AUSTRALIAN NATIONAL UNIVERSITY

DEPARTMENT OF NUCLEAR PHYSICS

14UD TANK OPENING REPORT NO. 25

(February 24th to 26th. 1981)
(3 days open)

REFERENCES: Earlier Tank Opening Reports are referred to by the notation (12/4) etc.

A few readers have expressed their pleasure at the form and style in which the Tank Opening Reports are written. In the early days after the 14UD was handed over, we wrote quite informal notes to N.E.C. describing machine performance, problems and symptoms as they occurred, and then what we found when we had to go into the tank. We feel that anyone closely associated with accelerators will be sufficiently humble and sympathetic to prefer this chronological method in which the frustration and mistakes speak more eloquently than the bare facts themselves. Our preamble deals with events from a button-up until the next opening. The exploratory tour describes what we found in the tank without explaining what we did, and the remainder of the report gives the relevant details with the best justification we can think of.

A recent suggestion by Don Walker at Chalk River is that, instead of stating how many days the machine has been operational, it would be more meaningful if we quoted hour-meter readings for various conditions because they are helpful to others when making comparisons. We agree, and intend to include useful numbers wherever possible. We often leave the shafts running for vacuum reasons when the machine is not in use; also most frequently, only two, or even one chain is used. The only hour-meter which bears any relationship to operational time is the one on the charging volts supply. The almost relevant readings are: 1 Jan. 81/30207 hours, 2 March. 81/31044 hours for 837 hours. This period includes two tank openings of 1 and 3 days. In future, readings will be taken at tank openings.

PREAMBLE

The 14UD was last closed on January 9th. As reported (24/3) experimenters were taking data at 13.5 MV on the day after closure; the machine then ran for 90 hours at 13.3 MV following which it easily conditioned to 14.2 MV and after this there were some trouble-free silicon and bromine runs. Between times, whenever experimenters were not ready, rods were put in appropriately, leaving groups of six units live, and these were conditioned at 1.1 MV/unit. A silicon run began at 14.04 MV with 9 microamps on the H.E. cup, 1.9 microamps of 8^+ on stop and 1.5 microamps on target. In other words, for three days non-stop, everything was very pleasing until the ion source caught fire at 10 o'clock at night and put an end to hopes for another record for the southern hemisphere.

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The fire was discovered early by the experimenter, David Hinde, because he somewhat irritatedly went up to the source rooom to find out what was happening to his beam; having found out he acted extremely promptly with fire extinguishers at a time when things were well alight.

The fire began underneath the source platform at the top of the perspex structure around which the nylon tubes carrying water were coiled. It seems almost certain that condensation caused surface currents which ignited the perspex. The problem was exacerbated by a failure of the chilled water temperature regulating apparatus. The flames heated the metal deck above turning it into a barbecue plate. A bunch of leads, including those to the sublimer pump and the ionizer and reservoir heaters, had been lying on the deck, and their insulation, and a few plastic handled tools, were overdone for even the most extreme taste.

Fortunately the adjacent cabinets, with electronics, power supplies, control motors and rods were unharmed, but a lot of work was immediately necessary, including a realignment of the source because one wall of the perspex support structure had burnt and warped.

After the burnt debris was removed, but before anything else was done, the entire source, as it stood, was run up to volts to determine at what point it would break down. Several people stood, and watched with awe, as the charred, blackened structure took 100 kV without a murmur for several minutes, and was then reverently turned down.

Wishing to get back on the air as soon as possible all thought of rebuilding the support structure immediately was abandoned and a "cleanup and fix it" job was started at once. The charred surface of the perspex was ground with a coarse sand disc on a rotary grinder: then medium paper on an orbital sander. Though still far from polished almost all traces of blackening were removed. In view of the voltage holding ability of the charred structure this exercise was largely for aesthetic reasons.

While work was being done on the source the 14UD was conditioned and went to 14.7 MV before the first spark occurred. This increase in conditioned voltage threshold from 14.2 MV was brought about through running beam.

The source was under vacuum on the second day, and on the third day rose again and was put in use.

There was some more conditioning and the machine was stable, without beam, at 14.74 to 14.76 MV. An experimenter took over and ran at 14.27 MV for a while; he then made the following entry in the log book:

"Just as a joke ran beam at 14.61 MV. 15UD running beautifully."

However, a little later, a spark sent the intrepid joker scuttling back to 14.27 MV.

Continuing high humidity provoked more troubles with condensation on the nylon pipes carrying cooling water to the source and in three places surface currents welded them together. The tubes were punctured, causing significant leaks. The two pipes were renewed and enclosed in thermal insulating material in an attempt to avoid condensation on their surfaces. Work is continuing on the water temperature regulator apparatus.

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Lost charge, and terminal voltage instability associated with normal triode current (50 microamps) returned as a problem. With no beam to control on, and 50 microamps triode current, the terminal would vary by about 500 kV over a few minutes (see graph). The effect of this instability on experiments was minimized by operating with 10 to 15 microamps triode current. Here the instabilities were proportionately less and the slit control could compensate for them.

In mid February problems occurred with beam intensities through the machine. At times the terminal foil indicated movement in one direction only and eventually measurements with beam suggested that the foil in position was not changing, but reorienting with each actuation, implying that the coupling to the internal mechanism was slipping. It was decided to advance the tank opening already scheduled a week later for terminal foil change.

THE TANK OPENING

Exploratory tour.

When the doors were opened late on the day of the pumpout the sulphurous smell in the tank was worse than on the previous occasion, (24/1), when we reported it as unbearable. In the past (~~12/1~~, 12/8) one intrepid rotund canary was happy to go into the tank immediately the doors were opened. (That statement was a contribution by the younger and taller author). Reactivation has, for a long time, been carried out regularly each week and we decided to investigate the alumina during the shutdown.

A preliminary tour of the column revealed no loose rings, or tube to column stringers, or anything which could be expected to lead to instability. The chains were faintly moist and tacky, but not thickly tacky, as we used to find them before the most recent oiler modification (23/2). The pulley rims were also faintly moist.

We again found oil on the H.E. castings, especially at stabilizing idler positions, and there were pools on the floor of the tank. Though not unprecedented, the appearance of so much oil was mystifying since very little oiling had been carried out.

Because of our interest in the relationship between instability and buildup of breakdown products on corona needles, the stabilizing triode needles were examined closely and small crystalline formations could be seen with the naked eye on the tips. Similar formations were found on tube and column point assemblies. See photos.

These deposits were first seen in a corona point test apparatus at O.R.N.L. by D.W. Their production was reproduced in a test assembly at A.N.U. but this is the first time occurrence in a working accelerator has been observed. In the test cell one can view in a microscope corona taking place from the tip of the needle point. Under these conditions one clearly sees chunks of white material fly off the needle tip, accompanying jumps in corona current. This is precisely what happens to the triode needles.

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The terminal voltage instabilities associated with 50 microamps triode current must be caused by the white material being rearranged on, and removed from the needle tips. The correlation with excessive SF6 breakdown products in the tank is also confirmed. That these effects occur in the 30 tonnes of SF6 in our tank guarantees that they occur in closed corona systems using much less gas indifferently purified.

The terminal foil stripper, because of which the machine had been opened, was found to have two separate faults. When the foil system was turned by hand there was a noticeable notchiness which implied some sort of obstruction inside; also the pneumatic actuator was only working in one direction. The combination of these two faults explained the failure.

In the lower terminal the bearing retaining ring of charging pulley No. 3 was loose and some grease and rust powder had collected on the outside of the shaft. A similar, but less severe fault was found on Chain No. 1. Both assemblies were cleaned, and retightened. No noticeable movement or vibration was caused by this expedient procedure. The d.c. idlers on chains 2 and 3 were in fair condition but on Chain 1 an idler bearing was bad and the tyre on the other idler was badly damaged.

All castings containing stabilizing idlers were opened in order that we could observe performance of the A.N.U. bearing design since spark shields were installed (23/3). We were extremely disappointed to find the most widespread series of idler failures witnessed since the 14UD came into service. Two of the quarter-inch shafts had been spark-eroded until they broke off. In one case the erosion reduced the shaft uniformly down to about an eighth of an inch and in the other case erosion continued down to about a sixteenth before the shaft broke. We believe that either of these could have caused a chain break if the spark shields had not guarded the chain from the failed wheels. In addition to the two breakages there were ten cases of worn shafts, nine of which were on blocks which carry two wheels. There was also one case of an idler with a torn tyre.

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And so to work!

<u>The smell in the tank.</u>

The dryer was opened and the alumina taken out. All the spheres in the entire charge were somewhere along a tonal scale extending from pure white to dead black. Accordingly a photograph was taken and is one of the enclosures.

It is reasonable to assume that alumina in this condition would be ineffective in cleaning the gas in spite of regular reactivation. It would be the cause of the recurrence of lost charge problems as well as the deposits forming on needle points, to say nothing of the atmosphere in the tank at first opening. This charge of alumina was the original one supplied with the machine.

When we last experienced lost charge problems (12/7) new alumina was purchased, but did not arrive in time to be used. As the lost charge problem appeared then to be solved, the idea of changing the alumina was unfortunately forgotten. On the earlier occasion the alumina was generally white, with a few brown balls. Clearly our dryer, in which the heating elements are in contact with the alumina, causes very non-uniform heating. This means that only a small number of the balls carry the major purification load. A preheater for reactivation will be built.

A charge of new alumina was put in the dryer.

Chain oiling.

Our new method of oiling (23/2) is to let a few drops fall on stationary pulley rims, allow a few seconds for the oil to run down the rims and then give a quick on/off to the motor buttons so that the chains distribute the oil at very low speed before it is thrown off. That this procedure could allow so much oil to be taken up the column, and dispersed on fixtures in the bottom of the tank, eventually to collect on the floor, caused us to wonder whether oiling could be taking place accidentally when the chains were running. It was then remembered that the pneumatic actuators on the two foil changers (together with the terminal sublimer changer and the cuperture, though these are rarely used) vent to the tank by a common pipe shared by the oiler vents. This means that every time a foil is changed the venting SF6 slightly pressurizes the oiler vessels and oiling must occur until equilibrium is reached. Since foils are only changed when their effect can be observed on beam, these occasions always occur when the chains are running and volts are on the machine. The mechanical and electrostatic forces involved would easily account for the wide distribution of oil. The fact that over the last period the chains never exhibited negative self charge supports the view that inadvertent oiling occurred.

The pipework was rearranged so that the oilers are now on a separate vent to tank line.

Foil changer.

In order not to risk jamming a foil holder in the Weisser valve, it was necessary to let the entire tube up to atmospheric pressure. While this was regrettable it offered an opportunity to examine the foils in the H.E. stripper which has not been removed since it was installed nearly three years ago (11/6).

The tube was let up to argon with our traditional painful, but rewarding slowness and the terminal stripper was taken out. A slight internal adjustment made at the last opening in order to align the foils more accurately with beam position had relaxed the foil chains sufficiently to allow the foil holders to tilt to one side and scrape along a support. Torque from the actuator is transmitted by sextupole magnets through the wall of the stripper housing to the internal mechanism and the drag of the foil holders inside caused intermittent slipping of the magnets. When the actuator was taken to pieces it was found that an O-ring was displaced, accounting for the failure to work in one direction.

The terminal foils were changed where necessary and the stripper put back. Twenty-two glow discharge foils were also installed.

The H.E. stripper was then taken out and the mechanism was found to be working well. It has given no trouble since installation.

The used foils which had not broken showed pinholes over their irradiated area. These we presume to be caused by accelerated charged macroparticles in the accelerator tube. (Photo enclosed).

Chain stabilizing idlers and spark shields.

The dismal crop of failures does not, at this stage, reflect on the spark shields introduced three months ago (23/3). An A.N.U. version of casting idler assemblies was put in for test in November 1978 (14/2) and a year later was reported (19/2) to be in excellent condition; consequently all the remaining idler positions were fitted with production A.N.U. versions (21/6). These had no spark protection for the first three months of their lifetime. While the failures may well be an indictment of our modifications to N.E.C's original idler, it is also possible that we are seeing a delayed consequence of earlier shaft wear which the shields have arrested. In that case, admittedly an optimistic view, we felt that the lack of a tight fit between the shaft and the inner race could lead to mechanical wear and that such poor electrical contact would result in arcing and vastly accelerated wear.

As an experiment, shafts on blocks holding two idlers were nickel plated in order to get a push fit into the inner races. In casting 16, the first idler casting below the terminal, two blocks had both shafts plated and one block had one shaft plated and the other was fitted as hitherto.

Most spark shields displayed at least one line of dirty oil parallel to the chain. This presumably traces the highest electric field and corresponds to a current path. It may well be that the gradual falling off of charging current with increased voltage is a consequence of these oil currents and keeping the chains much drier might solve the problem. If the separate vent pipe for the oilers is effective there should be no undesirable oil on the chains in any case.

Only the shields in Unit 19 displayed spark marks. Whether these were caused by "charge leakage" from the chains or by machine sparking is not known although the latter is more likely. Robert Rathmell has suggested that the inside diameter of our spark shields is half an inch too small and so would cause a sudden charging efficiency loss correlated with a change of HE corona current. However the tests to disclose this proved negative. Subsequent to tank closure the droop of charging current versus inductor voltage was remeasured. The droop now occurs at 30 kV instead of 25 kV. The reason for the persistence of this droop is not clear and it is obvious that a problem remains. Our machine is equipped with flared inductors which should allow 150 microamps/chain.

AFTER BUTTON UP

There was some concern, that the less mature author roughed the accelerator tube a bit too roughly. As well, a vacuum cleaner was used to remove broken bits of HE stripper foil at Unit 19. These departures from procedure to minimize turbulence in the tube might well have reduced the conditioned threshold. Indeed when volts were first applied, loss charge current of 40μA at 11.3 MV was observed. This was associated with large increases in HE presure from 2×10^{-8} up to 1×10^{-6} torr.

In a matter of minutes, these phenomena lessened and the experiment commenced even as SF_6 was going into the 14UD. Within a few days, experimenters using the machine in mid 13 MV range, caused the conditioned voltage to reach 14.1 MV. Subsequent sectional conditioning allowed the voltage threshold to go to 14.2 MV. Sectional conditioning of the HE tube also showed that the old pattern of conditioning threshold increasing with distance from the HE end was still in force. We expected that the disturbance at the second stipper, Unit 19, would have caused a locally deconditioned section; this was not the case.

We divide conditioning phenomena observed into two categories. The first, and minor one, is associated with adsorbed gases. Even though the accelerator tube was vented to argon, some intercharge with air is unavoidable as flanges are removed. As gradient is reapplied, this gas rapidly evolves and is removed. Essentially no major sparks are triggered by this process. The second category is associated with particulate matter in the tube. In our machine, this material is more prevalent at the HE end and monotonically reduces, going to the LE end. This material, when disturbed by turbulence or major sparking, is much more difficult to shift to safe locations. Instabilities caused by the transport of this material are the triggers that detonate major sparks.

Our understanding of the role of breakdown products was confirmed by the stable operation of the machine at all voltages. The triode current instabilities were gone now that the white caps were gone. Interestingly enough, the white caps on the tube and column corona points do not seem to cause instability. This may be that there are so many of them that the total effect washes out.

MISCELLANEOUS

Reference Resistors.

About two weeks ago, instability on the ion source inflection magnet power supply (Spectromagnetics) was traced to failure of the reference resistor. The post to which the voltage sensing connection is made was corroded off and inspection inside the resistor housing showed the resistor assembly to be badly corroded in general. A new connection post was silver soldered on and the resistor and its connections were nickel plated.

Because of this failure, the equivalent resistor in the analyzing magnet power supply was inspected. In this case corrosion was less severe but the sensing connection post had been poorly soldered and fell off when it was poked not too vigorously. The assembly was cleaned and resoldered, then painted with marine epoxy paint. (The inflection magnet resistor was plated because there wasn't time for epoxy paint to set.) Both supplies are now operating stably.

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Inductor Power Supply Cables.

Over the past year or more, the 14UD has been plagued by spark induced puncture of the RG 8 coax cables which connect the charging supplies and inductor feed thrus. In an attempt to reduce this problem, series resistors were installed at the tank wall feed thrus. These resistor chains were made of old black carbon resistors from the EN tandem. They were ineffective in protecting the cable. Recently these resistors were replaced by six 40 MΩ "Welyn" resistors. So far, the cables have survived.

D.C. Weisser.

T.A. Brinkley.

9th March 1981.

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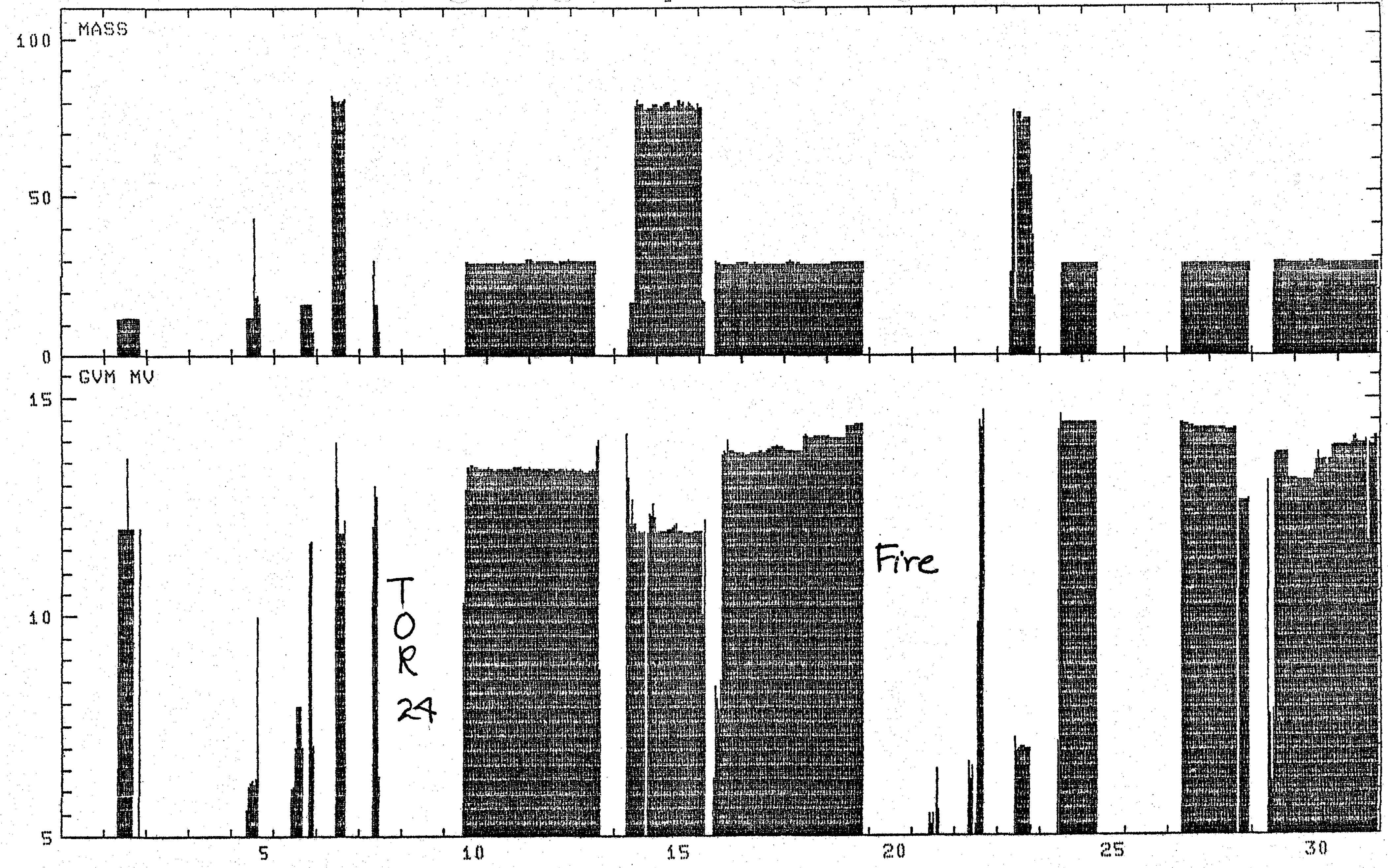
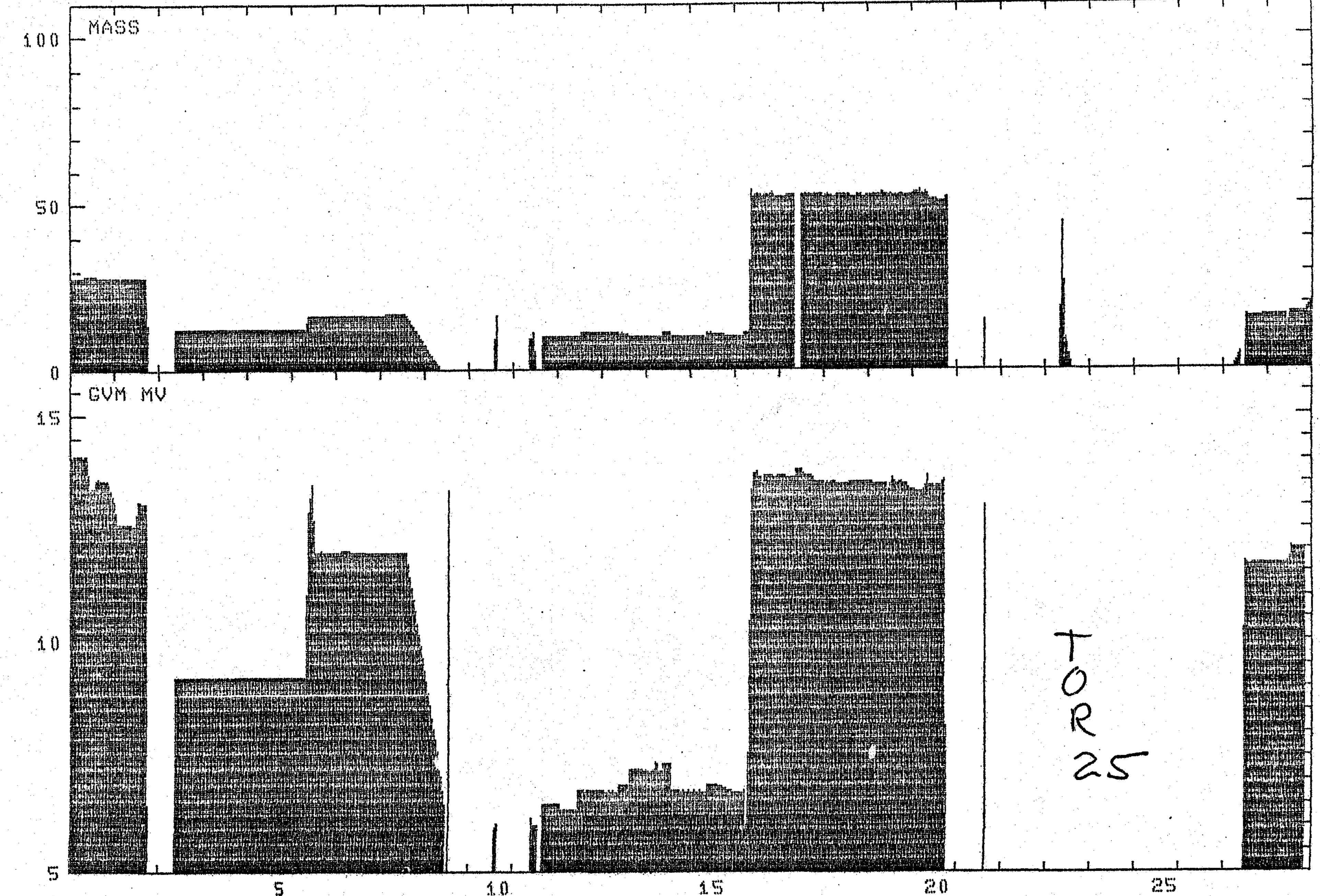
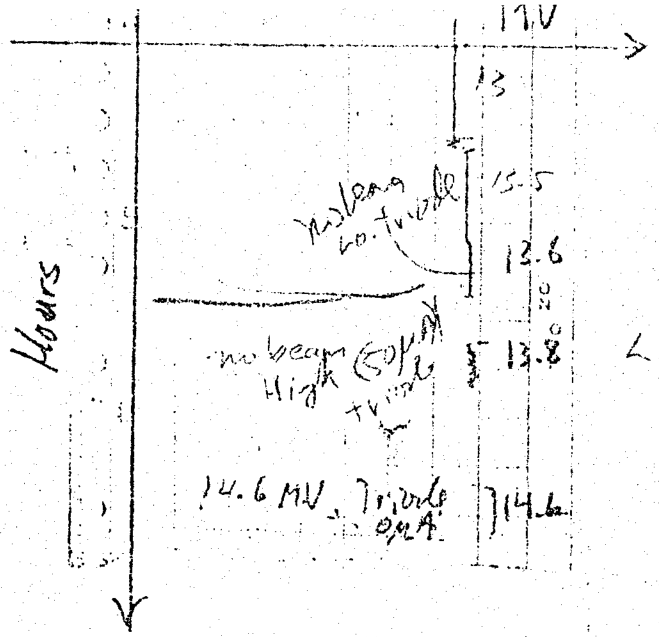


MASS .000 to 110.000
GVM MV 5.000 to 16.000

14UD log FEBRUARY 1981



MASS .000 to 110.000
GVM MV 5.000 to 16.000



LC ~ 20

below foil 120.

∴ @ 13 MV 50μA triode LC = 18 μA

Changed foils.

Cry CAg ① 8 Chg ② 12 Chg ③ 11

ETC	LECC	HETC	HECC	Triode	LE	CHG V
0	3	1	4	22	5	4KV