# DEPARTMENT OF NUCLEAR PHYSICS
# TANK OPENING REPORT NO 62

This report covers three tank openings;

2 May to 6 May 1988
22 July to 17 August 1988
9 September to 23 September 1988.

The highlight of this period is that the machine achieved 16.7 MV. The low light was a stubborn refusal by us to learn from history. We were plagued throughout these tank openings by poor beam transmission and spent most of our time following various red herrings in trying to cure this problem. There was an adequate supply of the fish due to many small problems in the accelerator after the massive changes associated with the compressed geometry tube installation. However, it wasn't until the very end, that we finally realised that the poor beam transmission was due to an accidental bias in the way NEC accelerator tubes of the vintage we have, were manufactured and installed.

**The first tank opening 2 May to 6 May 1988.**

This tank opening was the first one caused by accumulation of small problems that we mistakenly assumed were the cause of poor transmission through the machine. Each of these problems actually existed and we will go through them and describe their cures.

**Terminal Stripper**
Terminal stripper mechanism was found to be one pole out which resulted in the foils being at approximately 45° with respect to the beam rather than normal to the beam. This obviously can and does cause some reduction in transmission.

**Cuperture**
To try to deal with poor beam transmission, the cuperture at the entrance to the high energy tube was changed from 9mm aperture to 12mm aperture.

**Dust**
There was a significant amount of Vivalyme dust on the rings in the machine, presumably still associated with the relatively new load of Vivalyme.

**Second Stripper Ion Pump**

There was a short found in the second stripper ion pump. We chose not to vent the tube to repair this. The low energy mid section sublimer pump was once again causing electron emission into the low energy tube. This is evidenced by modulation of x-ray counting rate at about 300 Hz, i.e. that is the AC frequency supplied by the shaft. This problem was eliminated in the past, by allowing the sublimer pellets to electrically float and therefore self bias to a positive voltage thus not allowing further electrons to leave. Unfortunately, this technique relies on the accidental high resistivity of the secondary circuits of the sublimer transformers. We have reinstalled a small DC suppressor supply operating at about 120 volts, to eliminate the electron current. This has been successful.

**X Terminal Lens**

The carbon brush on the wiper on this variac had fallen off. A new carbon brush was grafted on to the old wiper.

**Shafts**

Shaft bearings in unit 2 were changed.

**Miscellaneous**

The resistors in unit 14 were tested and found to be OK. Chain 3 support bearings had a short to ground. The thin mylar washers were replaced with thicker polystyrene washers. For the first time we used detergent, RBS, rather than alcohol to chamois the rings. All splat marks on rings and terminals were polished. There had been a problem with the reading of the corona triode current. Transorbs were installed at the tank end of the coaxial cable which bring the triode current signal to the control room.. The oil stain on the terminal appeared for the first time not to be spit soluble. This was not investigated any further.

**Chains**

Black oily bits were found in the High Energy end of the machine. The build up of material on the pellets along the line of the shimstock contacts was a source of the black material. The chains were cleaned. During the wipedown of the chains, it was noted that on chain 3, there were groups of pellets with severe pellet-to-pellet spark marks with up to six per pellet. Weisser chose to ignore this problem at this time to his later discredit.

**Control Rods**

The upper sublimer control rod was replaced because it did not have enough torque to operate the variac. Whilst changing the motor we discovered stiffness in the control rod system. This was due to misalignment between the variac and the control rod. A bush between the control rod and variac was removed to allow the two shafts to find their own

centre. Nylon drive knuckles on the lens control rod had to be replaced because the old ones had split causing the coupling to lock. Substantially later, when we had other problems with other control rod motors, it became clear that the toggle switches used for operating these motors, had corrosion on their contacts. This results in the phasing capacitor not being consistently connected to the motor thus reducing its torque.

**Post Button Up Performance**

On 9 May the experimenters used the machine satisfactorily to 14.1 MV. On 11 May it was used for an experiment at 15.4 MV and on May 12, during tests it achieved 16.7 MV. The transmission problems which have been in the background became worse and starting interfering with the experimental program.

**Shorting Rod Transmission Tests**

The Accelerator Mass Spectrometry program requires the accelerator to operate at around 8 MV with good transmission. Calculations were done which suggest that the best transmission ought to occur when the low energy units are shorted out near the terminal. A series of tests were performed that confirmed this calculation. The alignment through the accelerator was checked by using the theodolite under the analysing magnet looking through the terminal stripper, checking the position of the entrance slits. The alignment of these appeared to be satisfactory. On 13 July the accelerator operated under tests at 16.6 MV though the transmission problems were still serious. These transmission problems had become characterised by the need for an offset in the beam entrance position in order to get the beam through the machine. In particular, the beam had to be displaced toward the sputter ion source by 3.5 mm in order to get through the accelerator at all. This problem should have alerted us to one that existed in the accelerator when it was first installed. Unfortunately it didn't.

**Tank Opening from 22 July until 17 August 1988**

**Reason for the Tank Opening**

Sparking in Unit 3 turned out to be caused by three rings having fallen down. When the tank was open, we took this opportunity also to do a major realignment of the low energy beam transport. We hoped beyond thought, that such a misalignment was responsible for the offset needed in the beam going into the accelerator. Essentially all of the low energy vacuum plumbing above and below the low energy quardrupole was removed. The inflection magnet alignment was also checked and reset on the machine axis.

**Exploratory Tour**

The top ring in unit 17 was displaced. There was found a flaky buildup of breakdown products and aluminium from the failed corona point bracket used on the top post shorting strap.

A black pattern on the material on the outside of the casting cover seemed to be coming from the unused securing pin hole. No other source of material was found. The unused pin was removed. There was a lot of junk on the rings - loads of breakdown products, grey powder on all rings. The machine had to be wiped down before any work could be started for comfort and health reasons. The sparking in Unit 3 was caused by the lower three rings having fallen down.

**High Energy Foil Stripper**

The high energy foil stripper was removed from the 14 UD and the magnet bearing housing of the vacuum side was machined so that the bearing was a slide fit. Prior to this, it was believed that the housing was sufficiently tight on the bearing to distort the shell. A new bearing was used after the modification. The high energy foil stripper housing was machined so that the separation between the magnet and the vacuum wall was reduced to a .003" gap from a .025" gap. The second stripper rotary magnetic drive had jumped one pole. The reduction in gap ought to improve the strength of the magnetic coupling.

**Drive Shaft Motor**

The low energy shaft motor was replaced with a reconditioned one at ..... hours. The old motor had noisy bearings. All low energy shaft bearings were replaced having run 17,000 hours. We took the opportunity to remove all the low energy casting alternator stators and rotor magnets. Since tubes no longer have heaters these alternators are no longer required.

**Phase Detector**

In order to increase sensitivity to low rep-rate pulsed beam, an 18 MHz phase detector was installed, replacing the 75 MHz version. The new one has a 25mm diameter drift tube that is as long as the vacuum housing, 17 cm. The effective length of the drift tube was extended by inserting carbon coated teflon sleeves from the end of the drift tube to approximately 15 cm along the beam line. The image slits had to be removed and realigned.

**Alignment**

The theodolite was installed on top of the inflection magnet to look for problems between it and the terminal. It all looks OK. The theodolite was reset on the pedestal on top of the tank. It would appear that Target A has shifted 1mm of arc. Target A is one of four welded to the tank used to establish the pedestal datum. New standard angles have been established based upon a 42 second of arc correction.

The Taylor Hobson telescope was put on the pedestal and aimed at the stripper tube. The tank slits were checked and found to be within half a millimeter of the correct beam line in one direction and a quarter of a

millimeter in the other direction. The bellows was removed from on top of the unit 1 tube. There is no evidence of any asymmetry in any of the electrodes. A "V" aperture will be installed at the tube entrance. We are installing this aperture in order to eliminate its absence as a possible cause of the poor beam transmission. No aperture was installed in the first place in order to minimise the distortions of the entrance lens.

**Alignment of the Low Energy Quadrupole**

To align the low energy quadrupole that sits immediately above the 14UD tank, we had to remove the following components: low energy pumping station, low energy ball isolation valve, iris, associated beam tube, and the bellows that sits directly on top of the low energy acceleration tube.

A target on top of the first electrode tube section was confirmed to be on line. Cross wires were used in the alignment fixtures on the top and bottom of the quardrupole. An error was found of .002" towards the Lithex source and .020" towards the sputter source. Beam optics calculations were performed and suggested this .020" error could in fact cause the transmission problems experienced. The quardrupole was adjusted back onto line. All components were reinstalled on top of the tank.

**Gas Stripper**

A new metering valve Granville Phillips Model 203.026, was put into the terminal. It is driven by an enclosed flexible drive cable that connects to a control rod. A ten turn potentiometer in the control rod box gives a read-out in the control room of the valve's position. The gas stripper bottle was installed under the central terminal spinning pressurized to 750 psi with nitrogen. The valve pressure was later reduced to 465 psi on 15 August in order to give a finer adjustment of stripper gas.

**Column**

There were no reconditioned posts available. There was post damage caused by post shorting straps failing. The worst failures were in unit 17, 11 and 13 where connecting blocks have been eroded almost away. To overcome the failures of these straps, it was decided that all comparable gaps on posts should carry a shorting strap rather than relying on a single strap per gap. This was finally done on 14 September 1988. In October 1988 a suggestion was made by NEC, that the failure of these straps or associated brackets is due to too much current passing through these joins. It is NEC's recommendation to use shorting loops that have sufficient inductance to reduce the current going through the circuit. The loops' main function is to supply DC contact across the gaps one wants to short. During a spark the current should pass through the spark gap rather than the shorting strap. The doors were closed on 5 May and on 6 May gas was put into the machine.

**Button Up**

Chain tests were done and everything was considered normal. The column was wiped down with chamois and 50:1 water to RBS. After pumping the tank it was vented to check for leaks. All appeared well. We started gassing up on the 11 August. When the pressure got to 29 psi absolute, there appeared to be a leak. The $SF_6$ was pumped out. Helium leak chasing showed a leak on the back flange of the low energy mid-section sublimer pump. This was removed and inspected without revealing any obvious problem. We concluded that the original tightening of the flange was not sufficiently uniform and the gasket was not uniformly compressed. The surfaces were cleaned and a new gasket was installed. Anti-scuffing paste was put on all the bolts. The gas went in on 17 August.

**Button Up Performance**

Transmission was checked. The beam position for best transmission was found by driving in the tank entrance slits until they just intercept some beam. Unfortunately the position of the slits for maximum beam through the machine was unaltered inspite of the realignment of the low energy quardrupole and the installation of the V aperture in the first unit. This confirms that external alignment was probably not the problem. On 29 August to bolster this hypothesis, we moved the low energy quardrupole up to 3mm from its nominal axis position to see if the transmission through the accelerator changed and to see whether the offset of the beam needed to get it through the accelerator had changed. Neither altered. This convinced us that the problem had nothing to do with the alignment of the external beam components.

Sparking was observed inside the accelerator and seemed to be coming from unit 16. There was a vacuum leak in the low energy ball valve bellows. Tank opening was decided on.

**Tank Opening 5 September - 23 September 1988**

At this stage we finally realised that the offset of the beam going in to the machine was exactly what was observed when the accelerator was first installed in 1974. That time, to get beam through the machine it also needed to be going in substantially from the nominal axis of the accelerator. The first heated aperture in the Low Energy tube was found to be warped. Since such an assymetry could steer the beam, the warped plate was replaced with a flat one. That too resulted in no improvement in transmission. We hypothesised that all the other warped heater plates coherently conspired to steer the beam and that this problem must be worst where the beam is at its lowest energy. The first four 11-gap tube sections were rotated through 180°.

In 1974 this solved the problem. Since the compressed geometry tube does not have heater plates and so no warped electrodes, it was felt unnecessary to retain the 180° rotation in the new installation.

Four spare tube sections were meaured to see if these flanges were parallel and if any lack of parallelism was consistent among them. Three were non-parallel by about .008" in an ~8" long tube and the short side was correlated with the position of the corona point brackets. If all the tube presently in the 14UD was similarly biased at one part in $10^3$, would that cause the injection offset observed? Yes! See the figure. A 150 keV beam injected paralled to and on the geometric axis of the 14UD would end up about 7mm from the center of the stripper canal. To get the beam to go through at all, it would have to be injected off axis and at an angle.

Confirmation of the angular effect was that the transmission got worse when the LE iris was closed down limiting the injected beam to its par-axial component and elminating the larger angle components.

Further support of the one part in 1000 hypothesis is found in the practice of NEC some time subsequent to the 14UD manufacture. NEC measured each tube and marked the short side. Tubes were then arranged in sub-assemblies with the short to long side compensating for the natural bias.

At the SNEAP 88 meeting, HVEC users confirmed, that MP tubes were to be installed in some up/down order to compensate for systematic electrode stamping bias!

Clearly, we had to rotate some tube. Which tubes? The best solution would be what NEC does, that is rotate alternate tubes, or better yet, measure each tube section and match its bias with that of another. This would require complete disassembly of the entire tube in the machine. Not acceptable. If one assumes a consistent bias, then one can calculate how many tubes to rotate to return the beam to the terminal stripper axis. But then the bias in the HE tube will still steer the beam that same 7mm! We choose a combination of tube rotation in the LE and the HE end which put the beam only 1mm off axis at the terminal stripper and .2mm off at the exit of the HE tube. This involved rotation U1; U2, U3/1 and U15, U16, U17/1,2.

**Exploratory Tour**

Sparking from Unit 16. All straps were OK but the rivets that held the bracket to the column had failed. In anticipation of rotating the tube, all the tube was blown off with nitrogen. Chain 2 scope trace had been showing sparks although this had not been written in the book anywhere. Inspection showed severe spark damage to a contiguous set of pellets that had been noticed by Turkentine in the previous tank opening and was

ignored. The low energy ball valve leak was confirmed. The mechanism was found to be stiff. The roller bearings had worn into and marked the stainless steel shafts in the mechanism. Stainless steel shafts will be replaced with tool steel and the roller bearings replaced. The O-ring carrier was found to be dinged. The O-ring was replaced and the carrier repaired. Subsequently leaks were found either in the bellows or in the bellows weld and another bellows had to be welded into place. It was finally leak tested satisfactorily off line. The high energy ball valve was known to leak through and its O-ring was replaced. There were leaks in that re-assembly as well. It was leak tested off line and then replaced. The high energy ball valve bearings were bought, shafts made, but they were not installed. We didn't want to take the time at this stage.

The bellows at the head of the low energy tube was removed in order to allow the removal and rotation through 180° of the top seven 11-gap tube sections. The 8-gapper was also rotated. The tubes were taken out as a pair followed by three, followed by three. The flanges in each sub-assembly were recompressed using portable compression unit made of three threaded rods and plates. This worked satisfactorily. The sealing surfaces were cleaned with emery paper and alcohol. When the tubes were replaced, there was no V-electrode installed at the top of the low energy tube as its presence or absence had not affected or improved transmission. The bellows at the head of the high energy tube was removed in anticipation of rotating all of units 15, 16 and the first two tube sections in unit 17. It was found that this bellows had a severe offset in it. When it was finally replaced, it had to be replaced in such a position to minimise the effect of the offset. The Taylor Hobson telescope was set on top of the tank and aligned with respect to the terminal stripper tube. This was used to align all replaced tube sub-assemblies.

The high energy mid section pump readout could not be seen because we had in the previous tank opening, neglected to plug in a power cord in that unit.

The tube sections were put back and tightened down using a torque wrench setting of 80 inch/lb. Chain 2 was inspected and found that the set of links were badly spark damaged as was mentioned in the last tank opening. We attempted just to remove this 20% of the chain and replace it with new links from a spare chain we had. The spare links were of a different thickness material than the previous ones and so when the chain was put together it was out of balance. All the bearings in the idlers were changed on chain 2. We felt that chain no 2 was not sufficiently stable and a complete new chain was installed with all identical links. It has run beautifully ever since.

Corona points were reinstalled on tube sections that were rotated. Because the corona points were so contaminated with hygroscopic products of

reactions with the breakdown products, we could not reliably set them electrically. They were therefore all set merely by eye.

The gas in the stripper gas bottle pressure was reduced to approximately 100 psi to further improve the sensitivity of adjustment. Chain 3 was removed and inspected for cracks. Although there were no cracks found in the nylon links, there were failures in the metal pellets due to breaking through of the holes that take the pins. Chain 3 had 21,000 hours on it. Three pellets were removed. It was clear that in both chain 1 and chain 3, the failure of the metal pellets will require the replacement of the entire chains during 1989.

During this tank opening, an opportunity was taken to perform other tasks. The main water chiller pumps were each removed and new bearings installed in all of the motors, with the exception of the chilled water to the heat exchanger on the level 5 demineraliser.

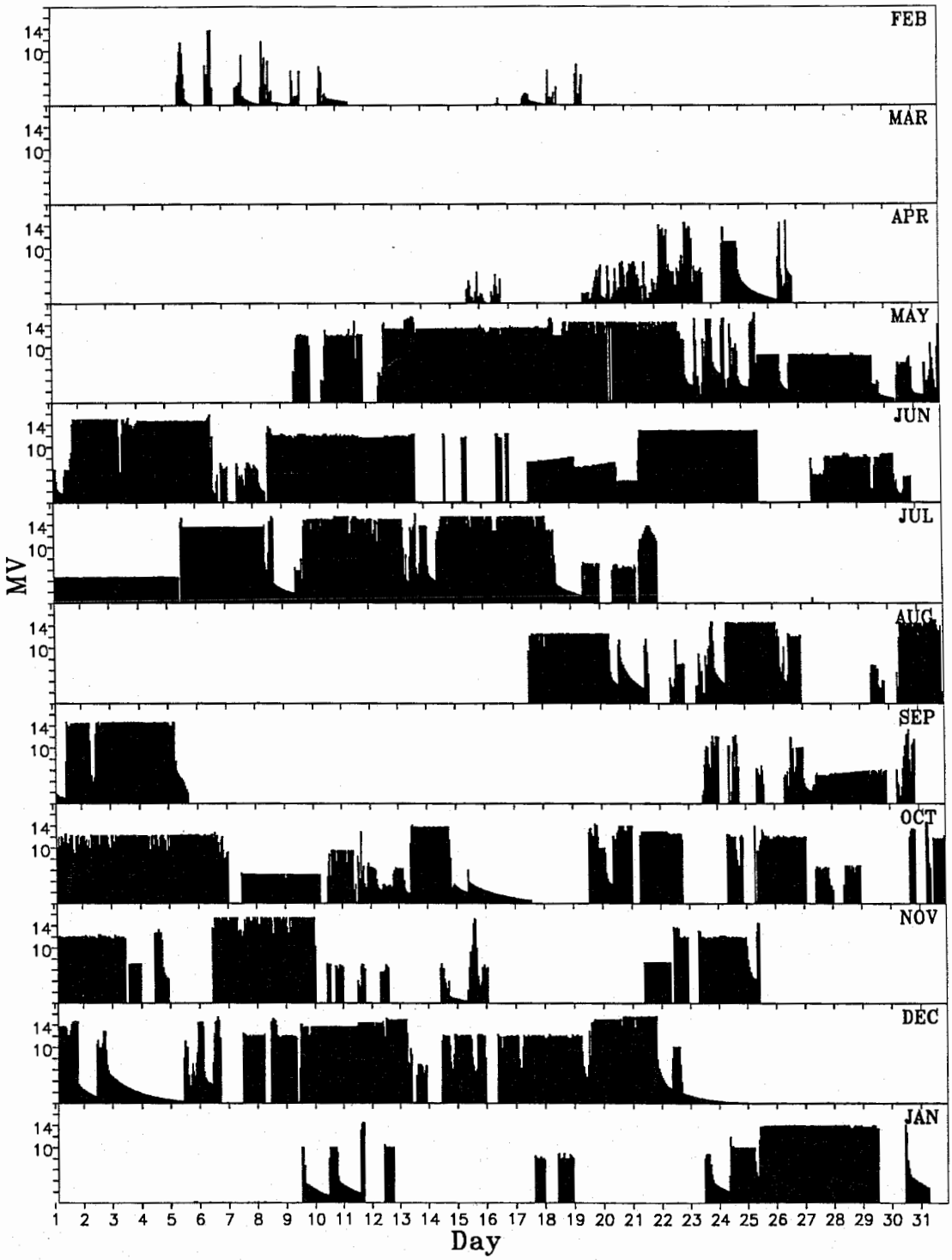
It was in this tank opening that we installed extra shorting straps on each of the posts for those sections that we had previously shorted out using straps on only one post. Our hope at that time was to reduce the damage to the straps and the clamps on the posts. All posts in unit 21 were changed. All high energy units were opened to clean up bits and pieces of black junk associated with oil and chains.

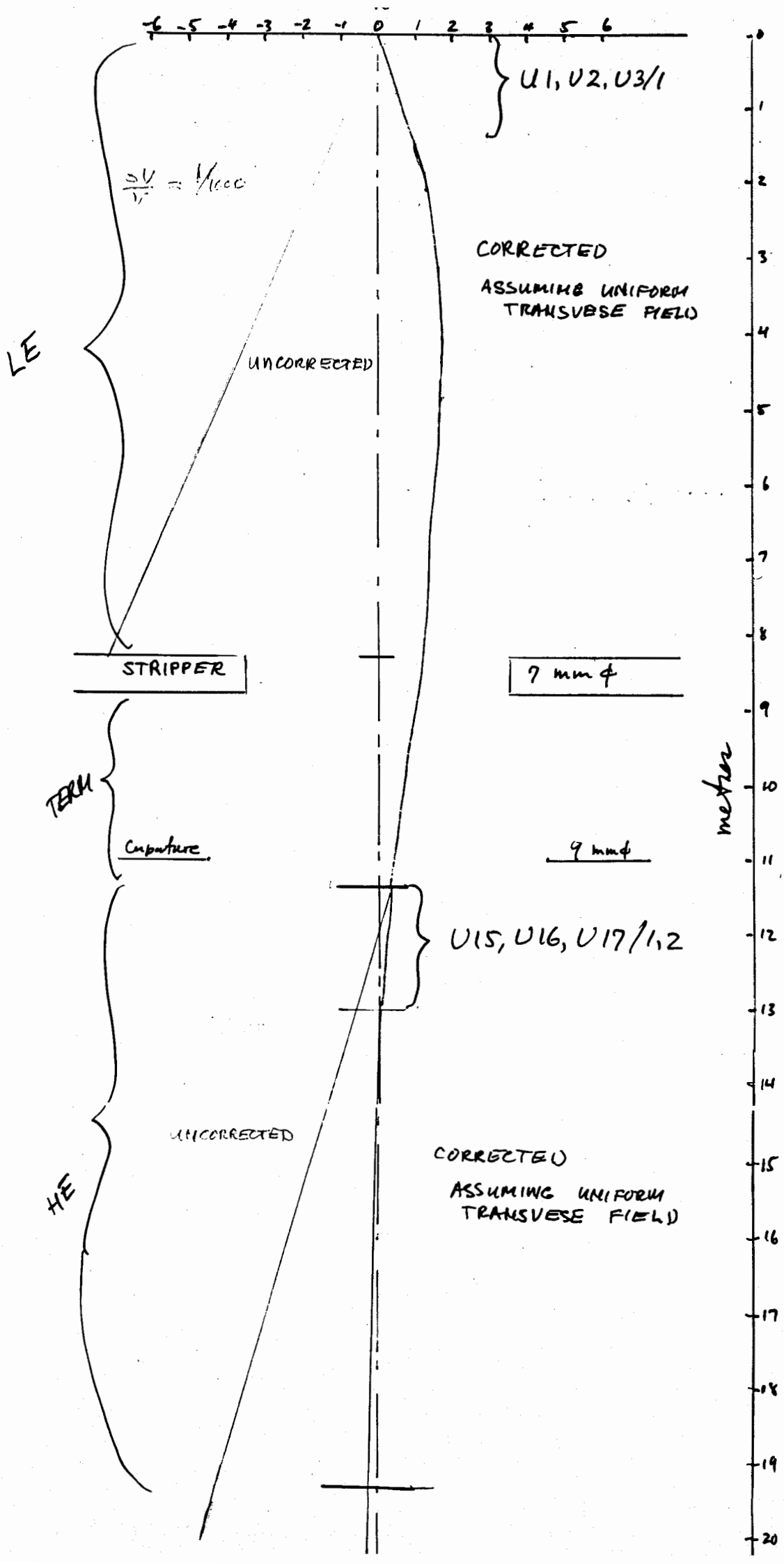
Unit 18 still has magnets on its alternator. They should be removed at some future convenient time.

The tank was closed on 22 September 1988. The first beam was transported and transmission checked on Friday 23. The beam was now found to be within 1 mm of the nominal optic axis to get through the accelerator and the transmission improved from the order of 10% for Chlorine back to our normal 50-60%.

See figure..

# 14 UD Log GVM 1989




-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
U1, U2, U3/1
ΔV/V = 1/1000
CORRECTED
ASSUMING UNIFORM TRANSVERSE FIELD
LE
UNCORRECTED
STRIPPER
7 mm ϕ
TERM
Curvature
9 mm ϕ
U15, U16, U17/1,2
UNCORRECTED
HE
CORRECTED
ASSUMING UNIFORM TRANSVERSE FIELD
meters
0
1
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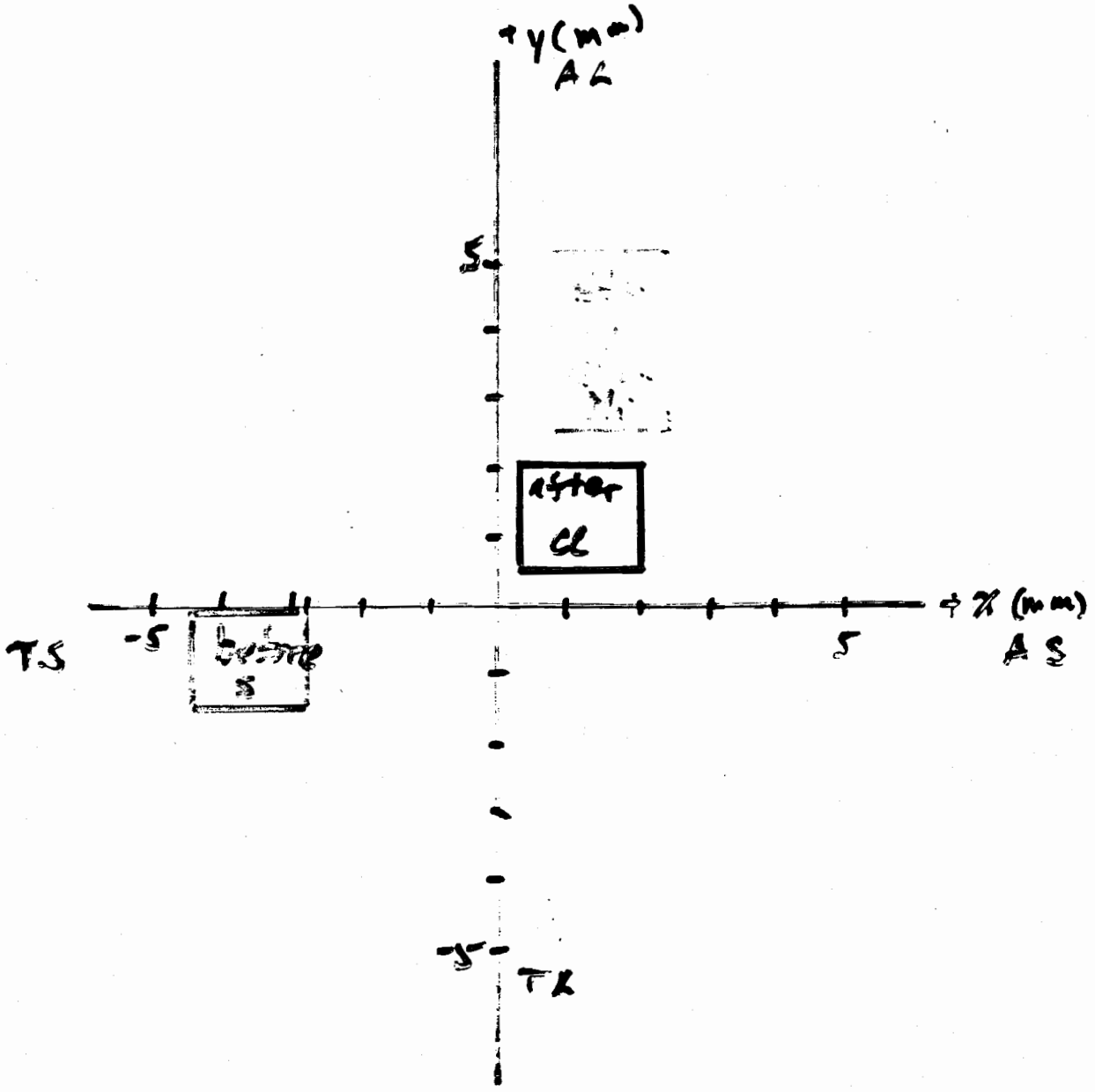


Entrance Slit Positions at edge of the beam.

Effect of rotating portions of the LE + HE Tube.