AUSTRALIAN NATIONAL UNIVERSITY

DEPARTMENT OF NUCLEAR PHYSICS

14UD TANK OPENING REPORT NO. 9

September 20th - October 19th, 1977
(21 working days)

The tank was last closed on August 19th after an unscheduled opening because of a broken chain. The machine ran well during the month from that time to this scheduled opening, and there was no recurrence of the high lost charge, the diagnosis and apparent cure for which were described in Report No. 8.

This tank opening was scheduled for several reasons: a foil change was needed; the machine was running on two chains, and the replacement had arrived; the shaft bearings had run for their typical lifetime; a set of A.N.U. shorting rod contacts, Type 2, was ready for installation. Additionally, it was believed that the limit on terminal voltage would be raised if the column was thoroughly cleaned; however, there would be little point in this unless the original heater plate leads, of rubber covered welding cable, were removed entirely since they are highly susceptible to spark damage and have been a continual source of fragments of charred rubber.

Accordingly, a long shutdown of four weeks was scheduled.

PRELIMINARY TESTS:

At the end of the experimental schedule two days were set aside, before the tank opening, for conditioning and voltage tests in order to determine the upper voltage limit before the thorough cleaning. The tank pressure was 80 p.s.i.a. At 12.76 MV the machine would run with only occasional sparks, some tank, some column, few tube, if any at all. The value 12.76 MV was accepted as the upper limit of the terminal voltage and the gas was taken out.

Once in the tank the terminal was left closed and every casting cover removed and taken outside. Some covers, on the opposite side of the column to the shafts, and where there are no idlers, have probably never been removed since installation. In one casting was found a length of six pellets of the first chain break in October 1975. An occasional newer pellet was found in random castings. From various castings distributed over the column, a useful collection of nuts, bolts, screws and washers was recovered, some obviously dating back to installation days when they had been carefully set aside.

HEATER PLATE TRANSFORMERS IN THE CASTINGS:

Every heater plate lead was disconnected carefully from the feedthroughs. The transformers, each with six heavy leads, were taken out. In every case the two leads which had been in use for the local heater plate were charred and spark-damaged at their point of entry into the casting where all six leads were tightly bunched to pass through the hole. Each hole was itself blackened and a little pile of charred rubber dust was found at the back of each transformer. Other leads, which had been strapped back against possible use to feed the intermediate heater plates, had many bad spark damage patches and the 80-odd leads removed exhibited a substantial total volume of eroded insulation which had been thrown onto the column at one time or another. It was noted that, in some cases, the crimped terminals were either loose enough to be tugged off without much effort, and in many cases there was discolouration at the crimp, implying relatively high contact resistance.

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The heavy, half-turn copper bar secondaries were cleaned and polished with a power driven brush and T-shaped copper conductors, nickel plated, were attached in such a way that the tops of the T parallelled the three secondaries, while the stems of the T projected through the holes in the castings to be joined by copper straps to each heater plate. The straps had been bent roughly to shape beforehand and were then individually tailored by twisting and bending so as to impose no stress on the individual heater feedthroughs. These are traditionally believed to be highly susceptible to leaks if knocked, or roughly handled. Either because they are more rugged than believed, or because our handling has been nervous and meticulous, no leak on a feedthrough has yet been detected. Of the photographs enclosed one shows a transformer fitted with the T-pieces, together with a typical original lead showing a burnt patch where the lead passed through the hole in the casting; another photograph shows a transformer installed, with new bare copper straps to the heater feedthroughs. By parallelling the secondaries in the casting, and feeding through massive leads in form of the stem of the T, the option to add temporary leads to the intermediate heater plates has been provided for. Report 8, page 3 describes the initial concept and the tests made on a casting transformer.

When the shafts were run currents were measured in all the heater plates; the values were generally 130-140 amps compared with 110-120 when the original leads were in use. The difference is held to be due to better contact. The new leads are made up of two straps of bare copper, 5/8 inch wide and 1/16 inch thick laid together, annealed and cleaned at the contact area before fitting. The leads were first fitted onto the heater plate and then tightly strapped onto the transformer T in such a way that no stress is transmitted along the lead to the heater plate.

CLEANING:

With all casting covers off, transformers out, no damaged and flaking leads remaining to re-contaminate as soon as the cleaning is completed, a very thorough cleaning was possible. Earlier cleaning has been by vacuum cleaner and brush, sweeping dust and particles towards the vacuum hose; this time a modified technique was employed. A long hose was dangled into the tank, with coverage over the whole height, and connected to the pressure line to the liquid nitrogen storage vessel. At the output end on the platform a thin copper tube directed a jet of gas towards a large plastic funnel on a vacuum cleaner hose. Dust disturbed by the jet was thrown back in the general direction of the collecting funnel. The fineness of the jet allowed each electrode on every tube and post to be blown out individually. The jet could be inserted into each casting cavity and the dust ejected either taken up by the vacuum funnel or blown off the column into the surrounding air; a fan at the top tank door was blowing inwards and another at the bottom was sucking outwards; it was hoped that good enough throughput would exist to generally take displaced dust out of the tank, though it was accepted that local dust at the higher floor might be blown into the tank. An air filtering system, and more powerful fan, are planned for the near future.

While this procedure was being carried out it was noticed that one cavity continued to produce dust even after thenitrogen jet had been inserted for a long time. When the cavity was examined with a good light it was discovered that a build-up of compacted sand lurked deep inside; this clearly went back to when the casting was made. The sand was caked an inch or more thick and, when jabbed with a steel rod, lumps of the size of a golf ball were broken off and hooked out. Eventually the entire cavity was cleaned so that no further sand could be either seen or blown out. The cavity was one of the narrow ones which carry the tube alignment rods and are covered across most of the front by a stainless steel plate which supports the alignment rod; these plates were already fitted when the castings arrived for installation. All other alignment rod cavities were examined and similar cases found. The sand had

to be broken up by hammering a thin steel rod to chip off lumps which were raked out as they fell, and the process became known as 'mining'.

'Mines' were found randomly along the column, predominantly in the alignment rod cavities, but occasionally in others. They were excavated carefully, but much of their produce fell onto lower levels of the column whichhad already been laboriously cleaned twice. Since no hope of a clean column could be entertained while such mineral resources existed, 'mining' fever became rife and every cavity in every casting was inspected with great care. Because of the difficulty of shining a suitable light into the depths of casting recesses it was suggested jokingly that miners' lamps should be used. Then the idea seemed to have merit and two such lamps, which can be strapped to the head, were bought and tried out. No such single blessing has yet been introduced to the 14UD because the lamps leave both hands free, the worker can look into casting recesses, detect dust on castings and the tube, check points, adjust inductors, and also crash the headlamp instead of the head on the top column cross members when working near Unit 1.

Eventually all mines were discovered, some 15 in all, varying from rich to sparse. In all cases the sand disturbed was the same as the particles which have endlessly appeared on the floors of the units, and been vaguely attributed to 'casting sand' without any real clue as to its origin.

It is warmly recommended that newcomers to such castings should have them meticulously inspected and cleaned outside the tank before installation.

Two more cleaning runs were made over the entire column, making four in all. On the last of these, after blowing and vacuum cleaning, the top and bottom of each casting was washed in alcohol, then cleaned with a Tac-Rag. For the first time the final clean of the rings and the terminal spinnings was with a Tac-Rag. The inside wall of the tank was wiped experimentally with a Tac-Rag; a good deal of dirt came off on the Tac-Rag and the wall was noticeablly cleaner. The remaining Tac-Rags were used to wipe the wall in the centre of the tank.

Immediately prior to button-up one more run was made down the column, blowing at the ring screws and at any dust which had settled on the castings.

CORONA POINTS:

The length and sharpness of the tube and column points were considered acceptable; not one point in the machine had failed. However, in view of the thorough cleaning intended, it was decided to change all points because of the sticky brown deposit which always forms on the assemblies and holds dust.

A complete set of new points, tube and column, was installed and the assemblies taken out were stored with a view to putting them back in time of need.

Corona point assemblies have hitherto been received from N.E.C. pinned by their needles on sheets of styrofoam. Inevitably tiny particles of this substance cling to the assemblies. The styrofoam sheets themselves, which crumble easily when handled in the tank, are a prolific source of undesirable particles. With this delivery it was noticed that N.E.C. had encased each styrofoam sheet in a sealed polythene bag before pinning on the column points; the tube points came as usual on bare styrofoam. We enclosed a set of styrofoam sheets in polythene and transferred every new tube point onto these before taking them into the tank; moreover since it was seen that almost every assembly had some styrofoam adhering to it, usually in the fixing screw holder or in the alan (or star) head of the screw itself, each assembly was held over a vacuum cleaner and picked clean with a dental probe.

CORONA TRIODE NEEDLES:

The needles were in good condition and the mushroom, which had been drilled with holes (Report No.8, page 3), was checked to see if there was any discolouration or other effect. The entire system was clean and the troubles with excessive lost charge are assumed to be over.

CHAINS:

The replacement chain was installed after appropriate alignment of the pulleys which were taken out after the chain break. After hanging for a day or so the new chain had stretched noticeably and was shortened by two pellets.

The other chains were examined. They were more wet with oil than usual when we first went into the tank and both oiler reservoirs were empty, though oiling had been rare. It was concluded that the oiling system had failed in some way and distributed excess oil.

All idlers were checked, with the usual crop of unsatisfactory, though workable, bearings. Again one of the contact springs in a d.c. idler had to be replaced.

SHAFT BEARINGS:

Again, after about 4,000 hours, most of the shaft bearings were noisy. They were all removed, inspected and renewed. It was noted that, in general, the lower of the pair of bearings became noisier before the top one. In addition there is evidence of spark damage on the outer races. The lower bearing is "more exposed" than the upper one.

In operation the only way for the voltage on the metal shafts in the alternators to accommodate themselves to the local potential is to pass current through the balls. The shafts are on surfaces which accumulate charge, as distinct from the bearings in the main alternators and motors. Our present hypothesis is that this gaussian surface exposure destroys the bearings. As a test carbon brushes have been installed across one alternator and a spring to short out the rubber flexible joint.

At the next occasion when bearings are noisy, expected at about April, similar brushes will be installed in the remainder of the alternators.

The midsection alternator key and keyway were worn to the point where half of the key was reduced to rust dust. In our view this is due to the inadvisable practice of having the grub screws bear on the shaft opposite the key rather than on the key itself. This was rectified in the remade coupling. In addition a slot was cut in the casting to allow for almost the full length of alternator shaft instead of the severely circumcized one regularly installed.

THE NEW HIGH ENERGY STRIPPER:

All rings were dropped from Unit 19 and the N.E.C. components of the false floor, which will enclose the new stripper, were assembled as a dummy run in what is now the lowest tube position. The 19 MeV casting was marked and drilled and the positions of the new stripper unit, the additional ion pump and power supply and the new foil counter were determined. The nearest viewing port is about 53 inches below the proposed position in Unit 19 and the T.V. camera will have to look up at an angle of 30 degrees to the counter and pump metering. After appropriate measurements the new assembly was dismantled and removed.

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STRINGERS (Tube to column d.c. connections)

During the voltage tests carried out on the column during the last tank-opening, (Report No.8, page 3), it was noted that corona occurs from the stringer wires, towards the terminal, before, or at the same time as it is initiated on the column and seems to perform as a third corona path. Because the stringers are known to protect the tube points it was decided to try to determine whether the protection arose from the third corona path by eliminating it; in order to achieve this the 0.030 inch nickel stringer wires were removed from the three units on each side of the terminal and replaced by ¼ inch aluminium rods.

A high voltage power supply was taken onto the platform and connected across the first tube section in the H.E. column. The test voltage was run up in darkness and corona was clearly seen on both tube and column, but not from the new stringers. The test was repeated on the third tube section of the same unit. In each case 45 kV was reached before breakdown.

The effect on local points will be noted as time goes by.

NEW CHAIN GUIDE:

A new chain guide, to perform the function of casting idlers, was tried out in the 'down' position in the lowest casting where there are idlers. The device, essentially a flared nylon tube about two inches long, and quite loose around the chain at the centre, had no moving parts. It was fitted in two halves, hence removable without parting the chain; it was attached to the original idler supports and could be aligned in the same way as conventional idlers.

When the device was tested, by running the chain for a minute or two, and observing performance, there was some bit of metallic clatter and significantly more ripple along the chain than for the N.E.C. idlers when they are adjusted to the closeness originally advised.

When removed, the sleeve was scarred by the chain screw heads.

FOILS:

The foils were changed, again without leaks or problems with the A.N.U. double-acting valve which isolates the stripper volume from the L.E. and H.E. tubes. Roughing and pumpdown after the change is affected by vacsorb only.

SHORTING ROD CONTACTS:

Because of serious spark damage the N.E.C. leaf-type shorting rod contacts originally supplied were removed in October 1974 and were replaced by an A.N.U. version involving springloaded metal rollers, contoured to fit the surface of the rods. A number of these rollers seized and a second version, using a stiff leaf, was fitted and mentioned in the first (but unnumbered) A.N.U. Tank Opening Report of February 2nd, 1976, and also in Report No.3, page 5.

Both types continued to give trouble and a new type of contact was devised; this consists of a phosphor bronze spring slipped into a circular housing so that it becomes a toroid, each turn of the coil contacting the shorting rod as it passes through the centre. All the earlier A.N.U. contacts were removed and the new version was fitted throughout the machine.

MISCELLANEOUS

1) The alternator in Unit 7 was found to have its winding open circuit. A spare winding was put in.

2) The heater plate in the bottom terminal has a high resistance and draws only 30 amps. This is the only heater plate in the machine drawing less than 100 amps.

3) When the terminal sublimer switches were re-installed with pneumatic operation they were fixed to the ceiling of the upper terminal by plastic-covered metal brackets designed to hold PVC storm water pipes; in order to make the brackets fit tightly onto the switches a 2-inch length of water pipe was used on each switch as a spacer. It was discovered that, even though both the brackets and the switches were grounded, the PVC pipes were pierced and burnt through in a number of places by sparks. Some of the PVC had crumbled away and many crumbs were found in the terminal. The covering was removed from the brackets and good d.c. contact arranged between them and the switches.

4) A small amount of machining was carried out on the housing of the GVM to remove about 0.008 inch play in the distance between the vanes and the terminal.

5) Several alignment rods were found to be loose, or off-centre on the tube. There was substantial spark erosion where the rod was nearly touching the tube. The loose rods were reset with the hope that there has been only negligible displacement of the tube. Unfortunately one of the cases was at the L.E. tube entrance and a careful optical check of this will have to be made at the next opportunity.

SOURCES

Both lithex and sputter sources have been in use and have functioned without trouble. No modifications have been made since the last report.

MACHINE PERFORMANCE AFTER BUTTON-UP

The 14UD was first run up to volts very successfully. No conditioning was apparent until 12.25MV and no sparks until 12.4MV. After previous tank openings the first sparks usually occurred at 10MV. During 14 hours of conditioning there were 24 sparks and the terminal achieved 13.8MV. This should be compared to a maximum stable voltage of 12.77MV just before the tank opening and it is felt that the performance amply justifies the alterations made and the meticulous cleaning carried out.

Following a tank spark at 13.8MV the stable operating voltage regressed to about 13.5MV. This limitation was traced to the L.E. end of the machine.

Although various combinations of less than 12 units can quite easily be conditioned to more than 1MV per unit, the stack as a whole has not achieved this. Tank pressure during these tests was 90p.s.i. absolute. Electron sources discovered subsequently in the L.E. tube have encouraged us to condition with the L.E. shaft off; this process is still underway. Units 3 to 14 behave at 12 MV in a similar way to the whole 14 units near 14MV. This is being investigated further.

THOUGHTS ON ELECTRON SUPPRESSION

Observation of machine conditioning after button-up highlighted the problem caused by electrons in the L.E. tube. Following a suggestion by Tom Aitken, of Daresbury, we looked for evidence of electron escape from machine pumps. It

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was first found that electrons from the heater filament of the midsection sublimer were entering the tube, causing X-rays and releasing positive ions in the tube. The X-rays were detected by a 5" x 4" NaI crystal in the tower opposite the terminal. The positive ions were seen as current on the back of the faraday cup at the entrance to the L.E. tube.

When the midsection sublimer was run at 30 amps the flux of X-rays greater than 1 MeV increased from 4K to 30K per second with 12.7MV on the terminal; at the same time the lost charge increased from 7 to 18 microamps and the positive ion current increased from 1.3 to 30 nanoamps. With sublimers off the positive ion current dropped to 0.03 nanoamps, which is consistent with system leakage. The X-radiation came in bursts at 330 cycles per second, which is the mains frequency of the accelerator.

The sublimer pellets are not optically shielded from the entrance to the tube pumping manifold, but there is a grounded grid across the hole.

With the midsection sublimer off, and the upper shaft on, there remained a 330 cycle radiation signal of about 600 KeV; through the use of shorting rods this signal has been traced to emission from heater plates in castings 10 and 11. These plates have the relatively low current of 115 amps compared with around 130 - 140 for most of the others. Presumably there is high contact resistance between the current feedthroughs and the plate, giving rise to local heat which is sufficient to emit electrons. There is no evidence of radiation due to the midsection triode pump.

These problems necessitate the consideration of electron suppression techniques. Magnetic suppression, which springs to mind as the simplest solution, is unsatisfactory because, for any uniform magnetic field, electrons below a critical energy can always be trapped in a Philips cell. The greatly increased path length of the electrons will, as in an ion pump or Philips gauge, ionize the residual gas. This might be the reason for the failure of the magnetic electron traps in the 12UD in Japan. A 200 gauss field over an inch diameter will trap 6 KeV electrons; these have more than adequate energy to ionize residual gas. The application of such magnetic traps to the symmetry axis of non-inclined field accelerator tubes would seem a very questionable step.

Three options to reduce the electron storage time might be considered:

1). Use a highly asymmetric conical magnetic field to dump electrons on the larger pole.

2). Enhance penetration of the accelerating gradient into the magnetic field region to sweep out trapped electrons.

3). Use extra voltage feedthroughs to introduce an electric field to sweep electrons.

THE EFFECT OF MID-COLUMN PUMPING

The first beam run in the 14UD after the tests and measurements described was 40MeV alpha particles (13.33MV on terminal) with an injected intensity of 200 nA.

With the midsection sublimer off, and only the 10 litre/secion pump on, the rate for X-rays above 1 MeV was 2.7 K/sec. With the shaft off this value rose by 30% to 3.5K/sec. No noticeable change in the L.E. pressure occurred.

It was surprising to notice the importance of the pumping contribution from the 10 litre/sec pump on a beam which spends as little time in the L.E. tube as an alpha particle beam; presumably this is because of the weak binding of the negative helium ion.

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Further tests were carried out later when ^{16}O was run. A beam of 1.15 microamps $^{-}$O was injected with 12.2MV on terminal; the intensity at the H.E. cup was 7 microamps. Turning off the L.E. shaft increased the rate of X-rays above 1MeV from 20K to 26K, the same 30% change noted with the alpha beam. The rate change for X-rays above 300 KeV was from 60K to 70K. In the absence of beam, turning off the shafts lowers the $<$ 300 KeV rate from 4K to 3K. Clearly radiation associated with collisions between beam and residual gas is dominating the effects of the elctrons produced by the faulty heater plate. The increased pumping by the 10 litre/sec midsection pump plays a substantial role in reducing this radition.

It should be noted that, before these tests, sufficient titanium was sublimed in the midsection pump to ensure adequate chemical pumping throughout the testing period. What is highlighted here is the crucial role of ion pumping.

Enclosures:

Photograph of casting transformer with A.N.U. connections; showing also an original rubber-covered lead with bad spark damage.

Photograph of transformer installed, showing feed emerging from casting with bare straps to the heater plate.

Experimental schedule since previous button-up.

D.C. Weisser.

T.A. Brinkley.

October 28th 1977

SEPARATE EXPERIMENTAL RUNS SINCE END OF LAST SHUTDOWN.

SOURCE	PARTICLE	ENERGY (MeV)	DURATION OF RUN (days)
L	^{13}C	60	3
L	^{6}Li, ^{7}Li	52	2
S	^{16}O	80	2
S	^{24}Mg; ^{18}O	100	4
S	^{13}C	62	2
S	^{24}Mg	100	3
S	^{16}O	60	3
S	^{24}Mg	95	2
S	^{14}N	70	2
S	^{16}O	70	1
S	^{9}Be	50	2
L	^{2}D; ^{4}He	20(D), 30(α)	2
L	^{12}C; ^{16}O	70	2

LATEST TANK OPENING

(L = lithex; S = sputter)