AUSTRALIAN NATIONAL UNIVERSITY

DEPARTMENT OF NUCLEAR PHYSICS

14UD TANK OPENING REPORT No.42

Two Openings:

4th November to 1st December 1983

(27 days open; 19 working days)

and

14th and 15th December 1983

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

REASON FOR THE FIRST TANK OPENING

There was a leak in the H.E. tube somewhere in the tank.

PREAMBLE

The 14UD was last closed on 23rd September. We reported (41/8) our concern about the inevitable effect on breakdown product production caused by much higher corona currents with the new corona points. We tested the gas at frequent intervals with the conductivity cell, obtaining results which did indeed confirm that the equilibrium levels of breakdown products were substantially higher.

During the first week of operation, the moisture content of the gas was relatively high (dewpoint at atmospheric pressure - 42°C) and the responses of the conductivity cell were two to three times greater than would have been expected for the prevailing total corona currents of between 90 and 125 microamps. Two reactivations of the alumina/Vivalyme reduced the dewpoint firstly to about -48°C and finally to below -65°C. In this period, between October 5th and November 3rd, the conductivity cell response was normal, i.e. about 1 kilohm/hour for each microamp of corona current. Total corona currents during operation ranged between 65 and 150 microamps. The largest response measured was 114 kilohms/hr and the gas at the inlet to the recirculator had a slight sulphurous smell. When anomalously large responses were observed previously with moist gas, it was found that only portion of the response was due to hydrolyzable fluorides in the gas. It is possible that significant hydrolysis of thionyl fluoride (SOF_2) begins to occur at high moisture levels, producing sulphur dioxide which would cause large conductivity changes.

So far as the performance of the machine was concerned it can be seen from the plot of operating voltages enclosed that there was almost solid running in the region of 14 MV for much of October. All continued well until the early hours of 3rd November when a tank spark at 12.98 MV caused the pressure in the H.E. tube to rise to 7×10^{-7}. There was very heavy loading and the machine was closed down for the remainder of the night. Some hours later, during an attempt to complete the experimental run, 3 sparks within 2 minutes caused the H.E. pressure to rise very quickly to the 10^{-4} range. Trips began to operate, closing valves and switching off pumps.

2/...

The next morning, Friday 4th, we confirmed that the leak was inside the tank and that the tube pressure had risen to greater than 1,000 microns, but less than atmospheric. We began to take the gas out of the tank and the doors were eventually opened at 4.45 pm. The two authors agreed, at their simultaneous first sniff, that the atmosphere in the tank was "a bit acrid, but not too bad!".

OPERATIONAL TIME

During the 41 days since the last closure, the 14UD operated for 802 hours. This was 93% of elapsed time, excluding the days for gas transfer and 4 days when the machine was off for major chiller reorganization. Our estimate of operational hours is intended to indicate the serviceability and usage of the 14UD accelerator. We therefore exclude from elapsed time periods when the machine was scheduled off through no fault of its own, stating reasons; however, all breakdowns of the accelerator, sources, peripheral equipment and neglect of opportunity by slothful experimenters, are included in time elapsed between tank openings.

THE TANK OPENING

Exploratory tour.

Our first interest was to look for stain on the corona assemblies which had been put in new and clean at the last tank opening. The characteristic brown stain was on the column assemblies. We took one off and rubbed the stain with a tissue moistened with water. The stain was harder to remove than brown stains in the past. When it came off we found that it had taken the tin plating on the assembly with it.

On the tube assemblies there was a light grey deposit which could, with imagination, be termed greenish grey; it was certainly not pistachio, (35/2; 38/3).

In casting 19 a stabilizing idler in the up position of Chain 3 was in very bad condition. The bearing had seized and the tyre surface had been shredded by the chain. The spark shields at that position were coated thickly with fibre from the damaged tyre. The fibre shreds had also migrated to other units in the H.E. column. There were stalagmites of fibre between rings and on the castings.

Scanning the new corona assemblies to see how they had fared, we found that tube assemblies in two consecutive positions were missing in unit 17. The assembly below had one of its three needles worn to a stump and the other two were heavily worn. After searching the column and the bottom of the tank for the missing points we discovered that the nuts in the tube brackets were each stripped of thread, forcing us to concede that once again (40/5), we had buttoned up with corona points missing. We were utterly taken aback because the younger author had set every point assembly in the machine with Robert Rathmell's point alignment device (40/5; 41/7) and the older author had independently checked every point in the machine. We concluded that people of our calling can suffer from point blankness and it's not an easy thing to cure.

We then went over all the point assemblies yet again and discovered one tube assembly on which all three needles had hooks instead of points; clearly they had been thumped against something hard before installation. In one tube position we found that column points, which are significantly longer, had been fitted. The gap was negligible.

3/...

We then took a good look at the tube sections in the H.E. section to see if there was any evidence of sparking or other damage which might have precipitated the tube leak. We found nothing of this nature at all.

And so to work!

The vacuum leak.

We decided to find and fix the leak in the tube before we got on with anything else. Since the H.E. vacuum was 10^{-4} and the ion pumps at the terminal and the H.E. stripper were reading low currents, it appeared that the leak was much closer to the H.E. pump than the terminal; in other words, not very far from unit 28.

A bourdon gauge was installed in the terminal to confirm that the tube pressure was of the order of 1,000 microns and therefore safe to open to vacsorb pumps. After vacsorbing from both ends the tube was opened to the ion source turbo pump. The best vacuum we were able to achieve was 10^{-4} mm and at this we began to look for the leak with the detector head just below the bottom of the tank.

We started at unit 24 and began to work down. For a long time we chased elusive and inconsistent responses in units 24, 25 and 26. Eventually we bagged these units, exonerated them and realized that the leak was much higher up the tube than our evidence had suggested; the responses we had seen were due to helium rising from where we had been spraying to the real leak which we finally located in the tube section immediately below the second stripper. We pinpointed it to the 7th ceramic from the top of the unit. Because the second stripper is a trouble spot we had considered it likely that the leak was in its vicinity, but allowed our inferences from the pressure gradient in the tube to override the idea.

We took out the tube section and found one of the ceramics to be cracked completely across its width (photo). The crack could easily be seen on the inside of the tube. There were dark spots on other ceramics due to spark over. Carbon foil flakes from the second stripper were found in the tube section immediately above the stripper. This section was also changed. There were no flakes in the section below the stripper and we assume the foils were negatively charged.

The electrode in the heater plate below the leaking tube section was blue and looked as though it had suffered. We contemplated it studiously for a while and decided, without a really good reason, to put another in.

When everything was back together again, the best vacuum we could get was 10^{-2}. We found that the heater plate we had put in place of the blue one had a leak at a feedthrough. Having no spares that didn't have "leaky" written on them, we put back the blue one and felt a certain amount of pride in reaching 10^{-5}; this pressure was due to leaks on gaskets. With more leak chasing, bagging, removal of heater plates and resetting gaskets that seemed to have nothing wrong with them, and polishing surfaces on heater plates, we eventually sealed the last stubborn leak with prayers dissolved in glyptal. Residual gas analysis showed no air leaks, just the original forepump oil. Subsequent tests after gassing up to 100 psia with SF_6 showed no change in pressure from 4×10^{-8} and no SF_6 peaks.

Progress of the tank opening.

It took us 7 working days to get the tube leaktight and down to a good vacuum again. The tank had been open for 11 days, including two weekends, and there was still a lot of work to be done. It was a significant factor that the team working on the installation of the additional gas purifier had made substantial progress and would be able to complete the job in a further two weeks if the machine was not gassed up and running. Because we were very anxious to have the additional purification, especially in view of the higher corona currents, we decided to defer button-up until the pipework was finished, making the best use we could of the extra time in the tank.

Chains.

At the previous tank opening in September we had found cracks in only one of the two virgin chains put in at the same time (February 83). We reported (41/4) that one of these chains, Chain 3, had cracks in about 10% of the links and we replaced it with the last brand new chain we had. A careful check of this chain, after 796 hours of operation, now revealed another crop of cracked links and it was taken out. We shall refer to the two chains removed from No.3 position as the September and the November chains respectively.

When the November chain was examined in the workshop we were surprised to find that the total number of cracked links, 16 in all, were entirely confined to one length of 58 pellets.

Brian England, who was visiting us from Birmingham, gave us a helping hand. He made an unhurried, dedicated study of the November chain and observed that there was an uninterrupted sequence of 110 pellets, all with severe spark marks on their rims. No other pellets in the remaining 435 in the total chain had any sparking between the rims. The first pellet in the sequence had a severe spark mark on its side and there was a similar spark mark 30 pellets later. The collection of 16 cracked links occurred well inside the limits of the 110 rim-damaged pellets. (Positional plot of this section of chain is enclosed.)

Brian then concentrated on the September chain. He found in all, only 6 cracked links and washed away with alcohol some crack-like marks. This score was considerably less than our estimate of 10% at the time that the chain was taken out; however, when recent chains have been found to have cracked links, we have made a rough count and then extrapolated for the rest of the chain rather than waste time in the tank with a chain that has got to come out anyway. We concede that in the case of the November chain, such an extrapolation would have been horrifying if the 16 cracks had turned up early in the count.

We had just received from N.E.C. our first chain with hourglass-shaped nylon links (41/4). We were unwilling to press this hourglass virgin into service for the time being and so we cut the anomalous length out of the November chain and replaced it with a healthy-looking length, thoroughly vetted, from the September chain.

At this stage, with only Chain 2 in the machine, we set about arranging a fresh start all round. We have been planning (40/5; 41/6) to take out all the A.N.U. stabilizing idler blocks and bearing systems and go back to the N.E.C. set which we had put aside. This was a good time to do so. All idlers were removed from all chain positions. We parted our treasured Chain 2 in order to establish its terminal pulley exactly in the desired position according to our recent

5/...

findings (41/5; 41/6). Before removing the terminal pulley we did some measurements to find out how the chain was centred in the chain holes in the castings when it hung freely as a plumb line. A plot of offset in directions parallel to the rivets and at right angles to them is enclosed.

We then set the terminal pulley correctly and confirmed with a precision square level that it was perfectly vertical.

The driving pulley was located with a plumbbob dropped from the terminal pulley and a slight adjustment was made to correct the 1 mm departure from vertical which the precision level revealed.

After joining the chain we put in the idlers, starting at the highest position and ensuring that no idler deflected the chain. When we were satisfied we ran the chain to see how it behaved mechanically. The up and down sides looked like motionless rods and the older author remarked that he had never seen chains running so perfectly. The younger author, whose persistence had brought about the effect, concurred smilingly. Whether a chain running like that will make any difference to chain life, or is merely pretty, remains to be seen.

The pulleys in No.1 position, which has been empty since February, were set in the same way as those in No.2 position. The new Chain 1, made from the September and November chains from No.3 position, was installed with equal care. Chain 3 position was left empty.

Capacitively Coupled Pickoff Electrodes.

As part of our effort to do everything possible towards understanding charging chains, and what happens to them, we had already made the capacitive pickoff electrodes similar to the Brookhaven design (P. Thieberger, SNEAP 1978). We installed them on the up and down sides of Chains 1 and 2, and when run in air, with the terminal shorted and a charging voltage of 8 kilovolts, the waveforms closley resembled Thieberger's in the SNEAP report. Well, almost. The 'up' side of Chain 1 displayed an apparent pellet frequency of one third of the frequencies measured on the 'down' side and of both sides of Chain 2. So far, no explanation of this anomaly has been proposed.

Foils.

Most of the terminal foils were changed. Because the tube was at atmospheric pressure in order to remove the tube section, we took the opportunity to change the foils in the second stripper also.

In the terminal stripper we found some foil frames burned through at the edges in cases where the frames had not been normal to the beam. (Xerox pictures made by contact printing enclosed.) This confirms earlier conclusions that, contrary to beam optics calculations, the beam is of the order of a couple of millimetres in diameter, rather than 6 mm.

Shaft bearings.

Upper and lower bearings in castings 18, 20 and 21 were renewed. These are the first bearings to be replaced in the lower shaft since all bearings in the machine were changed in August 1981. The lower shaft has operated for 13,336 hours since then. Because of a timer failure we have only an estimate for the upper shaft; it is 9,923 hours. This performance is consistent with the manufacturers' specification for our mechanical environment and suggests that there is no significant electrical or chemical contribution to premature bearing failures.

Points.

The mistakes and omissions referred to in Exploratory Tour were attended to, we think.

Upgrading of the insulating gas purification system.

The new system was designed by Alan Cooper, who also piloted the manufacture of the pipework and purifier vessels through the main workshop. It centres round a Spencer Gas Booster, rated at 135 CFM at 7.5 psi differential.

Preliminary work had been carried out during a tank opening in June when pipework was connected to a little-used viewport on the 14UD tank and valved off (40/5). During the present tank opening Alan, and his team of Allan Harding, Alex Lawson and Tim Sawkins, put a tremendous effort into the project. They manhandled the components and long 5 inch pipes up the tower, into position and connected them all up.

The first vessel after the blower was filled with Vivalyme and the second with alumina. When put into operation the flow rate was determined by the pressure differential across an aperture to be 129 ACFM. We consider this an excellent approximation to the design goal of 135 ACFM.

Chillers.

In October the accelerator was closed down for four days to allow completion of work on a new chiller configuration. The original chiller in the level 6 lift tower, above the source room, was disconnected and chilled water for the sources is now piped from the main installation at ground level. At the same time, fan-coil units were mounted at the various levels to cool the tank and therefore the SF_6. This measure is a further step towards reducing the activity of breakdown products. The air coolers are not yet connected to the chillers.

Button-up.

The charging tests were satisfactory and we closed the tank. When we began to gas up we found, during the usual early tests for leaks of SF_6, that there was a significant leak at the power feedthroughs to the new recirculator blower motor. We had to reduce tank pressure and get the gas out of the new purifier in order to attend to the fault. We discovered that the manufacturers had tightened up the electrical connections on the three feedthroughs so strongly that conductors on two of them had been wrenched away from their pressure seals and could be turned with two fingers. The only leaks in the completed installation were at these feedthroughs. We remade the feedthrough flange with nylon insulators and O-ring seals. The main flange O-ring had only 0.004 inch compression or 0.139 inch diameter. The groove was remachined for a quarter inch O-ring with adequate compression.

7/...

Initial performance.

The tube had gone through several sequences of being let up to atmospheric pressure, then pumped down again. New sections were installed and several tube elements in units 19 and 20 disturbed. Even though we employed our usual care there was a distinct loss of conditioning to 11 MV. The machine conditioned to about 13 MV in 8 days.

In spite of several hours spent sucking thumbs and observing the anomalous waveform at the Chain 1 "up" pickoff mentioned earlier, no believable theory was suggested. Since the chains appeared to be operating properly, even though the charging efficiency of No.1 is only about 70% of No.2, we shall patiently await inspiration and/or disaster.

On the morning of the eleventh day after closure there was a change of experimental groups and volts were turned off in order to put in a lot of shorting rods. When the chains and volts were put back on again the H.E. column current fluctuated wildly and was accompanied by clicking over the amplifier system which picks up bangs and other noises in the tower. These effects caused the younger author to accuse the older of having connected the wrong bit of wire to the shorting rods to transfer metering, this being the only possible explanation since everything had been working normally for days. The exchange of viewpoints which followed involved, on the one hand, advocacy of plain common sense in the face of evidence, and on the other hand, basic tuition of grandmothers. The heated debate subsided suddenly when it was noticed that current was being drawn from the charging supply. Since the charging and suppressor supplies feed open circuit devices in the tank, if current is drawn from either it means that something is grounding the inductors or the feed wires. This is almost invariably a broken chain, piled up onto everything sensitive to high voltage. Usually, but not always, both positive and negative electrode systems become grounded by a fallen chain and current is drawn from both supplies; it just depends on how the chain falls.

We eliminated the high voltage coax outside the tank and even went to the trouble of removing all the shorting rods, prior to the insertion of which all had been well; however, the short was still indicated by a 500 volt megger. We had no alternative but to open the tank so we began transferring gas straight away, continuing through the evening until it was all out when the gas handlers opened the air inlet valve and went home.

The Second Opening

The bottom door was opened next morning, 13th December, at 7.30 am and apprehensive eyes peered into the tank. Both chains could be seen hanging normally. No shiny heap, fallen inductor, or anything else like that was lying under the column and the only abnormal thing in the bottom of the tank was a substantial amount of white powder spread over a large part of the curved surface on one side only. There was little doubt as to what it was, or where it had come from. A glance up the column revealed a large area, from about Unit 20 down, thickly coated with the powder. The wall of the tank surrounding the new recirculator input port was also heavily coated.

We concentrated on opening the upper door and thoroughly ventilating the tank before going inside to find out what had caused the short circuit on the charging supply. Whatever it was we were grateful to it for making us open the tank before very much more Vivalyme had ended up on the column that we go to such pains to keep free of dust.

8/...

When we were able to get in the bottom of the tank we found that the charging inductor of Chain 1 was lightly touching the shimstock contact band on the pulley. Since the machine had been running well before the volts were taken off to put in shorting rods, it was obvious that stopping and starting No.1 motor had been the last straw for the loosened inductor. We realized that the inductor, so carefully checked for position and tightness at the last button-up, had loosened and moved because of stretch in the nylon rod which passes through all the elements of the inductor system, locating and clamping them. These rods are significantly longer than their predecessors because of the extra electrodes and extra insulating length involved in the new pickoff assemblies. We found only marginal looseness in the other inductor for Chain 1 and the two of Chain 2. We removed all of them and put cross-hatched score marks on all adjacent surfaces so that much less tension was needed on the nylon rods to produce a reliable non-slip assembly.

We opened up the new recirculator system and found that the Vivalyme level had fallen and it was apparent that violent agitation from the new much higher pressure recirculation system had caused the loose Vivalyme pellets at the top of the load to vibrate wildly, abrading each other to powder. The filters installed were intended to have reasonably low throughput impedance, but inhibit the passage of large fragments. The pressure buildup due to Vivalyme dust clogging the filters led to a breakthrough of the fine dust as it was produced.

We arranged that the Vivalyme load should be full enough to be restrained from vibration by our heavy stainless steel mesh, in the space below which the grinding process had taken place. We then blew out the big pipes with high pressure nitrogen, collecting the dust as well as we could with a vacuum cleaner.

A massive cleanup began in the machine. The first order approach was a vacuum cleaner to remove as much as possible of the powdered Vivalyme from the walls and floor of the tank and the outer surfaces of the column. We were very relieved to find that the powder responded remarkably well to the vacuum cleaner, removing almost all the visible deposit. We then went through a sequence of cleaning runs which started with tacragging the walls of the tank, outer surfaces of the column and inside all H.E. units. Then we blew the column with nitrogen and tacragged everywhere again. This was the preliminary cleanup, following which we did the work on the inductors and checked every one of the idlers, all of which had been removed at the last opening. All the idlers appeared to be in faultless condition and there was nothing else for us to do but have a good look at everything, blow the column with a nitrogen jet, tacrag the rings again and button up.

D.C. Weisser

T.A. Brinkley

9 January 1984

In order to devote his entire time to the module and other aspects of the post accelerator, David Weisser will relinquish command of the 14UD for the whole of 1984. Trevor Ophel (Deputy Head of the Department), will take over the responsibilities, decisions and headaches of the accelerator and inherit co-authorship of these reports. Tony Brinkley, now forcibly retired from everything except the fun of an accelerator laboratory, will continue in the Department as a Visitor, pottering about and remaining the other co-author. Owing to the youth of Trevor Ophel, the relative status of Young and Older Author will not be changed and inferences should be drawn accordingly.

9/...

Enclosures.

1) 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.

2) Plot of centre of chain position in casting holes.

3) Xerox of burned foil frames.

4) Plot of section of Chain 3.

Photographs

5) Cracked ceramic in tube section.

6) Spark marks inside tube section.

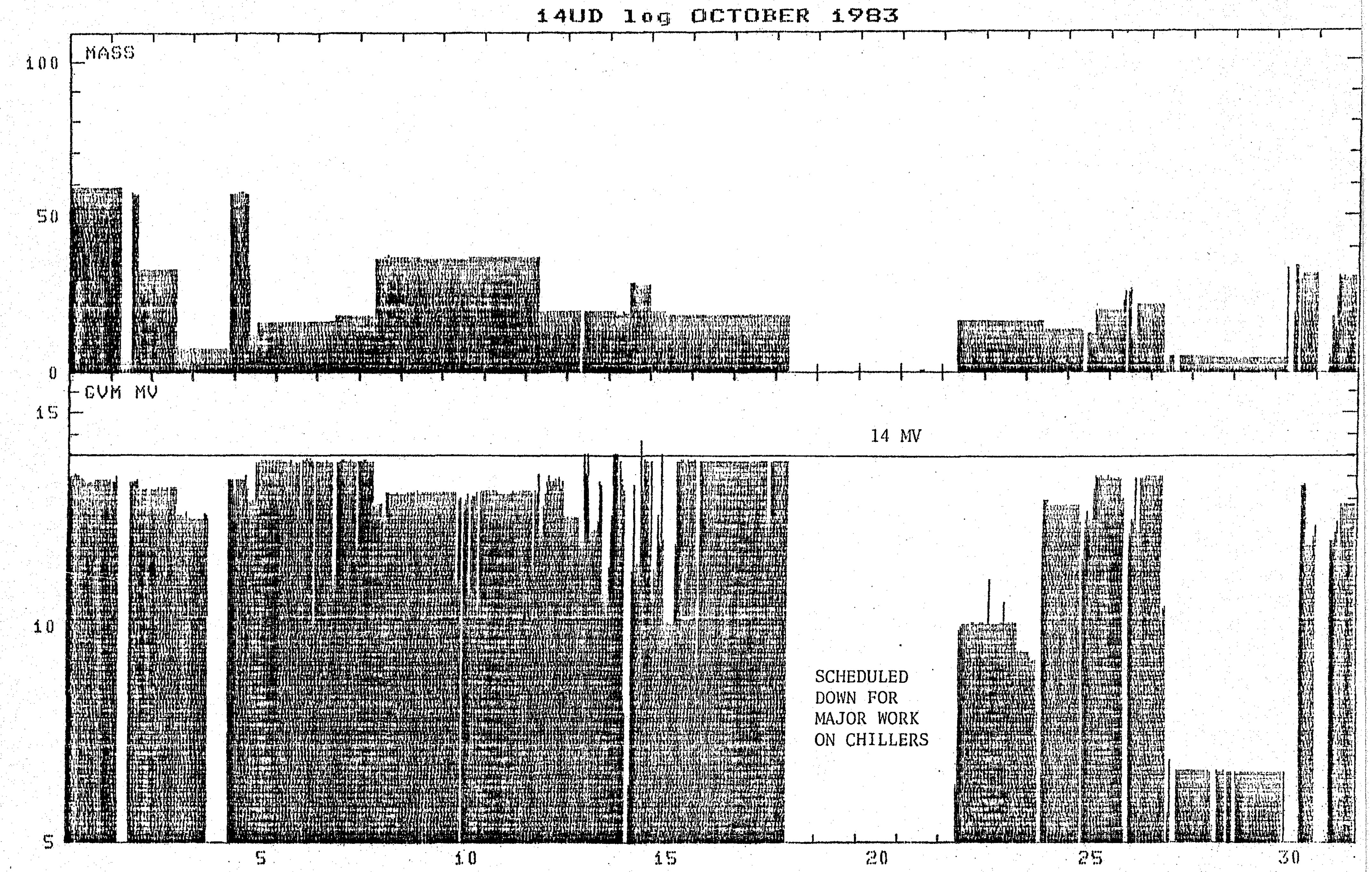
7) Crack in nylon link.

8) Dust on heater plate.

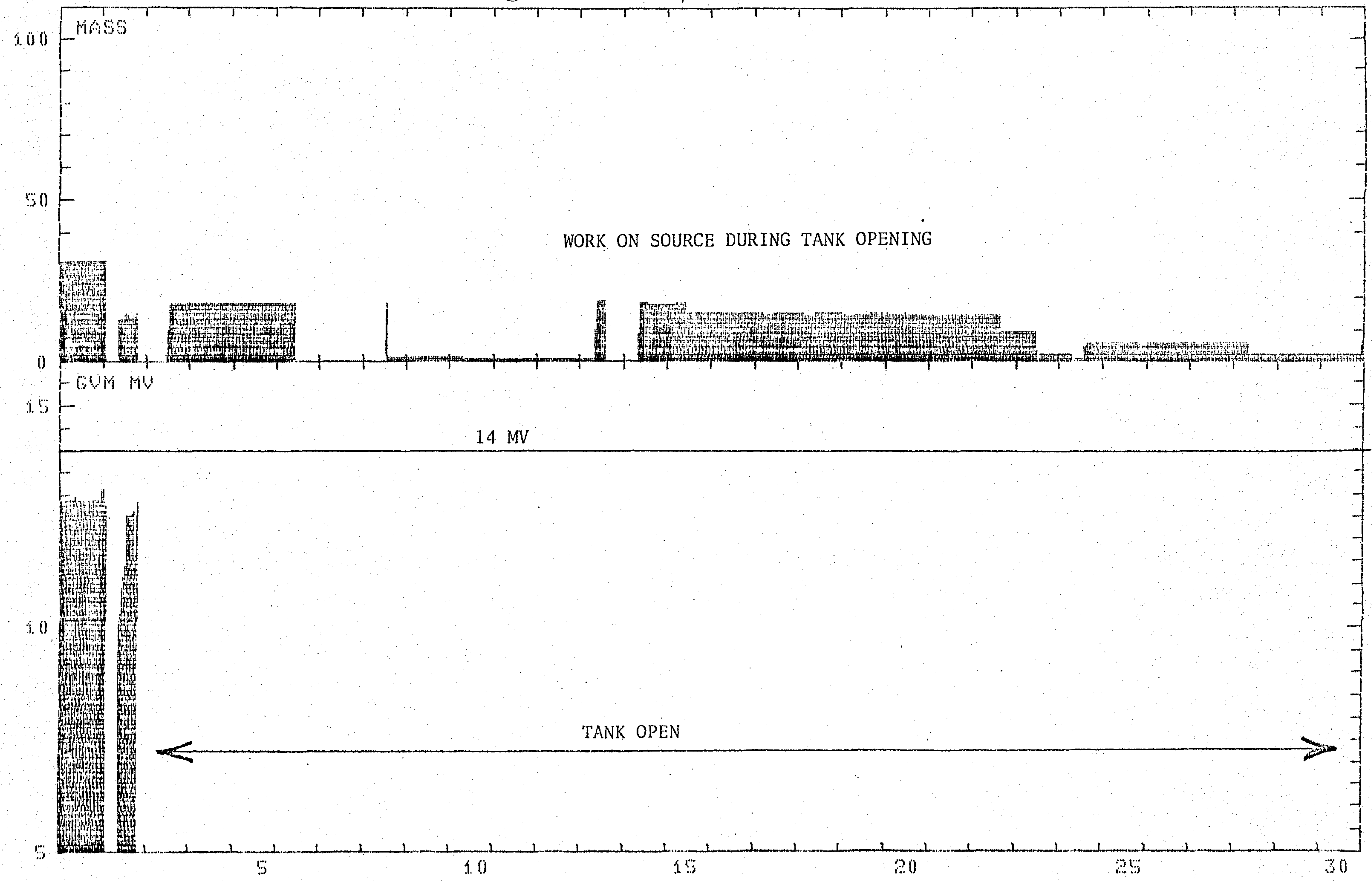
9) Idler dust.

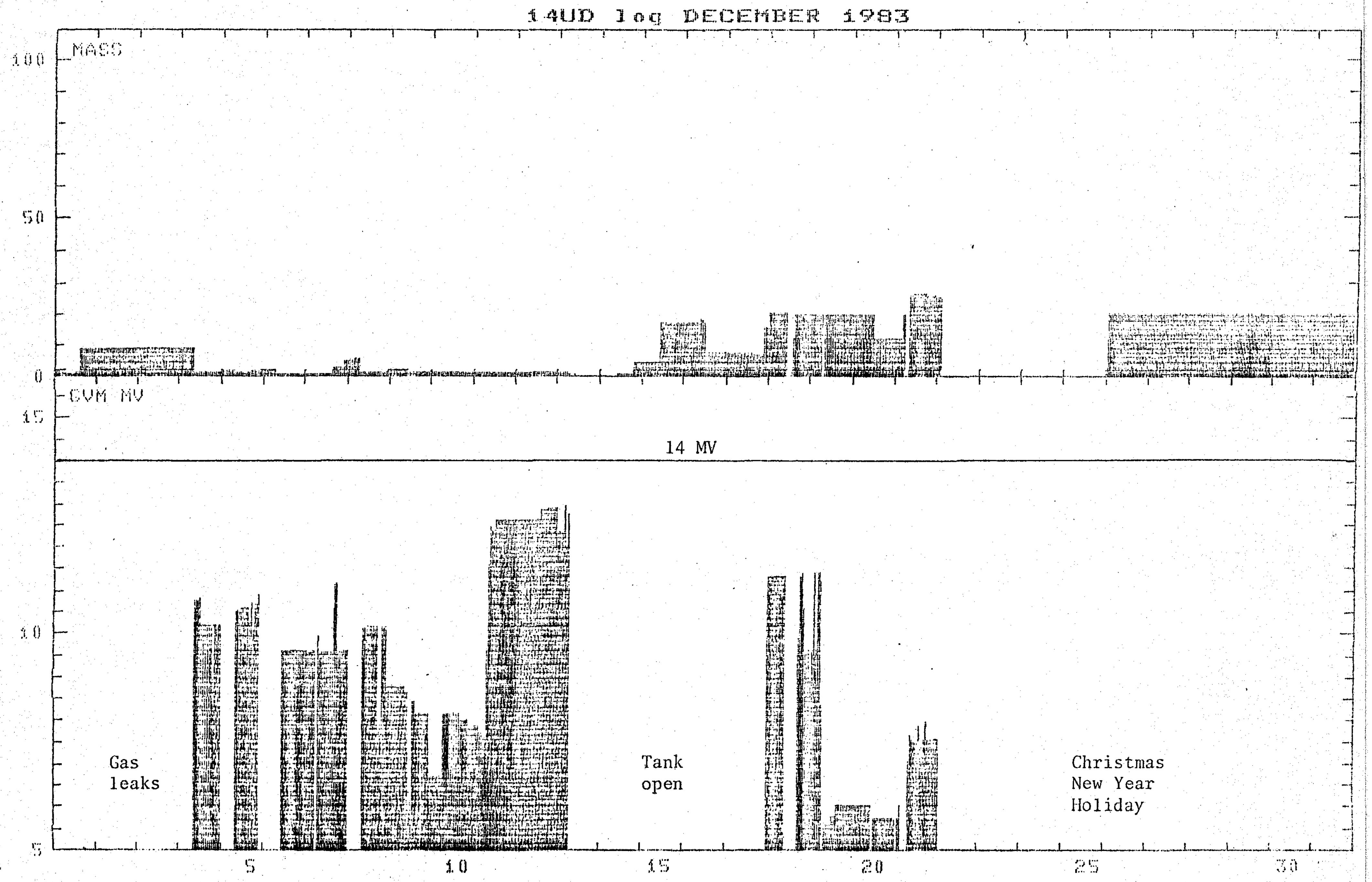
10) Idler tyre.

11) Spark marks on chains.

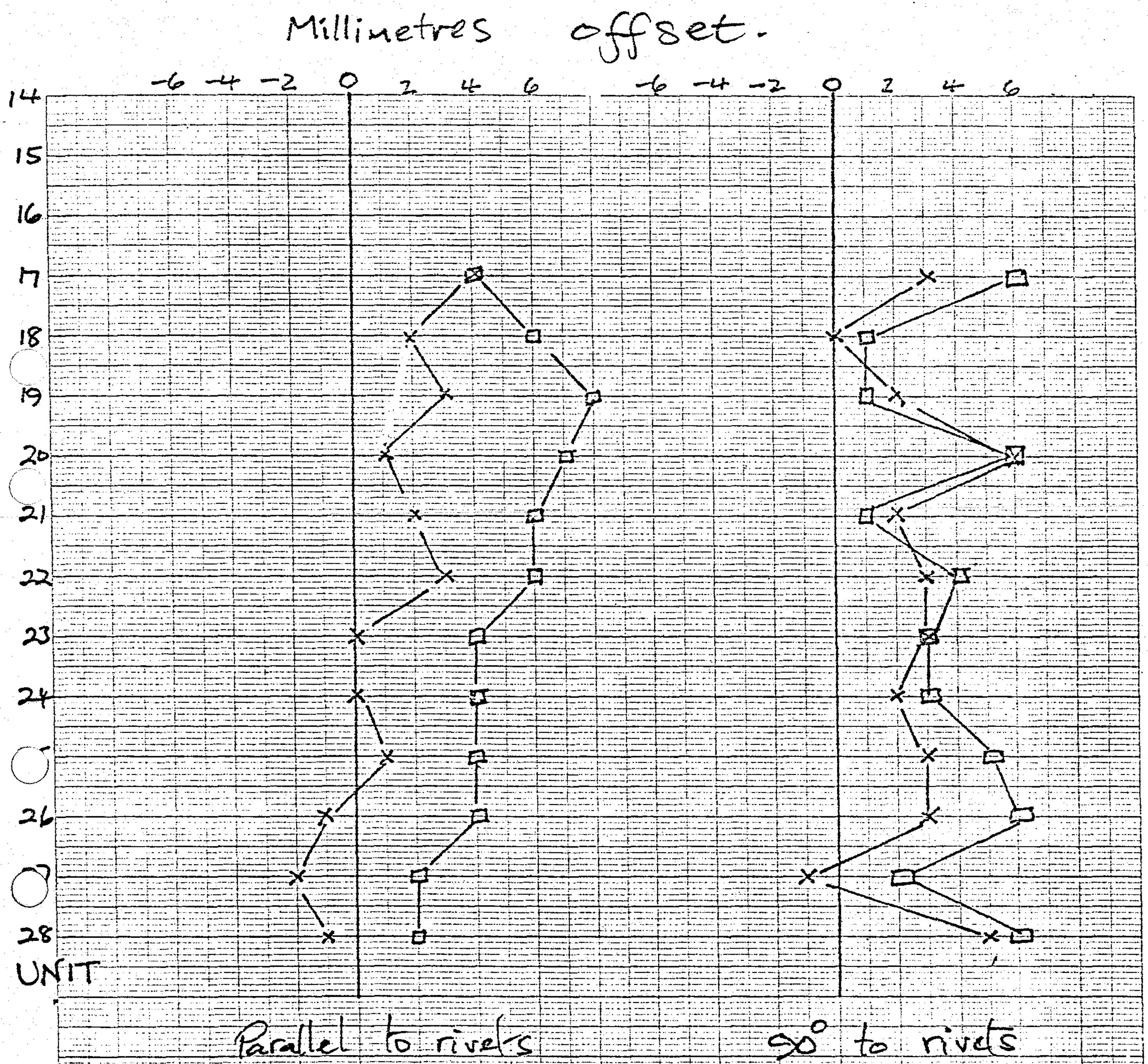

14UD log OCTOBER 1983
MASS
100
50
0
GVM MV
15
14 MV
10
5
SCHEDULED
DOWN FOR
MAJOR WORK
ON CHILLERS
5
10
15
20
25
30

14UD log NC EMBEI 1983




14UD log DECEMBER 1983
MASS
100
50
0
GVM MV
15
14 MV
10
5
5
10
15
20
25
30
Gas leaks
Tank open
Christmas New Year Holiday

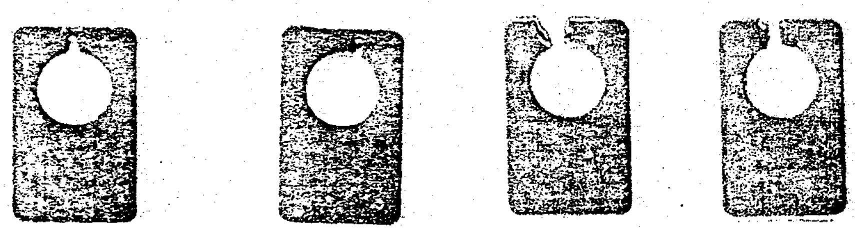
2).



OFFSET OF CHAIN 2 WHEN HANGING FREELY THROUGH HOLES IN CASTINGS. 17 NOV 83

FOIL FRAMES BURNT BY BEAM

3).



4).