AUSTRALIAN NATIONAL UNIVERSITY

DEPARTMENT OF NUCLEAR PHYSICS

14UD TANK OPENING REPORT No. 34

13th to 15th April 1982

(3 days open.)

REFERENCES: Earlier Tank Opening Reports are referred to by the notation (12/4) etc, meaning Report No. 12, page 4.

PROLOGUE

The last report, No. 33, was a short one which was issued after Chain 3 broke on February 27th. We gave details, (33/2), of how the discovery of yet another miracle link led to a meticulous examination of Chains 1 and 2, and Chain 2 was found to have fine cracks on 22 of its nylon links.

We had no spare with which to replace Chain 2, and the options were to take it out or make use of whatever life it had left. For all we knew, hairline cracks could take months to develop to breaking point. We left Chain 2 in the machine for use only if the other two chains failed to meet requirements.

For two weeks the 14UD operated normally, with periods of successful running at high voltages, using Chains 1 and 3 only. One afternoon, when conditioning at 13.8 MV, there was a tank spark following which the machine refused to hold voltages in excess of 8.5 MV. While we were trying to determine what was amiss, we noticed that current was being drawn intermittently from the suppressor power supply, and at the same time the charging current meter for Chain 2 was going negative. These effects were occurring only above 9 kV charging voltage, and no current was being drawn from the negative charging supply. The effect was unlike anything we had seen before. We concluded that a high voltage feed wire had come adrift and ended up close enough to Chain 2 pulley to break down. Whatever had happened, it was clear that we were about to go in the tank again. We began taking out the gas at 4 p.m. and finished at midnight.

Next morning, anticipating a quick dip into the bottom of the tank, without having to lower the platform, we opened the bottom door and saw Chain 2 on the floor. This was just about the last thing we had expected. Chain 2 had not been used at all since the button-up only two weeks earlier; also there had been no dead short to ground on the inductor supplies, an effect which has emphatically characterized every previous chain break. In this case, Chain 2 had broken when it was not in use, and had fallen with such unobtrusive grace as to do no more than affect one inductor only intermittently. Chain 2 had operated for 5,700 hours; however, at the last tank opening, a length of it was replaced with some pellets from the Chain 3 break (33/2). As stated, this chain was never turned on after button-up, though it was run during charging tests. We emphasize that the chain was nominally stationary when it broke. This was in contravention of Robert Rathmell's advice (32/1), regrettably ignored at times, to avoid operating at a high gradient when a chain is stationary.

We lowered the platform in order to check the column. Chains 1 and 3 were examined in the terminal and two cracks were found in the nylon links of Chain 3, a brand new chain which had operated for 280 hours and been in the machine for just two weeks. Since chain 3 had stretched, we were able to remove the faulty

links without having to put back others. The same scrutineers found no cracks in Chain 1 (1,200 hours operation; three months in the tank). After ritual cleaning we closed the tank the same day, with only two chains.

Hitherto we have made a point of issuing a report following each tank opening. Now, a day or so after the demise of Chain 2, we are no more sure of the reason for the chain breaks than how to prevent them; also David Weisser is visiting Caltech, and is at least one telex behind the turn of events. This prologue replaces the usual report and summarizes the present situation before we try to do something about it.

(The younger author took no part in the above cri de coeur; I did the cri-ing alone.)

T.A. Brinkley.
23 March 82

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"Go, rub your chain with crumbs!".
("Twelfth Night".)

After informing N.E.C. of the latest chain break, and the new cracked links, we began our efforts by reading our own Tank Opening Reports; some back numbers led us to look at the alumina in the dryer. The existing charge, used for only 13 months, appeared to be in excellent condition. Nevertheless we took it out and stored it, replacing it with a full new charge. Next day a telex from N.E.C. arrived expressing their profound belief that breakdown products were greatly, if not alone, responsible for our chain failures. They recommended, 1): That we should immediately replace the alumina in the dryer; 2): That we should take out all the chains, wipe them with a dry cloth and store them in a dry place while we recirculated the gas through the fresh alumina for a few days; 3): That we should then put back only Chain 1 until we considered the gas safe. 4): The gas would be safe when a small nylon cable tie, stressed on the normal setting, would not spontaneously break after x days. Surprise! x is still unkown. They asked us to send samples of links from Chains 1 and 3, and these were posted immediately.

Having already changed the alumina we decided to leave the two chains as they were and continue the scheduled runs for another week until David Weisser returned from Caltech, then we would make up our minds what policy to follow.

Opinions, information and advice in follow-up communications from N.E.C. are summarized below; the statements, though condensed, are virtually in N.E.C.'s own words.

1) In 1975 Sao Paulo chains developed cracks in as little as 100 hours. They completely eliminated the problem by installing a larger dryer and increasing recirculation rate.

2) The A.N.U. breakdown product problem has reached a critical stage and it must be assumed that the recirculating system has become completely ineffective. N.E.C. are not sure whether this is because of inadequate flow or bad alumina, though the latter is suspected.

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3) Past periods in which A.N.U. has had reasonably long chain lifetimes suggest that the recirculating system is adequate; however, the present A.N.U. practice of reactivating the dryer once per week is too frequent, and might actually be harmful. A frequency greater than about six times per year is not recommended unless rising tank humidity indicates reactivation is needed sooner.

4) Tests at N.E.C. have revealed that nylon tie-wraps for bunching cables are a good indication of breakdown products. N.E.C. recommends that it would be useful to modify piping before and after the dryer with windows to monitor tie-wraps under tension, contending that, when the recirculating system is working properly, no tie-wraps should break.

5) The machining marks on nylon links pointed out by A.N.U. cannot be assessed until they are examined by N.E.C. but it is doubted whether they constitute defects because of the meticulous inspection which is part of the assembly procedure. Experience in many accelerators has shown that these scratches do not limit lifetime, but in the presence of SF_6 even unblemished links fail.

6) Given the present situation, it is not a good idea to install a new chain in the near future.

7) N.E.C. sent A.N.U. a copy of an article on insulating gases from the 1981 SNEAP proceedings and drew attention to statements by Charles Carlson of Brookhaven and Dennis Croll of Air Products and Chemicals, that alumina eventually loses its ability to remove SF_6 breakdown products, though it still dries the gas. From the SNEAP report, though, we might conclude that this time is from 2 to 10 years, rather than 13 months.

8) A.N.U. should study chains when running to ensure there is no resonant oscillation in the "stiff" direction. (This is always done at tank openings, but at the next one will be given extra attention.)

9) Following receipt and examination of the sample links from chains 1 and 3 N.E.C. stated that the cracking seen in Chain 3 is certainly extreme for such a short running time. They agree with A.N.U. that some difference in processing, probably the machining, has enhanced the rate of attack and cracking. However, evidence clearly supports the position that nylon links like those in Chain 3 are suitable and reliable for use in chains if SF_6 breakdown products are well controlled. N.E.C. have examined under a microscope samples of links from many different separate manufacturing runs and can detect no substantial difference in surface finish or machining marks.

10) N.E.C. have investigated the cost of completely polishing out all machining marks from the links without using coolants, water, oil etc, and find it can be done for about 25% increase in chain cost, which must be passed to the buyer.

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When David Weisser returned, and we once more had a quorum, we decided to continue running with the two chains. The SF_6 had already been recirculated through the new alumina for nearly two weeks and, at this stage, there seemed little point in removing and wiping the chains.

Taking N.E.C.'s advice we stopped the weekly reactivation and looked around for a new number. From the seven responses to our chain survey as yet received, we find that no-one reactivates more frequently than every two months; at Heidelberg they reactivate once a year and at Argonne they don't reactivate at all.

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The precision of this information led us to settle hesitantly, for the time being at least, on a flexible figure of round about once a lunar month.

We are contemplating carrying out future reactivation at higher pressure in order to increase efficiency. If one throttles the exhaust valve on the dryer to achieve the same 5 SCFM flow of nitrogen the pressure in the dryer rises to 45 p.s.i.g. Thus three times the quantity of nitrogen is in contact with the alumina and the thermal gradient between the internal heating element and the alumina is reduced. Also, since we speculate that the concentration of breakdown products is higher in the gas phase than in the liquid phase we shall avoid, as far as possible, taking SF_6 from storage in the gas phase.

We propose to revive our lapsed investigations into breakdown products, using a residual gas analyzer. Comparing our gas with that of other laboratories we have to take into account the fact that some machines have enclosed corona points and some conversions have none at all. Breakdown products are generated in widely different intensities in different machines, in part by corona currents, but largely by conditioning activity and full discharge.

The above discourse relates entirely to breakdown products; however, while we accept that they play a significant part in chain breaks, we have yet to be convinced that their attack can be so virulent as to induce cracks in a new chain after merely two weeks exposure, especially since the companion chain had been exposed for three months and had no cracks. This history is consistent with the hypothesis that a new chain would have a much higher water content than a veteran. This water, in combination with breakdown products and almost immediately applied gradient, causes attack upon the nylon.

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Now to proceed with the report for the most recent tank opening:

REASON FOR TANK OPENING

The terminal foil stripper mechanism jammed.

PREAMBLE

The 14UD was last closed on 18th March after a one day tank opening discussed in the prologue to this report. Following closure the machine ran well on two chains for the first experiment at 13.4 MV and the schedule continued uneventfully until we encountered trouble with the second stripper. Operating the mechanism did not eliminate the doubly stripped beam and we concluded that a foil had fallen across the beam path. Some dogged persistence with a microamp of Br beam eventually cleared the fault and we concluded that we had burnt the foil away. About a week later, on the day before Good Friday, it was the terminal foil stripper's turn, and it became clear that the mechanism had jammed. Enthusiasm for pumping out during Easter waned in direct proportion to the seriousness of the suggestion and the 14UD was allowed to relax for the four days.

OPERATIONAL TIME

During the 24 days since the last closure, the 14UD operated for 436 hours. This was 91% of elapsed time, exluding the days for gas transfer and the four days of Easter when the 14UD was off the air awaiting the tank opening.

THE TANK OPENING

Exploratory tour.

There was a thick brown stain on the terminal opposite the stabilizing triode needles. A drooped corona assembly was found on the tube in Unit 8. There was much more oil on Chain 3 than on Chain 1, implying that the #1 oiler was barely working. This led to the discovery that the common vent valve had been closed by an unknown person at an unknown time; also that the #1 oiler was blocked.

When the upper terminal spinning was removed in order to attend to the foils we found, lying in awesome significance on the floor of the upper terminal, 5 broken nylon tie-wraps: the silent, accusing voice of N.E.C. The voice, nevertheless, spake not all at once because the upper spinning had not been raised during the two previous tank openings for broken chains. We last looked in the upper terminal on 9th February, which means that the 5 tie-wraps broke somewhere during two months. Even so, we do not belittle the visitation. From memory, rather than record, the tie-wraps were put in about three years ago.

When the terminal foil changer was tested by hand it was found to be jammed. It freed itself when it was removed. This apparatus is a locally 'improved' version of a standard N.E.C. foil changer.

And so to work!

The tube was let up to atmospheric pressure with nitrogen in order to remove the second stripper. When it was taken out we saw that about half the foils were exposed as doubles and parts of the foil frames had been intercepting the beam; this was presumably due to magnet drive slip. Foil frames in the second stripper are larger than those in the terminal and it is thus easier for them to get in the way of the beam. There were quite a few foil flakes in the region of the beam path, and the edge of one of the foil frames had been burnt through, a witness to the dogged persistence mentioned in the preamble when we thought we were assaulting a carbon foil.

Foils

The terminal foils were renewed. No clear removable fault was found with the terminal foil changer. It is merely of very marginal reliability because of our own design flaw. This latest experience spurred more vigorous efforts towards yet another redesign. In the second stripper we fitted foils only in alternate positions to minimize interference with the beam. Although this only gave us 134 foils, this number is more than adequate in a second stripper.

Shaft bearings.

We ran the shafts and listened to the bearings. Some are getting noisy, but are not bad enough to need replacement yet.

Points

On examination these appear, in general, to be getting dull, but seem to be working well enough. We are not comtemplating renewing them as yet. The drooping point assembly was de-drooped.

Chains

Chains 1 and 3 were examined with great thoroughness, but we found no further evidence of cracks. Both chains were run and studied for signs of ripple in the stiff direction, as N.E.C. had suggested; we found nothing abnormal.

Miscellaneous

Some tie-wraps were put, with standard tension, round one of the legs, in the bottom of the tank. They will be inspected, if we remember, at each tank opening.

Cleaning

Blowing and tac-ragging was, as usual, by no means neglected.

Button-up

Charging tests went excellently and the doors were closed at just the right time for the apres-buttonup conference, 5 p.m.

Initial performance

The machine performed well with its two chains and there has been a significant amount of operation well over 13 MV with periods at 13.9 MV. It has been conditioned up to 14.2 MV.

Super Buncher tests at Caltech.

Applied Superconductivity and Caltech are selling us a lead-plated copper superconducting resonator system for use as a rebuncher on the 14UD. All performance test criteria were easily surpassed during two weeks of assembly and testing. The device should arrive in Canberra within a couple of months and be integrated into our beam pulsing system soon.

D.C. Weisser

T.A. Brinkley

8th May, 1982

ERRATUM:

In the appendix to Report No. 32 we gave a wrong date for the Munich MP conversion. N.E.C. chains were fitted in 1975 and N.E.C. tubes and corona tubes were fitted in 1976.

Enclosures:

Plots of particle masses accelerated, and operating terminal voltages.

NOTE: On the plot of terminal voltages we have drawn a horizontal line at 14 MV for easy reference to performance near the nominal voltage limit of the 14UD.

Appreciation follows:

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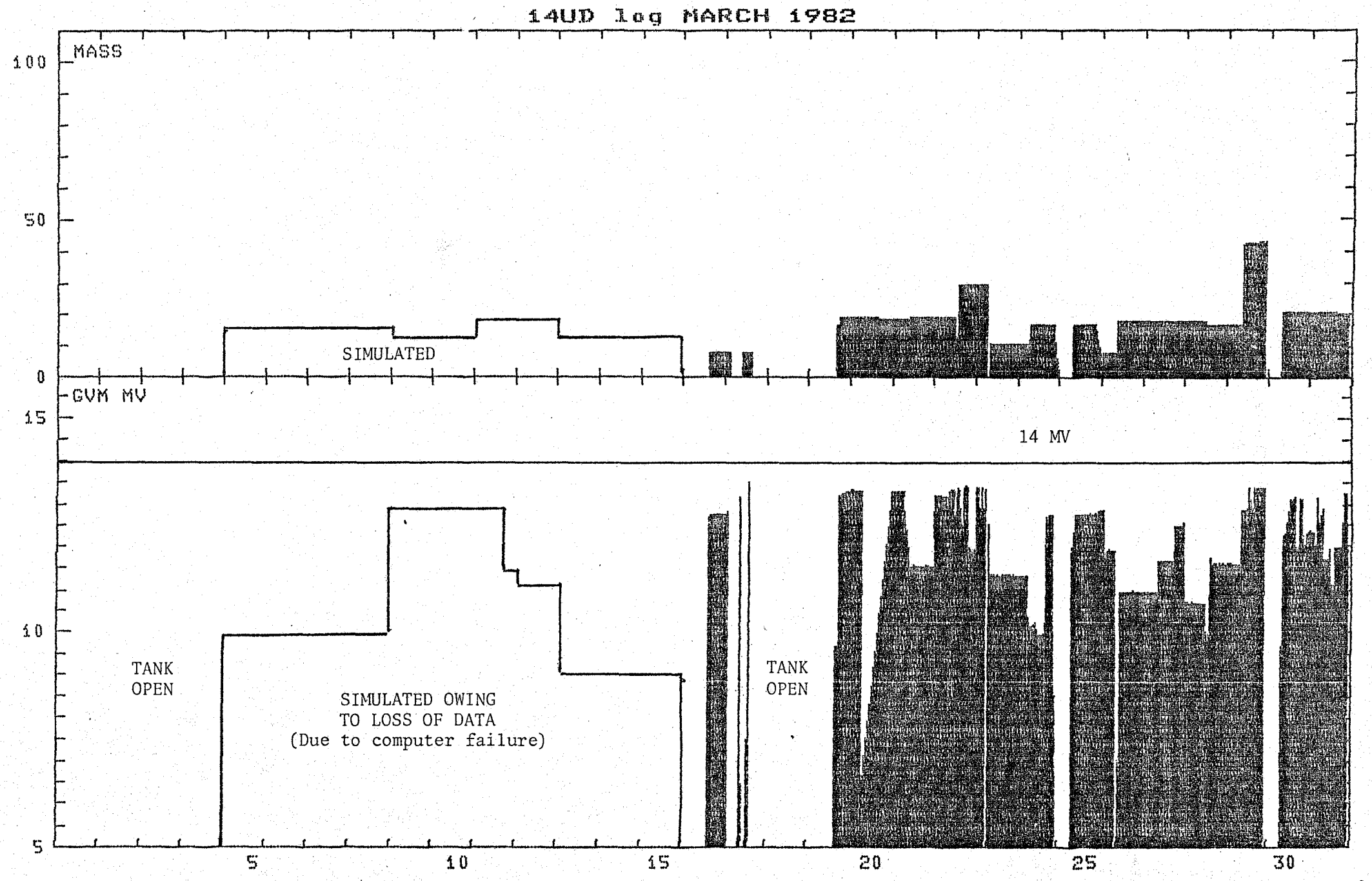
We would like to thank the following who have been kind enough to respond to our survey of chains in N.E.C. machines and conversions:

Neil Burn, Chalk River MP
Don Walker, Chalk River 2UH
Heinz Muenzer, Munich
Seiji Seiki, Tsukuba
Chiaki Kobayashi, J.A.E.R.I.
Robert Kaim, Rehovot
Pat Den Hartog, Argonne
Roland Repnow, Heidelberg.

This appreciation should, in no way, be taken as any form of hint to those who have as yet been too busy to complete the survey.

D.C. Weisser

T.A. Brinkley.


14UD log MARCH 1982
MASS
100
50
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SIMULATED
GVM MV
15
14 MV
10
5
TANK
OPEN
SIMULATED OWING
TO LOSS OF DATA
(Due to computer failure)
TANK
OPEN
5
10
15
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25
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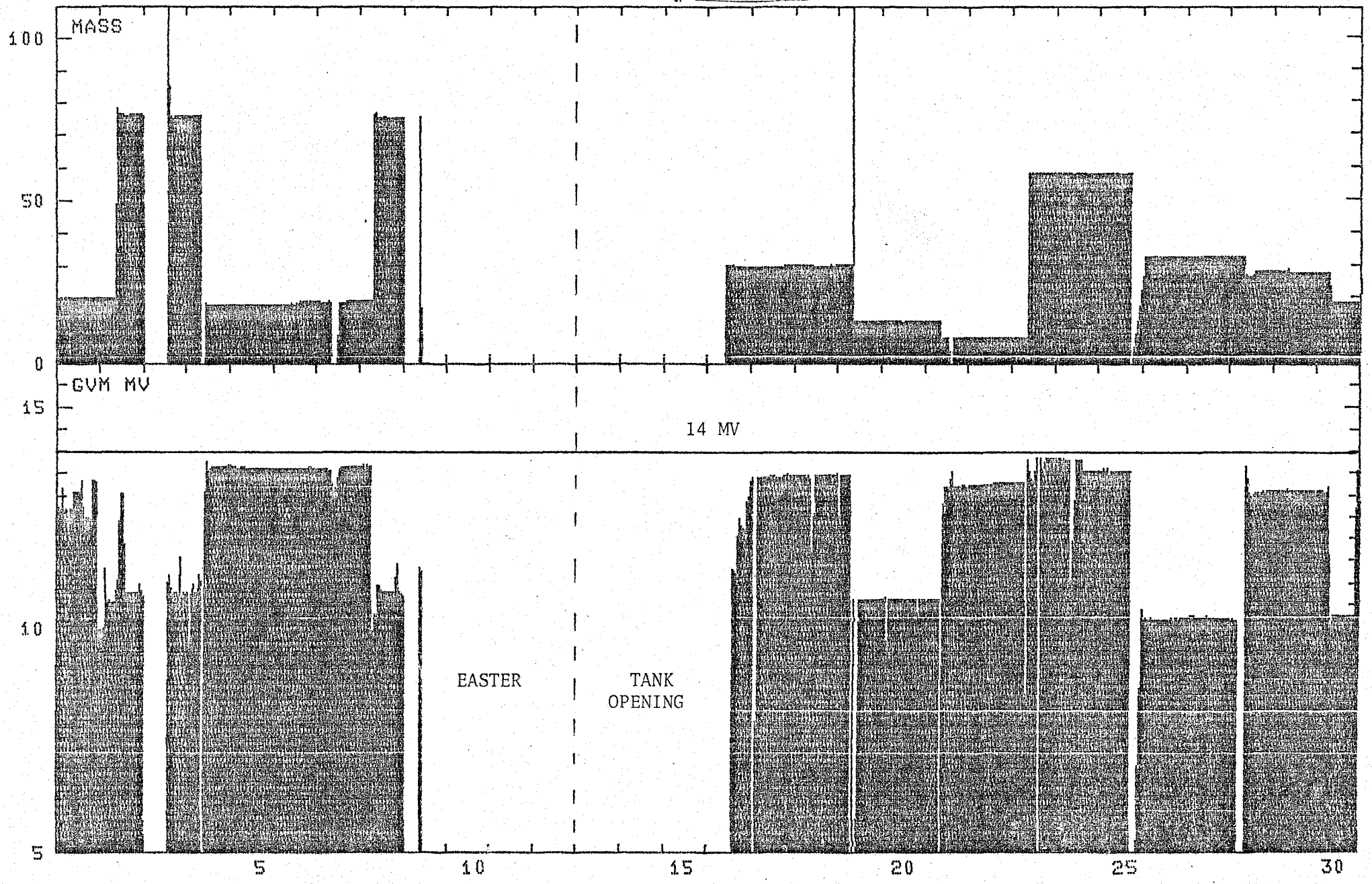
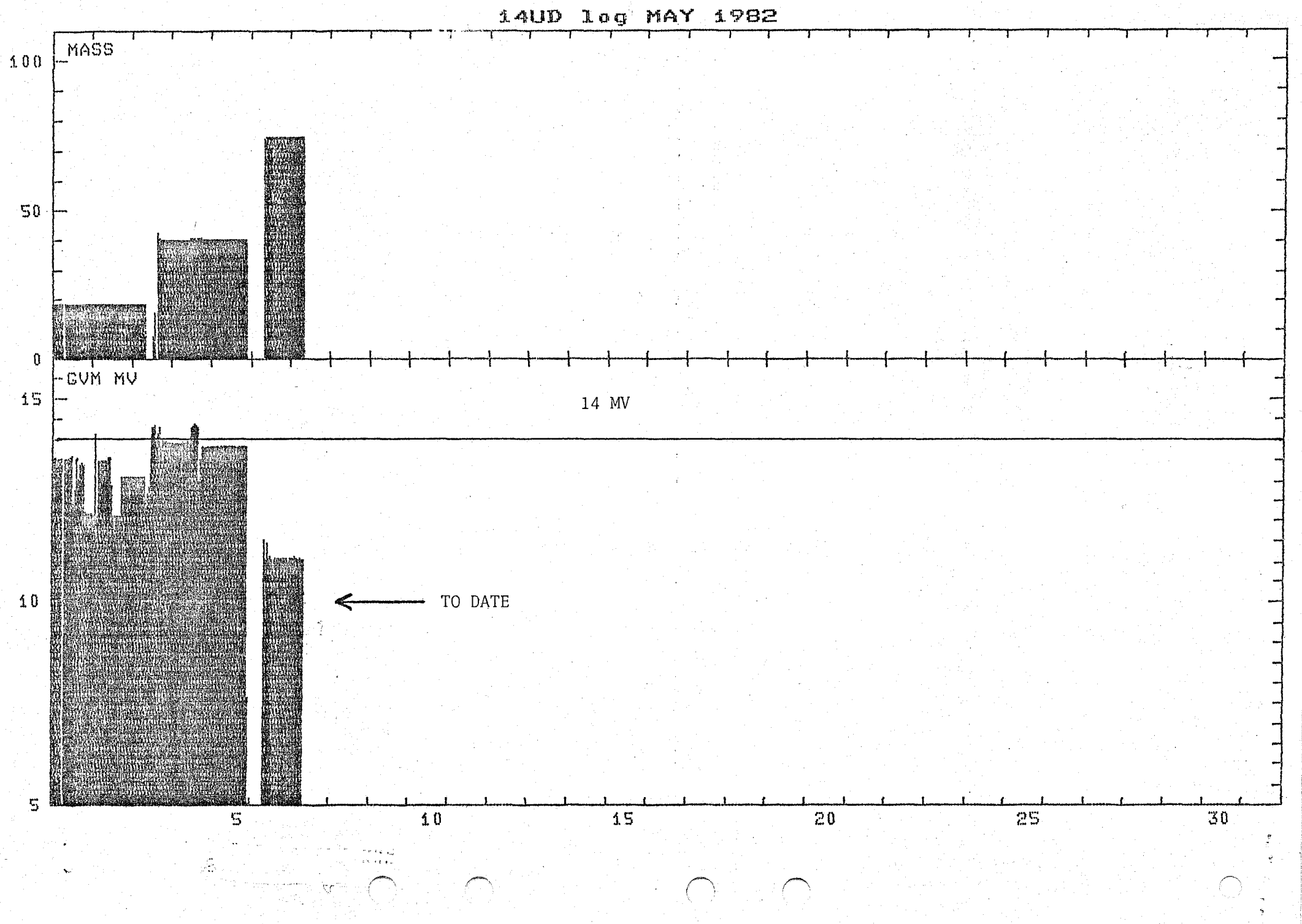
14UD log API L 19[illegible]




14UD log MAY 1982
MASS
100
50
0
GVM MV
15
14 MV
10
5
TO DATE
5
10
15
20
25
30