUMMARY OF COMMISSIONED ITEMS

Numbered as identified in the specifications document FR 51079

Basic HVEE ^{14}C-AMS system

The system has performed well above expectations for a complex instrument. A few items have intermittent problems, which are becoming understood but do not provide an immediate safety or health risk. As operational experience develops, it is expected that most of the problems will cease. As of the completion of this document, all devices identified below in this document are functioning correctly and to specification or better.

No.	Item/section	Includes	Changes to specification/modification	Commissioning results	Status
1	^{14}C ion source	Model 846B with vacuum systems and light guides for computer control	Factory set alignment has been changed to improve output from the source. The changes do not increase the hazards of that system.	Tested with HVEE and ANSTO samples. Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete
2	^{14}C Recombinator / Mass Spectrometer system	Recombinator, chopper, steering magnets, various diagnostic and shaping beam line components, vacuum systems, interfaces and light guides for computer control	Electron Suppression on C12 cup was interlocked to cup actuator to remove astigmentation in the beam optics when the cup is in the withdrawn state.	Recombinator has been aligned by HVEE engineers and as a crucial component in the AMS system has been demonstrated to be accurately aligned.	Complete
3	Low energy (LE) beam line	Retractable apertures, faraday cups, Q snout energy matching lens, interfaces and light guides for computer control	HV protective covers will be installed for increased safety at a later date. Current design is adequate but not ideal. A chain of pack resisters was installed between the lower tube segment and the Q-Snout electrode to suppress HV discharge damaging the HV supply.	Q snout power supply developed some intermittent HV faults which were found to be related to electrical connection inside of the accelerator	Complete
4	2.0 MV Medium Current Plus Tandetron accelerator system	Pressure vessel, accelerator tubes, GVM, spark detector, gas stripper, motor gen set, HV P/S, X-ray shielding, vacuum systems, interfaces and light guides for computer control	The drive axel and bearings were replaced. The drive axel was replaced with acrylic components. Special grease packed bearings were used.	Pressure vessel checked and certified by WorkCover. See notes above. X-ray surveys on the sides of the vessel show level above background but below 5µSv/hr maximum. Spark detector has intermittently caused the HV to trip off. All tripping events were associated with known but unexpected causes. All other components have given trouble free operation.	Complete

5	High energy (HE) beam line	Electrostatic quad, 2 x XY steerers, retractable apertures, slits, interfaces and light guides for computer control	One power supply on one set of XY steerers has been modified by the HVEE engineer. The company approved the modification and it does not increase the hazards of that system.	All components meet specification.	Complete
6	^{14}C HE Mass Spectrometer	Analysing magnets, Faraday cups, deflector, apertures, vacuum systems, interfaces and light guides for computer control, degaussing unit for 110° magnet	nil	All components operable and meet specification. Tested with HVEE and ANSTO samples. Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete
7	Final detection system	Ionisation detector, electronics, counting equipment, retractable Faraday cup	Nil	All components operable and meet specification. Tested with HVEE and ANSTO samples. Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete
8	Computer control system	Machines interfaces, overall system and data analysis computer, source control computer	nil	The complete computer control system has operated reliably since installation. No changes have been made to the original system.	Complete

System Extension for Ion Beam Analysis

No.	Item	Includes	Changes to specification/modification	Commissioning results	Status
Positioned before the recombinator					
9	Dual source injection system	Duoplasmatron 358 I/S, vacuum pumping system, interfaces and light guides for computer control	Some operational issues and design modifications delayed the testing of the positive ion side of the I/S. HVEE modified the charge exchange in the Holland factory. This change was verbally agreed to by ANSTO to improve output. (HVEE correspondence 20-1-04) The operation of this device does not create a hazard to the operators or other personnel. The heat exchanger element of the cooling system was upgraded by HVEE.	358N specification test successfully completed on 30-6-03 358P successfully tested during acceptance tests completed on the 30-6-04	Complete

10	Interconnecting Beamline	Aperture, F/cup, XY steerer, Einzellens, vacuum pumping system, light guides for computer control	nil	All components operable and meet specification. Functionally tested during the Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete
Positioned after the recombinator					
11	Interconnecting Beamline	Quad triplet, vacuum pumping system, light guides for computer control		All components operable and meet specification. Functionally tested during the Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete
12	Switch magnet	Switch magnet	Switch magnet P/S intermittently trips off during polarity changeover also causing the accelerator HV generator to trip off. This does not create a safety hazard but it is an operational issue. This was identified by HVEE engineers during the installation phase and is yet to be rectified. Last communication on this issue 14-12-04. ANSTO to provide operational information at the next opportunity.	All components operable and meet specification. Functionally tested during the Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete but requires further development by HVEE
Positioned after the switch magnet At the +10° exit port					
13	IBA Beam line	Slits, BPM, F/cup, Vacuum pumping system, valves		Not in regular use. Functionally tested during the Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete
At the -10° exit port					
14	IBA Beam line	Slits, BPM, F/cup, Vacuum pumping system, valves	Dismantled as it is a redundant beamline. Parts to be used as spares.	Not in regular use. When assembled it was functionally tested during the Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete

At the -30° exit port					
15	IBA Beam line	Slits, BPM, F/cup, Vacuum pumping system, valves	HVEE supplied a beam line but was never used. This beam line was designed and constructed by ANSTO and functionally tested during acceptance tests.	Functionally tested during the Accel. Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete
16	Extension of computer control system	Light guides for computer control		Functionally tested during the Accel. Voltage and Ion Beam Acceptance tests completed on 30-6-04.	Complete
17	Accessories, fittings and tools	Various spare components and special tools for servicing	HVEE tools returned to Holland 21-9-04.	All accessories, fittings and tools were supplied as contracted.	Complete
18	Documentation	Drawings, manuals, other pertinent documents	ANSTO have reviewed electrical drawings and found errors. A list of corrections have been sent to HVEE. Revised drawings have been requested. 23-12-04	2 copies of all electrical and mechanical drawings received.	Complete but revisions are yet to be received.
19	Installation, commissioning and on site testing	Installation, tuning, supervision	Unexpected delays of over 6 months occurred in the final commissioning phase. All delays were related to the development of the AMS system. This was rectified by HVEE engineers.	All components operable and meet specification. Functionally tested during the Accelerator Voltage and Ion Beam Acceptance tests completed on 30-6-04. See notes above relating to responsibilities.	Complete
20	Training of ANSTO personnel	Training of up to 3 persons		2 personnel were trained to operate the AMS system and 2 for the IBA system. 1 person was trained to operate the IBA system as well as maintenance training. A formal training program is now in place. 6 operators now approved. 23-12-04	Complete
21	Gas recovery system	DILO SF_6 gas handling plant	This pressure vessel is yet to be formally certified. Engineering Services are currently assisting in organising certification with WorkCover.	Unit complete and used by HVEE engineers during commissioning tests	Complete pending certification.
22	Insulating gas	SF_6 gas x total 525kg @ 6 Bar Presser		All gas supplied with no loss.	Complete
23	Spare parts for AMS system	6 x sample carousels, 200 blank cathodes		All components supplied	Complete

Additional Items ANSTO content

No.	Item	Includes	Changes to specification/modification	Commissioning results	Status
a	Shipment and storage of equipment prior to HVEE engineers arriving	Storage in cool dry environment	ANSTO suggested to HVEE that the 3 shipping containers that the accelerator arrived in should be unpacked as the temperature inside may have been in excess of 40°C. HVEE agreed (email dated 24-10-02)	Some items found to be damaged during shipment. These have all been replaced by HVEE and are now in use.	Complete
Accelerator site as described in the Installation Requirements and Recommendations manual					
b	Preparation of site for new concrete slab	Clear away redundant beam lines and shielding for old accelerator	nil	Area cleared and inspected by S&RS.	Complete
c	Construction of the concrete slab	Engineering design to HVEE's layout plan, remove old slab, construct new slab, paint	Modification of HVEE design to allow for wider and deeper trenches for the services.	Slab completed and finished to ± 2 mm over the length of the slab (>8m). This exceeds the specification of ±2 mm per metre. Painted. Approved 1-4-04	Complete
d	Electrical services	All power required for the installation and operation of the facility	Power test of the supply transformer supplied by HVEE failed. HVEE were informed that we would have it repaired in Australia on 25-8-03. HVEE agreed to the repair on the 27-8-03. Sent for testing but found okay. Fault with wiring at site corrected.	Electrical installation meets Australian Standards	Complete
e	Grounding system	All power grounding required for the installation and operation of the facility to HVEE requirements and additional ANSTO requirements to Australian Standards.	Existing earths tested on 17-9-02. All within specification however further earth points were established in the building stations near the accelerator.	Dual earth points back to substation 5. Earth runs assessed to be long enough to dissipate transient voltages to earth.	Complete
f	Compressed air	All compressed air required for the installation and operation of the facility	nil	Argon and Nitrogen reticulation system installed and tested okay. Pressure relief valves installed cylinder supply point.	Complete

g	Cooling water system	Plant as described in the manual, Installation requirements and recommendations	HVEE requested an open drain system, which is inherently problematic with algal contamination and water wastage. A closed loop system has been installed that was assessed by the HVEE during the accelerator installation.	Plant provides cooling within the specification.	Complete
i	Ion source materials	Helium, hydrogen, regulators, caesium, lithium and cathode coating	nil	All materials supplied and stored to Australian and local (ANSTO) standards and regulations.	Complete
j	Accelerator process gases	Argon, nitrogen, isobutane	nil	All gases supplied and stored to Australian and local (ANSTO) standards and regulations.	Complete

k	safety	Management	Integrated into the management of the existing 2 accelerators at ANSTO	Safe operation of the accelerator is managed through the processes documented in the Institute for Geophysiology procedure, ENV-P-076, Management of the ANSTO Accelerators.	Complete
l	radiation	Fixed radiation monitors	Fixed radiation monitors have been installed at points recommended by HVEE	Radiation surveys made under the requirements identified in the procedure, ENV-P-076, Management of the ANSTO Accelerators. Monitors routinely calibrated at ANSTO	Complete
m	Dangerous voltages	High voltage equipment including HVG, ion sources, steerers and Einzel lenses	No change. ANSTO will be installing bump barriers around power supplies that protrude from the beam lines into the passageways.	All equipment once conditioned operates to specification	Complete
n	Vacuum exhaust system	Ventilation system to remove vacuum pump vapours directly from the pumps	An exhaust fan has been installed to create a slight negative pressure within the ventilation tubing. It exhausts to the plant area on the south western end of the building	Pump operational.	Complete
o	Test equipment	Test equipment requested by HVEE included oscilloscopes, signal generators, frequency counters, HV probe, SF_6 (halide) detector, helium leak detector, 500V megger, radiation detectors	Not all equipment was used. The equipment used was for the purpose of functional testing and course calibration. HVEE was responsible for using other techniques and equipment to calibrate for commissioning purposes.	See final Acceptance Tests	Complete

17. ACKNOWLEDGMENTS

The author would like to thank the High Voltage Engineering Europa engineers who provided the expertise to install and test the 2.0 MV Tandetron Accelerator. The author is also indebted to Adam Sarbutt, David Button, Kevin Thorpe and Steve Gatt for their technical expertise utilised during the assembly and testing phases of the installation. This project was made possible by the collective efforts and dedication of all Accelerator Operations technicians and support from ANSTO Engineering.

18. REFERENCES

18.1 HVEE Installation Requirements and Recommendations, A-4-35-175-0006-51079

18.2 ENV-P-076, Management of the ANSTO Accelerators

18.3 HVEE supplied conceptual drawings (D-9-33-018)

19. APPENDICES

19.1 Appendix 1 - ANSTO Engineering Memorandum, Independent earth system for HVEE 2MV accelerator

19.2 Appendix 2 - Layout of the STAR Accelerator and beam lines

19.3 Appendix 3 - Summary of the Acceptance tests of the Tandetron Accelerator at ANSTO System (STAR)

19.4 Appendix 4 - Copies of Radiation Surveys

19.1 Appendix 1

ANSTO Engineering Memorandum	Job No. 0110E-1-2	Index No.
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Subject: **Independent earth system for HVEE 2MV accelerator**	Date 20/9/02	Time

To:	From:
David Cohen David Garton	Ron McCann

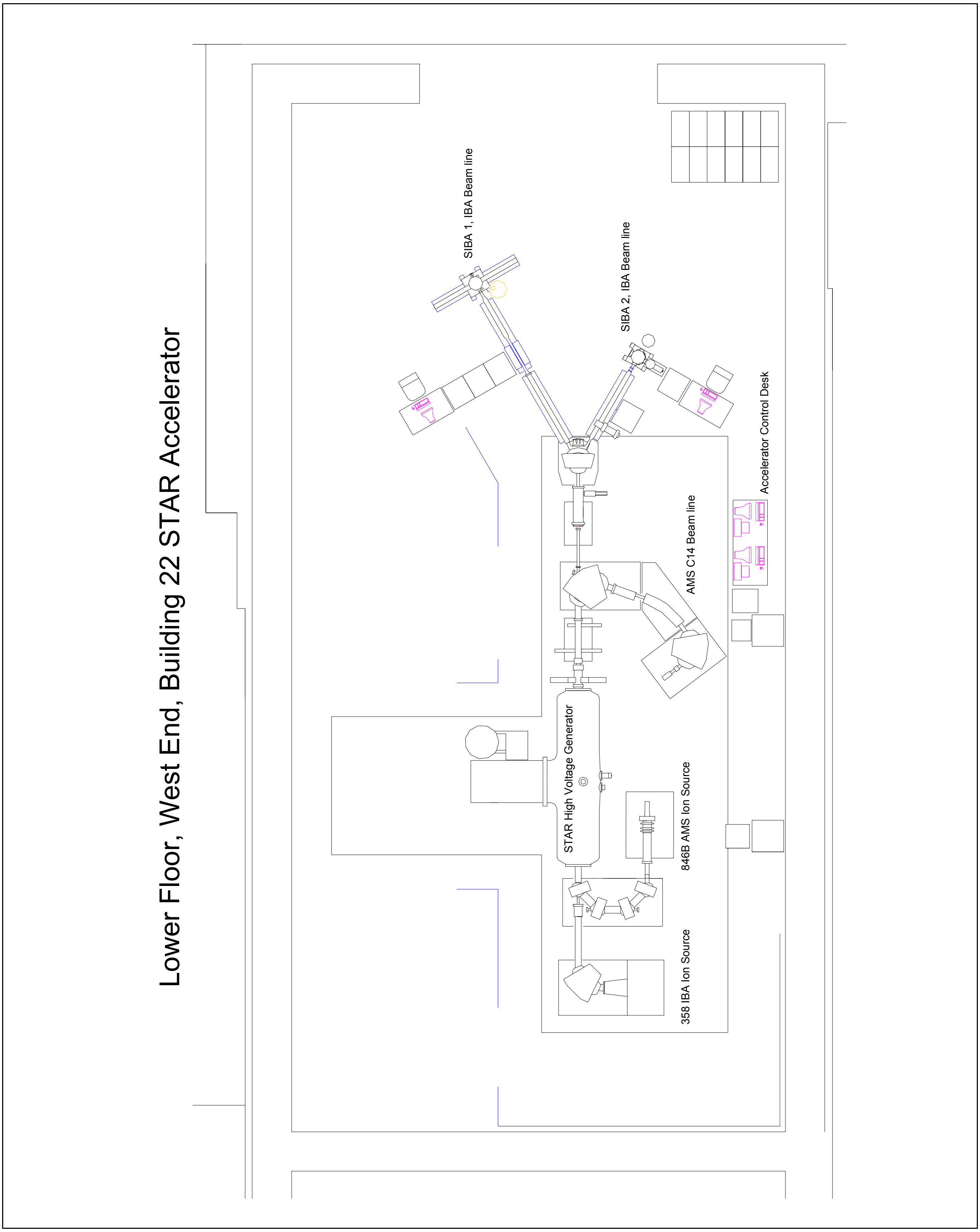
Item No.	Details
1.	An earth bonding resistance check was carried out on Tue 17/9/02 by Connect Engineering Pty Ltd using a YEW Type 3235 tester with electrodes placed at 20m and 40m from the earthing point. The measurements were taken following some sporadic overnight rain showers.
2.	The test was carried out on: i) The copper water pipe at the NW corner of Bldg 22 for which the earth bond resistance measures as: **0.38 Ω** ii) The building column located inside Room 12 for which the earth bond resistance measures as: **0.21 Ω** iii) The building column located in Room 12 annex close to the Bldg 22 Main Distribution board for which the earth bond resistance measures as: **0.23 Ω** iv) The building column located inside Room 13 for which the earth bond resistance measures as: **0.22 Ω**
3.	These columns are placed ~4m apart but the depth below floor level is not yet known.
4.	The resistance between the building columns and the power earth-to-neutral link in the Main Distribution board has yet to be measured to establish the degree of “independence” of these earth connection points.

Prepared by: Ron McCann Signature:	Copied to: Adam Sarbutt

Form E F 5.8.1.2 Rev. B 25/11/93

19.2 Appendix 2

Layout of the STAR Accelerator and beam lines



19.3 Appendix 3

Summary of the

Acceptance tests of the Tandetron Accelerator System (STAR) at ANSTO

The following acceptance tests were agreed upon by responsible people of both ANSTO and HVEE for the STAR Tandetron Accelerator. The tests were divided into two parts, those for IBA and those for AMS. The Ion Beam Analysis (IBA) performance tests were performed on May 31 (for Hydrogen) and June 1 (for Helium) and the Accelerator Mass Spectrometer (AMS) performance tests on June 10, June 11 and June 30.

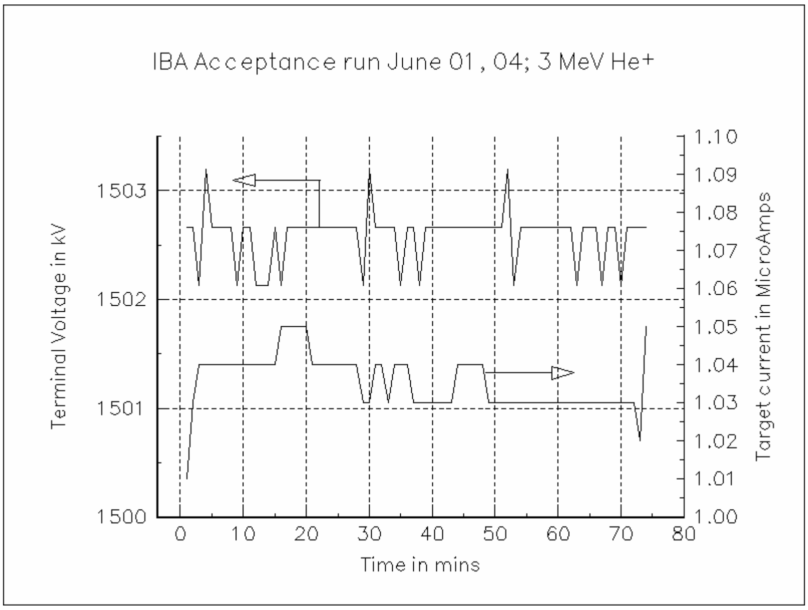
Results of the IBA acceptance tests

	Hydrogen				Helium					
	600 keV		3 MeV		600 keV		3 MeV		5 MeV	
	Meas	Spec	Meas	Spec	Meas	Spec	Meas	Spec	Meas	Spec
Current (μA)	13.0	5.0	14.0	10.0	1.05	1.0	1.04	1.0	2.55	1.0
Beam size FWHM (mm)	1.5	1.5	0.7	1.0	1.8	3.0	1.0	2.0	0.7	1.0
Stability (%)	0.8	5.0	3.5	5.0	5.0	5.0	1.9	5.0	3.0	5.0

Table 1: Measured and Specified beam performance on H and He, measured at the end of the 10 deg. beamline.

Table 1 compares the measured parameters versus the specification values for beam current, beam size and beam stability. The results were evaluated using a range of conditions close to the expected operational conditions.

It was demonstrated that all parameters have easily been exceeded. The figure below is an example of terminal voltage and target current stability. It was collected during ~1 hour at 3 MeV using a He^+ beam. The current was measured in a 10° beamline faraday cup.



Results of the AMS acceptance tests

Three tests were performed on 3 different days. ^{14}C and δ^{13}C were measured in each of the following samples and the results and tabled below.

	Day 1	Day 2	Day 3
Large OX1	5	5	5
Large OX2	5	5	5
Small OX1	5	3	3
Very small OX1*	4	3	1
UPCG	3	2	3

* Samples loaded in a smaller 1mm-diameter cathode

1. **Acceptance Criteria:**
   There were four agreed acceptance criteria:
   - 110 Hz counting rate for modern samples
   - 0.5 % precision and accuracy for ^{14}C concentration in large modern samples
   - 0.15 % precision and accuracy for □^{13}C values in large samples
   - Maximum machine background of 0.1 pMC.

2. **^{14}C Concentrations**
   (acceptance criteria 0.5 % precision and accuracy for ^{14}C concentration in large modern samples)

   Results for large OX2 cathodes (should be 135):

Day 1		Day 2		Day 3	
Cathode	14C concentration	Cathode	14C concentration	Cathode	14C concentration
L195	134.73 ± 0.44	L064	134.34 ± 0.50	L323	134.44 ± 0.48
L196	134.97 ± 0.42	L065	134.59 ± 0.38	L324	134.49 ± 0.51
L197	135.02 ± 0.71	L069	134.52 ± 0.48	L325	135.15 ± 0.47
L198	134.82 ± 0.40	L072	134.22 ± 0.38	L326	134.94 ± 0.43
L199	135.36 ± 0.40	L200	134.43 ± 0.66	L327	134.89 ± 0.58

   Results for small OX1 cathodes (should be 104.6):

Day 1		Day 2		Day 3	
Cathode	14C concentration	Cathode	14C concentration	Cathode	14C concentration
L207	104.31 ± 0.36	L206	103.92 ± 0.54	L212	103.75 ± 0.37
L209	104.96 ± 0.65	L208	104.53 ± 0.35	L213	104.38 ± 0.36
L210	104.27 ± 0.46	L215	104.46 ± 0.48		
L211	104.12 ± 0.47				
L219	104.12 ± 0.41				

   Results for very small OX1 cathodes (should be 104.6):

Day 1		Day 2		Day 3	
Cathode	14C concentration	Cathode	14C concentration	Cathode	14C concentration
L010	104.40 ± 0.49	K987	104.48 ± 0.48	L008	104.54 ± 0.50
L071	103.47 ± 0.45	L002	104.41 ± 0.48		

L073	103.61 ± 0.63	L072	105.59 ± 0.38		
L074	105.42 ± 0.40				

Results for large UPCG cathodes (should be < 0.1):

Day 1		Day 2		Day 3	
Cathode	14C concentration	Cathode	14C concentration	Cathode	14C concentration
GC16	0.022 ± 0.007	GC21	0.028 ± 0.006	GC20	0.017 ± 0.005
GC17	0.019 ± 0.008	GC22	0.012 ± 0.005	GC24	0.009 ± 0.008
GC18	0.023 ± 0.008			GC25	0.015 ± 0.005

3. □^{13}C

(Acceptance Criteria 0.15 % precision and accuracy for □^{13}C values in large samples)

Results for large OX2 cathodes (should be –17.8):

Day 1		Day 2		Day 3	
Cathode	13C concentration	Cathode	13C concentration	Cathode	13C concentration
L195	-16.92 ± 0.66	L064	-19.66 ± 0.54	L323	-16.99 ± 0.30
L196	-19.34 ± 0.50	L065	-17.84 ± 0.56	L324	-17.54 ± 0.23
L197	-18.21 ± 0.45	L069	-17.42 ± 0.54	L325	-17.26 ± 0.33
L198	-18.11 ± 0.54	L072	-19.14 ± 0.48	L326	-17.72 ± 0.23
L199	-17.82 ± 0.57	L200	-18.60 ± 0.58	L327	-16.96 ± 0.24

Results for small OX1 cathodes (should be –19):

Day 1		Day 2		Day 3	
Cathode	13C concentration	Cathode	13C concentration	Cathode	13C concentration
L207	-19.52 ± 0.53	L206	-21.83 ± 0.78	L212	-19.24 ± 0.42
L209	-19.00 ± 0.71	L208	-20.74 ± 0.64	L213	-20.44 ± 0.58
L210	-18.38 ± 0.69	L215	-19.23 ± 0.64		
L211	-18.70 ± 0.58				
L219	-19.81 ± 0.64				

Results for very small OX1 cathodes (should be –19 + possible fractionations in the graphitisation):

Day 1		Day 2		Day 3	
Cathode	13C concentration	Cathode	13C concentration	Cathode	13C concentration
L010	-23.06 ± 1.38	K987	-17.54 ± 1.61	L008	-22.50 ± 0.55
L071	-20.51 ± 1.26	L002	-19.67 ± 1.46		
L073	-22.58 ± 1.24	L072	-10.06 ± 1.22		
L074	-17.26 ± 1.15				

Results for large UPCG cathodes (should be –7.8):

Day 1		Day 2		Day 3	
Cathode	13C concentration	Cathode	13C concentration	Cathode	13C concentration
GC16	-7.26 ± 0.63	GC21	-3.56 ± 0.83	GC20	-7.42 ± 0.27
GC17	-7.61 ± 0.57	GC22	-6.99 ± 0.77	GC24	-7.95 ± 0.34
GC18	-6.73 ± 0.58			GC25	-7.80 ± 0.32

4. Summary:

For each day this table shows:

- number of cathodes that obtained the required 0.5% precision for the ^{14}C concentration (large OX2 and small OX1)
- number of cathodes that are within one sigma of the accepted ^{14}C concentrations and □^{13}C values.

The acceptance criteria is passed if at least 2/3 of the cathodes are within specifications.

	Day 1	Day 2	Day 3
110 Hz	Yes	Yes	Yes
background	Yes	Yes	Yes
^{14}C precision	8/10	7/8	7/7
^{14}C accuracy	9/10	4/8	6/7
□^{13}C accuracy	12/13	5/10	10/10
Acceptance test	**Yes**	**No**	**Yes**

<u>The AMS acceptance test should be considered as achieved.</u>

19.4 Appendix 4 - Radiation Surveys

Radiation Survey Report for the STAR accelerator

Radiation surveys are completed as a step in the control of radiological hazards for the ANSTO accelerators. For each new set of accelerator operating conditions or when there is substantial change in the routine operating conditions, it is necessary to complete a new radiation survey.

The STAR accelerator was commissioned in July 2004 and since has undergone various stages in testing and routine usage. During these stages most of the routine formats of operation have been defined and radiation surveys completed. The attached lists show these radiation surveys for both gamma and neutron radiations during routine operations.

The surveys record radiation as measured from the predefined locations represented on the diagram. To establish these locations, extensive radiation measurements were made by ANSTO staff during the testing and commissioning stages, along the entire length of the accelerator and adjoining beam lines and components. These selected points represent the areas that are most likely to produce measurable radiation above background levels and also areas that are most likely to be frequented by staff during accelerator operation.

All measurements are in μSv/hr and taken at 1 metre from the predefined “point of contact” measurement points. TV = Accelerator Terminal Voltage.

Date	Time	TV (MV)	Particle	Gamma									Neutron								
				1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
[1] 22-7-03	14.20	1.5	H+	0.3	0.31	0.31	0.18	0.18	0.18	3.2	3.0	1.5	-	6.0	-	-	-	-	-	20.0	10.0
[1] 21-8-03	15.30	1.0	H+	-	0.9	-	-	-	-	22.0	-	0.15									
2-11-04	14.45	1.3	H+	0.15	0.18	0.13	0.11	0.16	0.10	0.3	0.9	0.3									
31-12-04	11.45	0.43	H+	0.3	0.12	0.3	0.25	0.25	0.2	0.18	-	0.05									
21-2-05	12.00	2.0	C14	0.2	0.1	0.2	-	-	0.2	-	-	-									
23-3-05	10.00	1.0	He+	0.1	0.2	0.2	0.3	-	-	0.3	-	0.2									
6-4-05	10.00	1.3	H+	0.1	0.1	0.2	0.2	-	-	0.2	0.2	-									
1-7-05	11.00	1.3	H+	0.1	0.2	0.1	0.2	-	-	0.1	0.2	-									
19-7-05	10.30	1.95	C14	0.17	0.22	0.23	0.16	0.16	0.26	0.22	0.2	0.22									

Notes:

1. *These measurements were conducted during commissioning tests and do not represent routine operating conditions. As well some materials used in the manufacture of certain beam deflecting and collecting components were changed to minimise radiation production. The ion beam current used in these experiments was up to 70 times higher than the currents used in routine operation.*
2. *Some gamma measurements have not been recorded, as the measurement points do not relate to equipment in use for that operation.*
3. *Neutron measurements not made as routine operating conditions are generally below the threshold for producing neutrons.*
4. *Gamma radiation is near background levels at all measurement points. As per management procedures for the accelerators, additional radiation measurements are made if there is a change to the “normal” operating conditions or when it is necessary to work adjacent to the accelerator vessel whilst ion beams are accelerated.*