AUSTRALIAN NATIONAL UNIVERSITY
DEPARTMENT OF NUCLEAR PHYSICS
14UD TANK OPENING REPORT No. 48
Two openings.
20th to 28th November 1984.
(9 days open.)
8th to 10th January 1985.
3 days open.

REFERENCES: Earlier Tank Opening Reports are referred to by the notation (38/4) etc, meaning Report No. 38, page 4.

REASON FOR THE FIRST TANK OPENING

Problems with lost charge which were serious and confusing enough to give us no alternative but to open the machine.

PREAMBLE

The 14UD was last closed on 12th October. It misbehaved for the first day then settled down to high voltage running. An interval of five days below 5 MV was followed by an almost troublefree spell at 13.5 MV which took us well into November. At this stage, lost charge was about 15 microamps. Just before midnight on 13th November the experimenter wound down the charging volts, turned off the ion source, closed all the right valves in the right order and went wearily and virtuously home - leaving the chains running with no charging volts. This, unhappily, is a big "no-no", because under those conditions, the terminal charges negatively and the needles on the corona assemblies point in the wrong direction for smooth gradient down the column. This leads to a negative voltage buildup in region of the terminal. When breakdown occurs, the surge continues down the column, the time constant of which determines the next spark.

At 7.30 a.m. next day the first arrival in the control room noticed the situation and turned the chains off, having recorded that sparks were occurring for about 2 MV indicated terminal voltage.

At startup later that morning lost charge was very high, 98 microamps for 13.3 MV without beam in the machine. We carried out diagnostics with shorting rods and established that lost charge depended on terminal voltage, and radial gradient (column to tank), not column gradient. The SF6 was tested for moisture and hydrolyzable fluorides and found to be satisfactory. We concluded that the lost charge we were seeing was due to corona from particulate matter on the walls in the form of solid SF6 breakdown products, driven there in abnormally high concentration by the protracted sparking. The machine was offered to experimenters who could run at about 9 MV until the following

Monday, when we planned to take out the gas. Lost charge of 33 microamps persisted, even at this voltage.

OPERATIONAL TIME.

During the 39 days since the last closure, the 14UD operated for 668 hours. This was 79% of elapsed time, excluding the days for gas transfer (42/2) and the weekend when the tank was left roughing after the last closure (47/6).

THE TANK OPENING.

The doors were opened at about 5.30 p.m. when the only qualified sniffers were in the darkroom, therefore the subtlety of that first moment was lost irrevocably and cannot be quoted.

Exploratory tour.

In view of the uncertainty as to what had gone wrong, and what elusive clue might be missed, the exploratory tourists on this occasion were the most august assembly yet to descend the column at the same time: Trevor Ophel, David Weisser, Bob Turkentine and the older author.

Nothing was found mechanically wrong in the machine and there were no short points in units 15 and 16 (47/2). It was soon very clear that continued sparking due to a negative terminal had thrown a lot of particulate matter about the machine, some of it coming from the accumulated deposits on the corona assemblies. Debris had collected on the castings round the bottoms of the posts and opposite surfaces of the L.E. rings were rough from local sparking. There was white powder on rings opposite the gas recirculator input to the tank, in spite of recent efforts with the filter. The tank wall was gritty and dusty. There were spark patches on many casting covers where they faced rings, but surprisingly none at places where there were old wounds from being handled unlovingly. The L.E. column was more dusty and gritty than the H.E. and this seemed to be because oil on the H.E. column prevented debris there from being distributed. Oily globules were seen on the tank wall near the terminal. Black, oily deposits were found on the pellet rims of Chain 1. The appearance of the blobs was consistent with instabilities seen on the pickoff traces for that chain. The section of L.E. tank wall opposite the column corona points was more gritty than elsewhere; this was consistent with severe voltage sparking dislodging solid breakdown products and sending them to the tank wall from which they caused corona, resulting in lost charge. This subtle, tactile observation was also consistent with it being in support of the theorist fondling the wall.

Because of the overall condition inside the machine, more attention than usual was paid to tube and post gaps. This led to

the discovery of a fine, vertical line across one of the post ceramics. Because the line was pointed out by the older author, who is traditionally held to lack proficiency in the use of his bifocals, not a great deal of enthusiasm was shown at first. However, the line did not appear to be a surface mark and more youthful and critical eyes assessed it as a fine crack in the ceramic. We could do no more than note its position and plan to keep a check on it.

The lower tube to column stringer in Unit 14 was missing; it had been spark eroded close to the post and the loop was still under the fixing screw, whereas nothing was left on the tube flange. The stringer was found in the terminal. A deep wear mark about two inches from the end made it clear that the beryllium copper stringer had been held against the shaft by its own springiness when it broke from the post. Examination of the shaft showed 3 score marks in the perspex; these had been caused by sparking when the shaft was not running.

And so to work!

The dirty condition of the column and the wall of the tank not only accounted for the heavy lost charge, it also substantiated our diagnosis. We set about a thorough cleanup, including attention to all rough surfaces on rings and casting covers. We took all the L.E. covers out of the tank and a willing team of conscripts, including the sad, absentminded experimenters who had left the chains running, worked their fingers to the bone with emery cloth, orbital sanders, linear sanders and substances and recipes cherished by polishers over the centuries. All the L.E. rings were smoothed with emery tape. The tank wall was tacragged and the debris that had been dislodged from everywhere was assaulted with another multitude of tacrags. The H.E. rings and covers, distinctly less troublesome because of the oil, were cleaned as well as possible.

In the tranquillity of early morning, before the hubbub began, an observer went into the tank having suffered during the night from the conviction that if there was one cracked post ceramic, there might be others that even he could see. Because the lowest units take the weight of the entire column, including the terminal, those ceramics could be expected to show the first signs of mechanical failure. Starting at the bottom the front halves of the ceramics on each post were examined (the rings were still on in most cases). A variety of marks turned up, a lot of which were horizontal 'tidemarks' on the H.E. column where ceramics had been cleaned of splattered oil from the chains, but there were also vertical marks. In Unit 16, below the terminal, there were two vertical cracks on the same ceramic. They were thin, and would obviously have to be subjected to a high voltage resistance test.

Above the terminal, in Unit 12, one of the post ceramics was in such a condition that it wouldn't have mattered which way up the bifocals were used. There were several thick cracks, one

running part way round the ceramic at about 45 degrees and met by vertical cracks above and below it. There was a cavity several millimetres deep where material had fallen away. A feeling of dismay quickly gave way to one that this was the most serious and ominous failure that we have ever encountered in the 14UD. (Photographs).

Continuing the search up the column revealed no more ceramic failures on the front halves of the posts. Later in the morning a resistance test was made between adjacent rings throughout the machine at 7 kV, (in other words, where rings were still on, all four posts were measured together). As well as the badly failed ceramic, which was an effective short, two other ceramics gave the same indication, yet not the one with two cracks at the top of Unit 16.

We then took enough rings off all units to examine the backs of the posts using lights and mirrors. Four young, visually acute observers took a post each and every ceramic in the machine was checked.

Having only two spare posts, both defective, we chose the one removed in November 1973 because of spark-damaged electrodes and put it in place of the one now found to be faulty. The three defective gaps, two with short circuits and one with damaged electrodes, were strapped with stainless steel hose clamps which were put, not only on the defective posts, but also on corresponding gaps on the other three posts. This shorting technique was reported by Tom Aitken , at the SNEAP 84 meeting.

In general, most of the ceramics we tested at 7 kV gave currents of about 5 to 8 microamps, corresponding to about a thousand megohms. These currents were probably due to moisture on the surface; the post we took out was tested on the bench at varying temperatures. Higher temperatures gave rise to lower currents across the gaps, even for the crumbling ceramic. This would be consistent with moisture in the crack.

Chains:

The chains, which had not been fully examined for some time, were given a thorough check on this occasion. No cracks were found in any links. We are still running with only two chains, having already said (46/4) that the 14UD runs beautifully with them.

Idlers:

The stabilizing idlers were checked in all positions and there were no signs of failures. The contact springs on the d.c. idlers were all in good condition.

Foils.

Foils.

The terminal foils were renewed as necessary. We change them as a routine now when the machine is open.

Shaft bearings.

The bearings were accepted without tests.

Points.

Though the points in units 13 and 14 were dull, we didn't renew any in the machine.

Insulating gas.

Tests made from time to time since the last closure - usually when we had something to be apprehensive about - gave satisfactory values for both moisture and conductivity.

The A.N.U. conductivity cell was sent to N.E.C. in March 1983. We reported (39/2) that they had tried it on their test machine and measured a resistance change of 200 kilohms/hour. Later it was used at Oak Ridge where the readings indicated no problems with the gas. The cell's next destination was McMaster, where it has probably arrived. As we said (37/10), we shall be glad to lend the equipment to anyone interested.

Miscellaneous

The year's history.

From the 1st January 1984, to the closure date of this occasion, the tank was opened 7 times. In all, the doors were open for 29 1/2 days. Adding gas transfer time, the machine was out of commission because of tank openings for 46 1/2 of the 333 days elapsed. From the start of the year until this tank opening began, the machine operated for 5808 hours. Taking (333 - 46.5) x 24 = 6876 as the number of hours for which the machine was closed and gassed up, it operated for 84.4% of this time. That is to say, all off-time other than for tank openings is included.

Button-up.

During the charging tests, bearing noise was heard on the Chain 1 pulley. It was replaced with the unused pulley from the

No. 3 position. The spherical bearing surface was worn, indicating the source of the material in the oily blobs found on the Chain 1 pellet rims.

Initial performance.

Performance at startup was worth all the effort. There was 1 microamp of lost charge for 13.25 MV with no beam in the machine. Later, at 13.34 MV, with beam in the machine, stability was excellent and there was a bright smile on the face of David Weisser, the wall-fondling theorist referred to earlier.

The post with the crumbling ceramic was sent off by air freight to N.E.C. for their assessment. In order to avoid encumbering N.E.C.'s evaluation we made no attempt ourselves to determine the cause of the damage, or its extent.

The machine continued behaving well until 10th December, when it became very unwilling to hold volts at 13.3 MV. There was also a curious effect with the charging current on Chain 1: it went negative when charging volts were started, then went positive, with lost charge behaving correspondingly. We decided that the insulation which separates the charging pulley from ground, in order to meter charging current, was failing and that the peculiar negative readings crossed over to positive when terminal voltage was high enough to give tube and column corona currents. (We take charging, 'up', and corona and triode 'down' currents to a busbar which is grounded through the lost charge meter). This effect, however, had nothing to do with the 14UD's intolerance of higher voltages. On 11th December charging currents were unstable and the pick-off trace for Chain 2 was bad. We found that the machine ran better with only one chain, though it wasn't clear which of the two was the better. Chain 2 was chosen to stay off, largely because its pick-off trace was said to be worse than that of Chain 1. Once again we handed over to the ever-accommodating group who have such success with their low voltage runs. The closeness to Christmas, and shorthandedness because of annual holidays, made us decide to hang on with low voltages until 7th January. Because another opening is not far ahead, this report will be held back to include those details.

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The Second Opening.

Exploratory tour.

Once again the first sniff was missed by both the established sensors; the report by an inexperienced learner, commendable

though its initiative was, was discarded on the grounds that "Not bad" was neither here nor there.

The coating of fine grey dust, nearly always seen on shiny surfaces, was much more heavy than we would have expected since the last closure; a hand stroked across rings, casting covers or the terminal was discoloured by the dust and the surface rubbed was left shiny.

In Unit 27 a nylon pneumatic pipe had broken at the casting surface and had come to rest on the heater plate feedthrough at the junction of the second and third tube sections. In the unit below, two more pipes had broken, but had not fallen. We mentioned (47/4) how brittle these pipes had become and how easily they broke. Because it's a bit of a fight to feed in new pipes, and this had to be done last time, we suspect that some of the 12 pipes in the bunch had been triggered on the road to failure. The broken pipes fed the actuators of both the terminal foil directions and the second stripper reverse. At least one of these functions had failed, one was intermittent and there were conflicting reports about the third. Also in Unit 28 a tube point had drooped onto the one below.

In the lower terminal we found, in the Chain 1 position, that the grubscrew which attaches one of the crossover wires to its inductor was missing and the wire was quite loose in its connection hole. This would certainly account for erratic charging and, presumably, a bad pickoff trace, but not on the chain reported. Pyrotenax from the lower terminal main alternator to the heater plate transformer was found to be burnt through and one of its conductors was shorted to ground. Another pyrotenax fault was detected but was not pursued because of limited time available.

The d.c. idlers were good for both chains, with their contact springs still complete. Stabilizing idlers in all positions were good, and we very pleased about this, yet cross our fingers each time we find them so.

In the bottom of the tank we confirmed our diagnosis for the anomalous behaviour of charging currents described above in Initial Performance. The bearing insulator of Chain 1 had failed, taking the charging current for that chain directly to ground, bypassing the common metering point.

Most serious of all we discovered, when checking ceramics on post insulators found to have fine cracks at the previous opening, (page 3 of this report), that two of them had worsened noticeably during the 40 days since they were last seen. Having received no report from N.E.C. since we shipped the damaged post to them early in December, we did the best we could and strapped the electrodes on each side of the cracked ceramics with more hoseclips. N.E.C. telexed us to say that the post was located in customs on 11th January, nearly five weeks after we had airfreighted it. A few days later we had another telex telling us that the post had broken in transit at the bad ceramic. N.E.C. recommended that we replace posts with cracked

ceramics, but delayed comment on the failures until they could be investigated.

T. R. Ophel

T. A. Brinkley

21st January 1985

Authorship: During the past year, Trevor Ophel, (Deputy Head of the Department), took over responsibility for running the 14UD in order to allow David Weisser to concentrate on the module, (42/8). David will resume the younger authorship in 1985. No change in regard to the older author has yet been threatened.

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.

Photographs:
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1). The worst region of the crumbling ceramic.

2). Vertical crack further round same ceramic.

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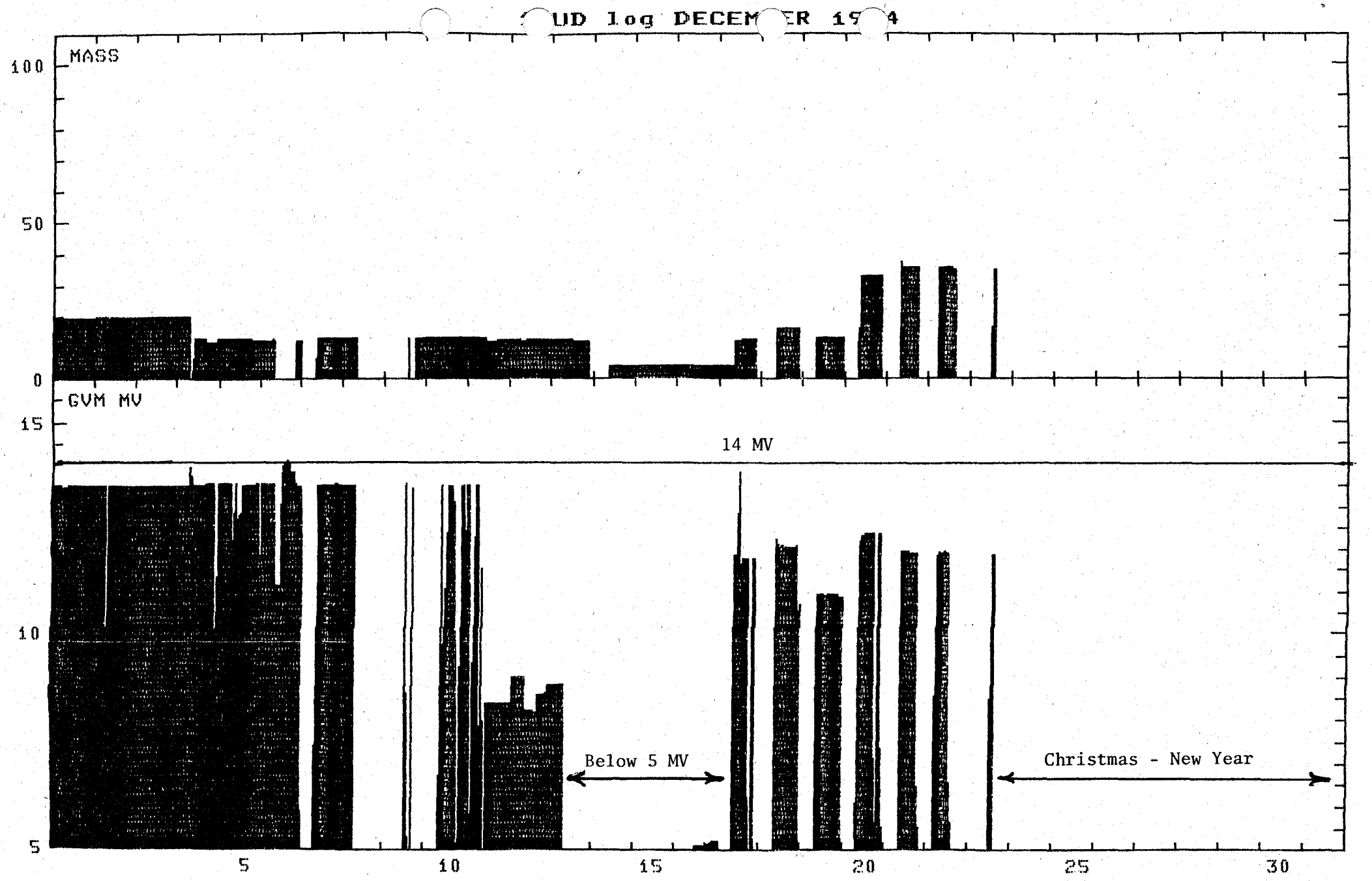
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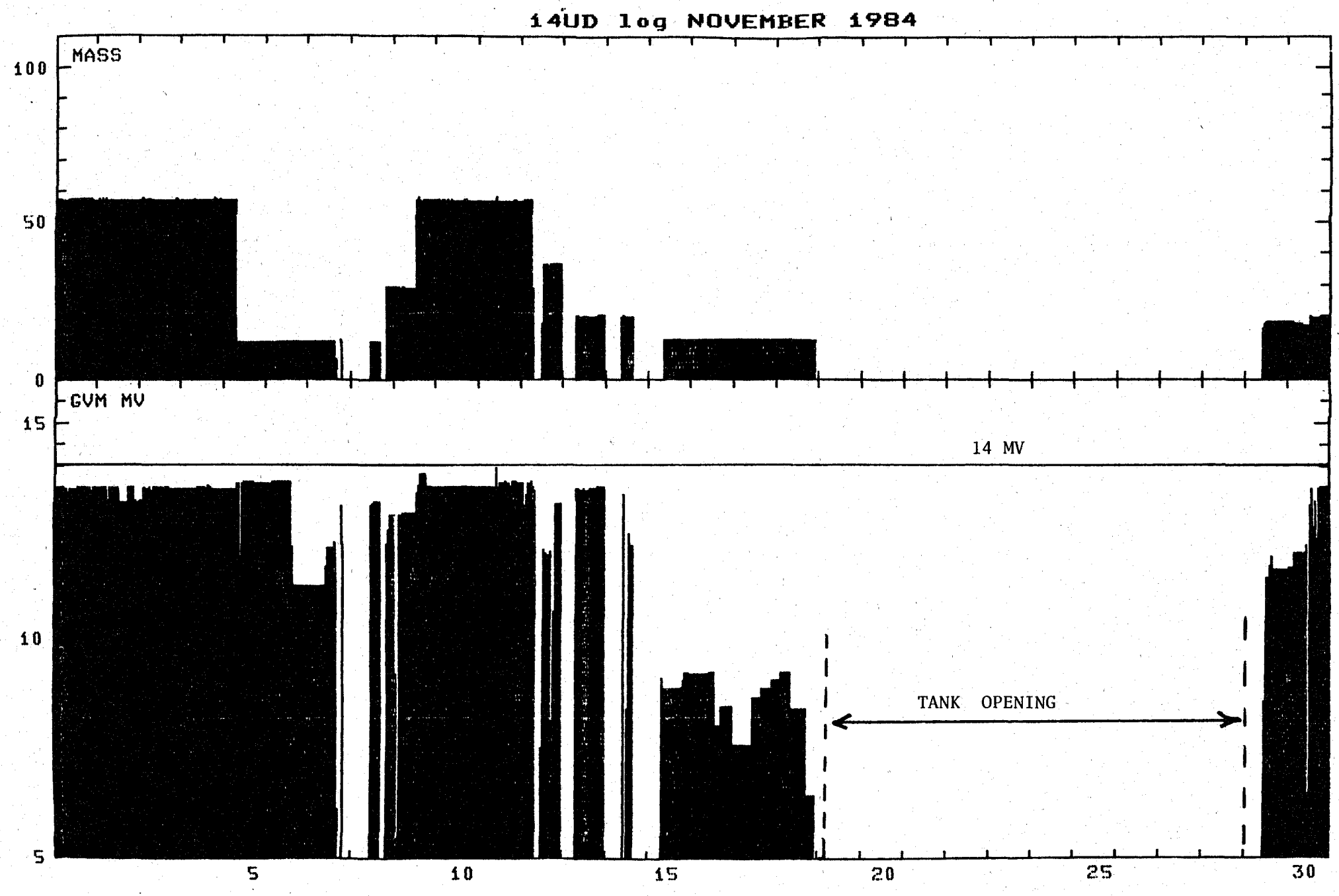
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