AUSTRALIAN NATIONAL UNIVERSITY

DEPARTMENT OF NUCLEAR PHYSICS

# 14UD TANK OPENING REPORT No.41

15th to 23rd September 1983

(9 days open, 7 working days.)

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

## REASON FOR TANK OPENING

The opening was scheduled because we were out of foils, also we hoped to complete the additions to the SF6 purification system by installing the new 135 C.F.M. circulation pump and make some progress with the SF6 cooling. If, on examination, the chains continued to look good, then with the added security of upgraded purification, we would put the new chain we had on hand in the No. 1 position, where there has been no chain since early February.

## PREAMBLE

The 14UD was last closed on 23rd June and went into use on a low voltage run. At the end of the last report we wrote of encountering lost charge again quite soon. We described some ideas that came to us, (including fuzzballs), and tests that we carried out (40/8). Later, we evaluated the Vivalyme we had removed and found that it had much less moisture than virgin Vivalyme, therefore it still had unconsumed drying capacity. This meant that the gas was dry, and that moisture could not be the cause of the lost charge. As stated then (40/8), fresh Vivalyme and alumina banished the lost charge.

Towards the end of July, some uncertainties in measurements made with the Shaw moisture sensor led us to question our technique and the location of the sensor on-line in the gas recirculation circuit. A new sensor head was installed on a separate chamber which could 1), sample SF6 from various locations; 2), check the calibration of the detector and 3), confirm the zero setting. Although none of us can understand why sensing the moisture in line, at tank pressure, shouldn't work, it doesn't.

Early in August we noticed charging problems with Chain 3. When they persisted, we plotted charging current against volts on the inductors for the two chains, at first running together, and then running separately. For various inductor voltages we found that Chain 3 was putting up only 60-65% of the charging current of Chain 2. Apart from that, all else appeared to be well and we tolerated the effect and continued running.

At regular intervals we kept an eye on the level of breakdown products by means of the conductivity cell (37/5; 37/10) and established that this parameter was remaining at a level which we regarded as consistent with a fully effective purification system.

The machine performed excellently, running very reliably during July and

above 13.5 MV for about 23% of August, with three periods at 14.3 MV.

We had intended to take out the gas on Sunday, 11th September, but serious and bewildering problems developed with the gas handling system when we began to transfer gas. A pressure relief valve blew, dumping liquid SF6 into the gas handling room. When the operator ran to close the storage valve he discovered that the pipework near it was frozen. It was presumed that water in the pipe froze with expansion of SF6 and the expanding ice could have distorted the internal structure of the ball valve, which of course was in the fully open position when we began to transfer gas. We closed down for the day, after securing everything, leaving the storage valve closed.

The following day, all gas in storage was transferred to the accelerator. The pipework to the storage ball valve was opened and about 750 ccs of brown water came out.

When the ball valve itself was taken off, leaving an open pipe to atmosphere, we were impressed to discover that we were unable to pull open the door of the storage vessel because of partial vacuum inside. Eventually something gave, and we got the door open. The younger author warned that there would be some residual SF6 inside but, unable to resist a newly opened tank, the older author stuck his head inside for a look, taking only one quick breath. He then pronounced, in a deep, sepulchral voice, that it looked quite clean in there. The younger author remarked, sarcastically, that one should always take a little helium with it.

We soon discovered that the pipe between the ball valve and the tank had been full of wet, rusted scale which, at the last moment, was sucked up into the tank. We cleaned the pipework and renewed the ball and gaskets in the valve. Apart from the sludge that had been in the pipe (about one imperial double handful, or 180 ml) the floor of the storage vessel was clean. The piece of sand-blasted steel angle left in the tank last time was slightly rusted.

The sequence of events had been that the pipe onto the storage vessel had been almost completely blocked. Expansion of liquid SF6 which did get past the blockage, caused the wet sludge to freeze and the pressure relief valve blew when the buildup between the compressor and the blockage reached the release setting.

Before we closed the storage vessel we made a sludge-proof dam, 6 inches wide and 2 inches deep and fitted it round the exit hole in the bottom of the storage vessel.

Preparation for installing new type corona points.

The entire set of corona point assemblies in the machine, tube and column, were A.N.U. "rebuilds" (26/2) which were installed in June 1981 (26/4). We reported (39/4) that we were not satisfied with the quality control of our own rebuilds. We gave up any idea of further "homebrew" units and ordered a full set of N.E.C.'s latest type corona assemblies. The design and construction of the new versions is an ingenious departure from types 2 and 3 assemblies, which had to be discarded in their entirety and replaced when they were worn. The new assemblies incorporate holders which are common to both tube and column and take discs into which are swaged three needles of appropriate length. The discs slip into the holders and are fastened by a special hand-held tool. The ease of assembly is indicated by the fact that Howard Wallace, (who is half the hawk-eyed duo which examines chains), fastened point discs faultlessly into

3/...

1200 holders in one working day with ease. In future we shall refer to these corona point assemblies as 'Type 4' because they are the fourth version (39/4) that N.E.C. has supplied. (Type 3 were experimental, and did not remain in use.)

There was one aspect of the Type 4 points that we did not like at all. The screws which fix the assemblies to tube and post electrodes in the earlier three types were captive, whereas they are not in the new units. Screws are supplied separately, if you ask for them, and have to be inserted by the users. Hundreds of assemblies taken into the machine with loose screws would inevitably shed some into the column during handling and the frustration of finding them would be intolerable. To have to insert screws at the moment of installation would be fiddling and time-wasting; also, the problem of shedding would be perpetuated for all future point changes because the same holders will now be retained forever - or until Type 5 comes along and there might not be captive screws in those either.

We devised a crimping tool out of a pair of pincers, inserted the screws in the holders and crimped them captive before the point discs were fastened. This task was accomplished by the undergraduates we employ to 'baby-sit' with lone experimenters during night shifts. We therefore had a complete set of points for the entire machine ready for installation by the time tank was open, (or so we thought).

## OPERATIONAL TIME

During the 80 days since the last closure, the 14UD operated for 1722 hours. This was 89% of elapsed time, excluding the days for gas transfer.

## THE TANK OPENING

The doors were opened at 5.15 pm on 14th September and the older author abandoned his 65th birthday festivities, which had just begun, long enough to take the first sniff in the tank. The air, being clear and excellent, allowed us all to attend to darkroom matters with an easy mind. When Trevor Ophel (37/1; 40/6) was reproved for not being present at the sniffing, he said: "I didn't need to sniff; I knew it would be good because I've kept my nose on the gas outflow from the moisture tests."

### Exploratory tour.

Once in the tank we found the column to be reasonably clean, but there was more grey powder on shiny surfaces than we had hoped. The brown patch on the terminal was dry, and not very dark, and we could distinctly see patches corresponding to the triode needles. This must mean something, we're just not sure what.

An early priority was to discover an excuse for the poor charging efficiency of Chain 3 (page 1) and no sooner had we driven past the terminal than we found a d.c. idler lying on the floor of the first high energy unit. We lowered the terminal and found that the idler had come off the 'up' position of Chain 3 and therefore was from the position feeding the "charge doubling" inductor. This explained the behaviour of Chain 3. That the patron saint of charging chains should have shepherded this Fallen Idler to safety, without allowing its loose behaviour to bring about the downfall of an innocent chain, left us profoundly grateful.

4/...

We wrote earlier (40/6) that it would be sensible to perform, as soon as we got in the tank, the same tests that we carry out before closing the machine. In that way we could spot any time-consuming problems while we were able to organize them, rather than panic or slave through them at the last minute.

Accordingly, we ran the chains and found, as we cruised up the column, that there was a serious oscillation, about plus or minus three eighths of an inch, in Chain 3 between castings 16 and 19 where there are stabilizing idlers. The oscillation was predominantly in the 'stiff' direction - that is to say along the direction of the link coupling pins. There were no seized or displaced idlers, though we felt that they were more closely set than is our usual practice. We then observed Chain 2 and found it to be running faultlessly. We adjusted the idlers on Chain 3, oiled the chain and rechecked for oscillation. There was no real improvement, but, with nothing further done, a retest after 24 hours showed a marked improvement. During this period, idlers were checked. One bolt on a double block was found to be loose. The aluminium block had rubbed against its base plate producing material that coated the chain. Chain 3 was much dirtier than Chain 2, presumably due to the aluminium dirt.

Before proceeding with anything else we began the now hallowed meticulous chain inspections. Approximately 10% of the nylon links in Chain 3 were found to have cracks, whereas none had been seen in the equally meticulous inspection at the last opening (40/5). The cracks were indistinguishable from those found on so-called "breakdown product attacked" chains; that is, the cracks were at the transition between the neck and the head of the links where the curvature was sharpest and followed machining marks. Finding the cracks was a considerable blow, because we had come to believe that our observation and control of breakdown products had put us well ahead in our efforts to resolve the long-standing chain problems.

Dispiritedly we began the examination of Chain 2. The gloom which had descended on us all was delightfully shattered when the Meticulous Examiners pronounced that no cracks at all had been found in Chain 2. We now had the interesting situation that two virgin chains, installed at the same time, had run in the same atmosphere for almost an identical number of hours (about 3800). One of them was distinctly the worse for wear while the other was, so far as we could tell, like the driven snow. Surely even the patron saint of chains would raise his eyebrows in questioning concern.

We feel this to be our first inescapable evidence that breakdown products are not the sole, and perhaps not even the heavily predominant cause of chain breaks. We are glad we said (37/10; 40/7) that we would wait for better statistics before laying the blame solely on breakdown products.

Chain 3 appeared to have deeper machining marks on the nylon links. This might have been an illusion caused by the dirt revealing the marks, much as latent finger prints are revealed. Our chain inspectors are adamant that the surface finish on the links of Chain 3 was worse than that on Chain 2.

In July 1982 we wrote to N.E.C. suggesting that the nylon links might be less susceptible to mechanical failure if they were machined to a profile in which the necks were more smoothly contoured, (see sketch). We believed that there was a stress concentration where the radius of curvature was smallest and this was where we were seeing all our cracks. The idea was not pursued, but when Robert Rathmell was with us in June this year we discussed it at length with him. Now, with the evidence of the two virgin chains before us our interest, wise or foolish, has revived. We telexed N.E.C. for a quote on the world's first

chain with hourglass links and N.E.C., helpful and co-operative with us as ever, accepted the order cheerfully. In spite of the fact that laddertrons use hourglass links, we shall still try them.

## And so to work!

### Chains.

We took out Chain 3. After checking the idlers carefully, we threaded in the last virgin chain we had, confirmed that it passed through the idler positions correctly and then ran it. An oscillation occurred at the same place and to much the same degree as with the chain we had just taken out.

We took out all the spark shields for that chain with the intention of moving all the idlers well away from the chain so that its line from top to bottom was free from deflection. In order to set the idlers in Unit 16 the bolt holes had to be shifted a quarter of an inch. It soon became apparent that almost all the idler blocks needed to be butchered savagely to align them to the chain. When our noses had been rubbed into the obvious long enough, even we finally realized that the chain was in the wrong place.

This work occupied a considerable amount of platform time which we had no hesitation in allocating. When finally the chain was run again the younger author pronounced that he was far from satisfied with the overall mechanical performance of the new chain, in spite of the work expended, and decided to continue investigations at the expense of the scheduled button-up.

The chain was taken out. We then lowered the plumb-line and confirmed that the terminal and driving pulleys were on the same vertical line. The next step was to carry out a pulley alignment starting from scratch. The method we grew up using has its origins far back in antiquity; our only remaining technician who worked on the installation remembers no other. The historic technique is: a string is tied in the terminal in such a way that it runs tightly between the centres of the steel posts; the path of the string defines the position of the centre of the terminal pulley. Plumb lines suspended from the string, touching the centre of the groove, define the position of the driving pulley in the bottom of the tank. Based on the same assumption that motivated the historic techniques the centre of the terminal pulley was set on the line joining the centre of the posts in the terminal. Plumb-bobs hung over the pulley in the centre of the groove were used to align the bottom driving pulley. The chain was put back without any idlers in contact. Driving down the column to 'get the hang of it' the younger author noticed that the chain was not hanging in the centres of the chain holes in the castings. In a unit part way down the column we related the line through the centre of the chain holes to that through the centres of the posts as follows: laying a straightedge so that it touched the insides of the bases of the posts we scribed a line on the casting. With the straightedge on the outside of the posts we scribed another line. We could see by eye that the chain holes were not in the centre of the two parallel lines, but were closer to the outside line. This meant that the traditional starting point for positioning the pulleys was in error by 0.15 inches, enough to account for our inability to get sufficient adjustment on the stabilizing idlers to position them in suitable relationship to the chain.

Once again we made a new start, moving both pulleys across 0.15 inches and resetting the stabilizing idlers.

It was now apparent that the chain was not centred in the castings near the bottom. This misalignment was too great to be accounted for by the arc

6/...

moved by the motor mount. Indeed, we had to move the motor about 0.3 inches away from the pivot point to accommodate the chain at the centre of the casting holes for the motor mount horizontal. Judging from the dirt marks on the pivot attachment this misalignment has existed since the 14UD was installed. There is no point in describing all this trial, discovery and correction in greater detail; suffice it to say that we ended up with Chain 3 running as classically as Chain 2 which, presumably, had an accidentally better position in life than Chain 3.

It is arguable that the chain developed cracks because of an axial misalignment of main pulleys caused by using the wrong datum. It is not clear when the confusion over the datum occurred, or whether it exists at other chain positions. One might speculate that setting the stabilizing idlers more tightly than normal turned this error into a problem. The type of cracks, identical to those in "breakdown product attacked" chains, reinforces the view that mechanical stress played a very important role in previous chain breaks.

Idlers.

We had intended to remove all the A.N.U. idler supports, with their bearing systems, and put back the N.E.C. versions (40/5) which we had been preparing; however, replacement components did not arrive in time and we delayed this step. The idlers were reset to a considerable extent as mentioned above in the discussion on chains.

Foils.

The terminal stripper unit was removed. The blank positions left to allow operation of the Weisser valve, were some distance from the position indicated by the counter. The inventor of the valve, however, has now become experienced enough to operate it slowly, two or three times, across only part of its travel; by this means, foil frames in the way of the valve are displaced gently and fall to the floor of the stripper housing. To grasp the lever firmly, and close the valve with complete confidence, can leave the hero stranded with a foil frame jammed between the seals and the absolute necessity of letting the whole tube up to atmospheric pressure. In this particular case, two foil frames were dislodged harmlessly. The Weisser valve sealed so well that the tube pressure of $8 \times 10^{-9}$ did not change ranges when the stripper was 'let up' and removed. Most of the 264 foils were changed.

Shaft bearings.

We listened to the shafts and concluded that there were no bearings which needed to be changed.

Points.

As we mentioned in the preamble, we had an entire set of new corona point assemblies ready for installation, even down to captive fixing screws. We decided that we would at least put the L.E. set in, and, depending on how other things were, might make a big push and do the H.E. end as well.

Whenever the platform fell vacant during all the work on the chains we took out the old points (which had operated for 13,200 hours) and began putting in the new ones.

7/...

It fell, of course, to the older author to be the first to start installing new points and fail to get such a high percentage of them to screw on that remarks began to be made about age, hearing and general incompetence; his insistence that half the new screws must be blunt, or have left-hand threads, met with little credence and less sympathy. The introduction of someone young and skilled in the art of screwing in screws, led, after his similar frustration and confusion, to the discovery that the screws supplied for the new point assemblies were a sixteenth of an inch shorter than the original ones. In some cases they were not reaching the nuts in the brackets at all, while in other cases the screws were engaging by about one thread. It was our fault, of course; we (the older author) should have checked, but the new screws looked so prim and correct, all 1370 of them, crimped in the shining new assemblies.

There was nothing that we could do except remove the short screws so painstakingly crimped in the new assemblies and replace them with longer screws equally painstakingly salvaged from the old assemblies, then recrimp. Six people set to work with merry hearts and the place echoed with chuckling and cheerful banter over N.E.C.'s wry and unexpected little tease. We all had to admit that it was the most hilarious thing since star-headed screws.

We were glad that we had made up two alignment tools for tube and column assemblies according to Robert Rathmell's design (40/5) because, by their use, we succeeded in getting all the tube and column point assemblies level and correctly spaced. Theyounger author was so enthusiastic about uniform point spacing that he personally set all the points in the machine, including those already set by the older author.

When we had finished we were very impressed by the uniformity of the total installation. We gladly record, also, that the manufacturing and quality of Type 4 assemblies were really excellent. Additionally, there was a comforting feeling that the next time we need to change all the corona point assemblies, we shan't have to throw entire assemblies away, even if it means a bit of slavery to replace the bits and do the job.

Insulating gas.

A Shaw moisture sensor was put on the recirculator output at Level 3 with additional plumbing to flush room air past it. We have been in touch with Shaws, who were very good to us. We put in a brand new sensor which calibrated correctly, but when we put it on line it saturated. We are confused and are not prepared to say any more than that about it for the time being.

Breakdown products.

In August 1982 we put some nylon cable ties in the bottom of the machine, fastening them with a 'gun' set on standard tension. We tested the ties on this occasion and found them strong and resilient, exhibiting no brittleness.

Miscellaneous

Unfortunately, in spite of a magnificent effort by N.E.C. to get the new recirculator pump to us in time, it arrived too late for all the work involved to be completed. We have to admit that, even if the blower had arrived in time, the considerable amount of work with Chain 3 and its idlers would have commanded

8/...

too much manpower for work on the purifier to have been completed.

Cleaning.

Because every unit had been opened, the floors, ceilings and furniture of all of them were tacragged. After the rings were put back the column was blown with nitrogen and there was another run over the rings with tac-rags.

Button-up.

The chains were run once again and studied. The charging tests were copy-book.

Initial performance.

The machine was rock steady. The corona currents were steady, but much higher than before the new points were put in. It was not until the machine was operating that the grossly larger corona point currents led us to compare the point to plane gaps of the Type 4 assemblies with some unused Type 2 assemblies which we have kept as standards; (N.E.C. originals, not A.N.U. rebuilds). For the column assemblies the point to plane gap has been reduced from 12.9 mm to 11.4 mm. For the tube assemblies the gap is reduced from 4.2 mm to 3.7 mm. This geometry produces record-breaking breakdown product production rates. For these measurements we have assumed that the needles are still effectively facing a plane surface and that the concave cups holding the adjacent points don't make up for the apparently smaller gaps. Certainly the higher currents support this assumption.

There was no difficulty in getting up to voltages required immediately and in a few days the 14UD was running at 13.5 MV.

D.C. Weisser

T.A. Brinkley

11th October, 1983.

The 14UD Tank Opening Reports are circulated, by request, to the following people:

Dr R. Rathmell, N.E.C.
Dr R. Voss, S.E.R.C.
Dr J. Ball, Oak Ridge.
Prof. S. Skorka, Munich.
Dr N. Burn, Chalk River.
Dr H. Munzer, Munich.
Dr A. Vermeer, Utrecht.
Dr R. Siemssen, Groningen.
Mr C. Kobayashi, J.A.E.R.I.
Dr T. Aitken, Daresbury.
Prof. E. Skurnik, Israel,
Dr R. Repnow, Heidelberg.
Prof. K. Kemper, Florida State Univ.
Dr C. Jones, Oak Ridge.
Dr H. Wegner, Brookhaven,
Dr W. Kutschera, Argonne.

9/...

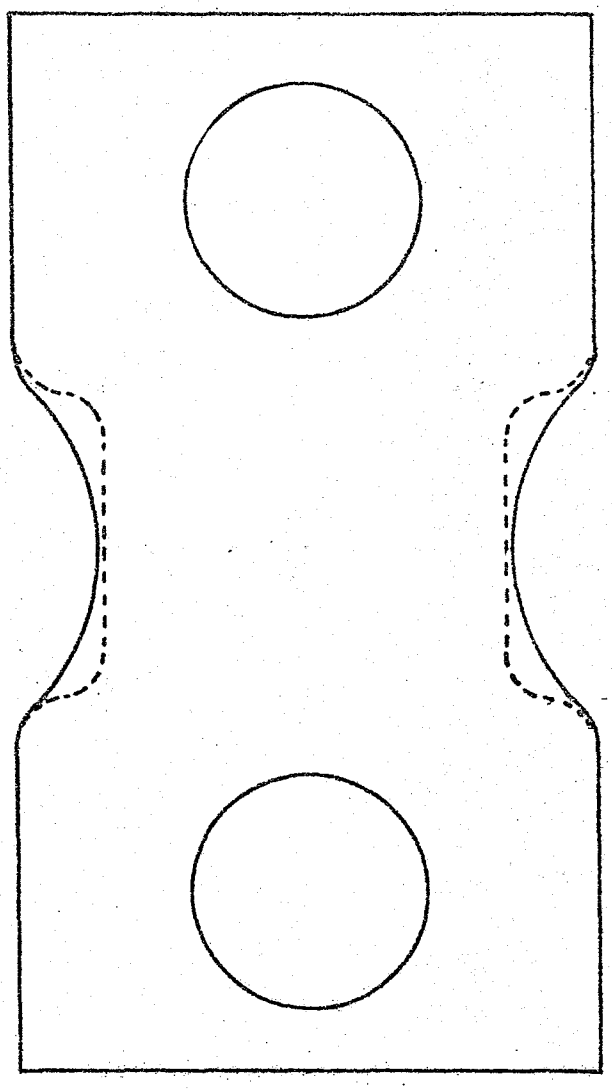
Mr R. Mck. Hyder, Oxford,
Dr J. Yntema, Argonne.
Dr D. Bohne, Darmstadt.
Dr R. Hellborg, Lund Inst.
Prof. C. Barnes, Caltech.
Dr P. DenHartog, Argonne.
Dr J. Noe, Stony Brook,
Dr K. Katori, Osaka Univ.
Dr C. Moak, Oak Ridge.
Dr W. Henning, Argonne.
Dr K. Prasad, Tata Inst.
Prof. H. Hubel, Bonn.
Prof. S. Seki, Univ. Tsukuba.
Mr T. Lund, Univ. Rochester.
Dr M. Letournel, Strasbourg.
Prof. O. Sala, Univ. Sao Paolo.
Prof. T. Trainor, Univ. Washington.
Dr S. Signorini, Padua.
Dr M. Mariscotti, Argentina.
Dr R. Sparks, DSIR, New Zealand.
Dr B. Spellmeyer, Hahn-Meitner Inst.
Mr P Asbaugh, McMaster Univ.
Dr V. Hattangadi, Bhabha Inst.

Enclosures:

Plots of particle masses accelerated, and operating terminal voltages.

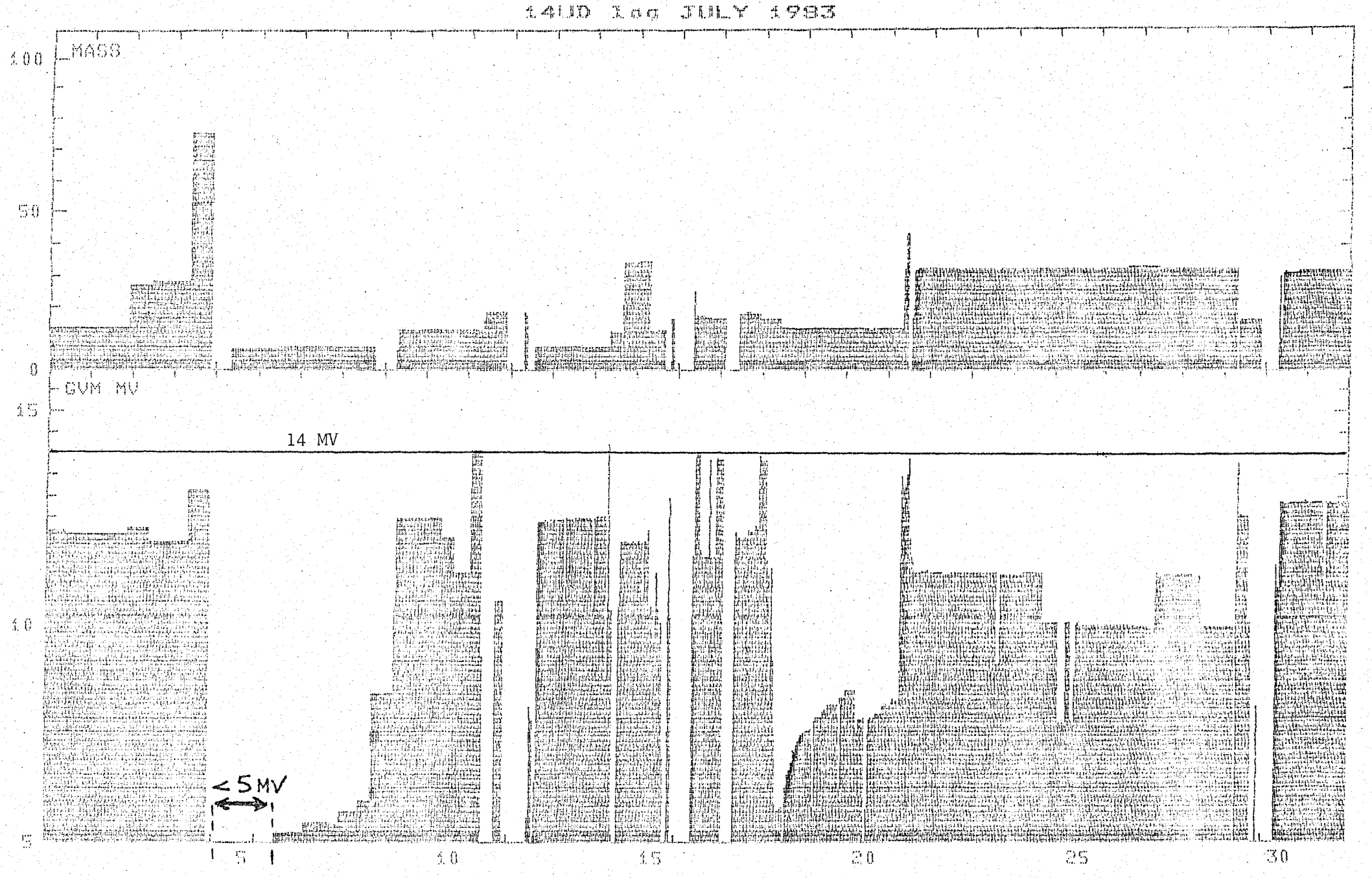
NOTE: On the plot of terminal voltages we have drawn a horizontal line at 14MV for easy reference to performance near the nominal voltage limit of the 14UD.

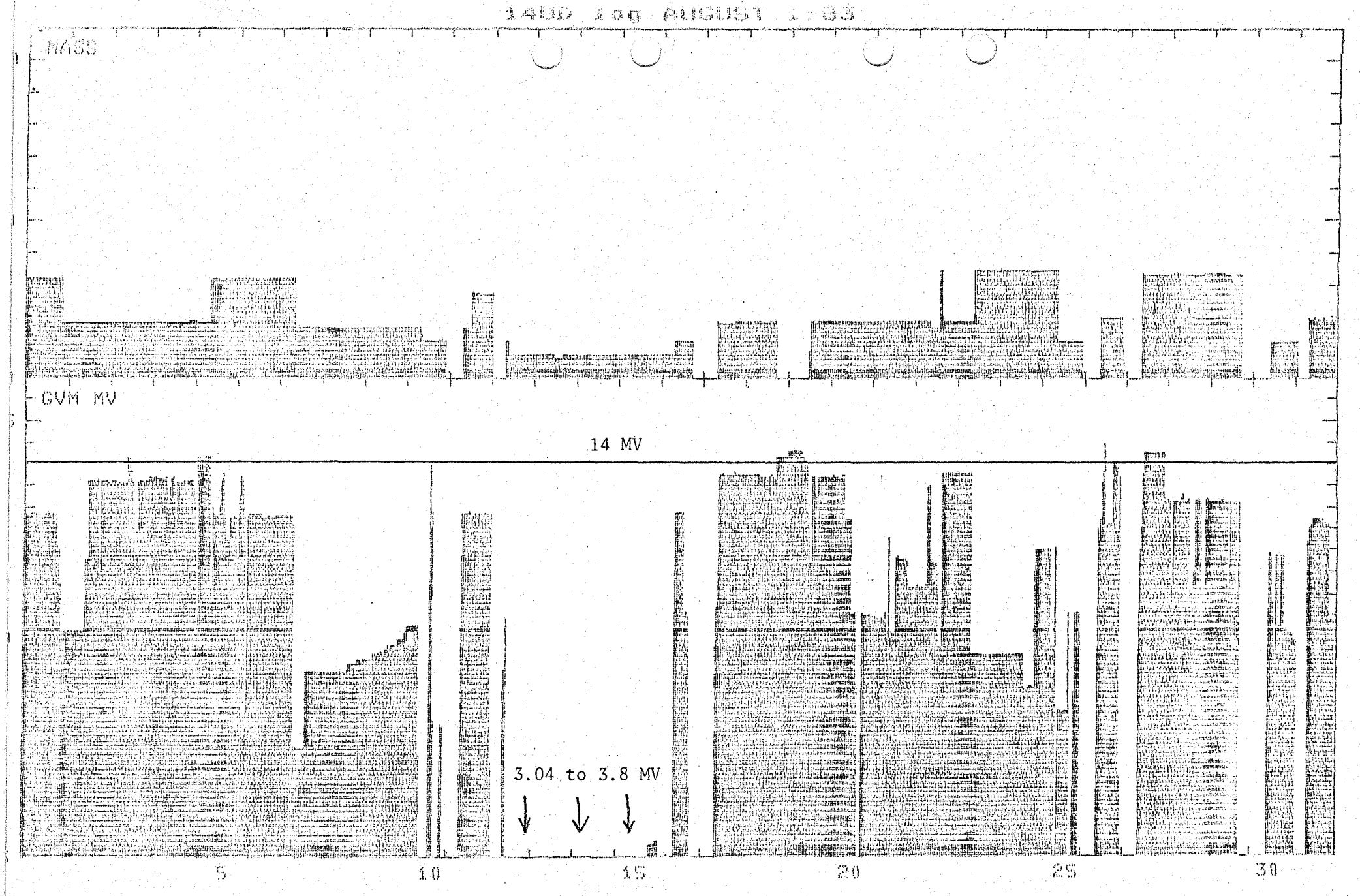
Sketch of "hourglass" profile for nylon chain links.

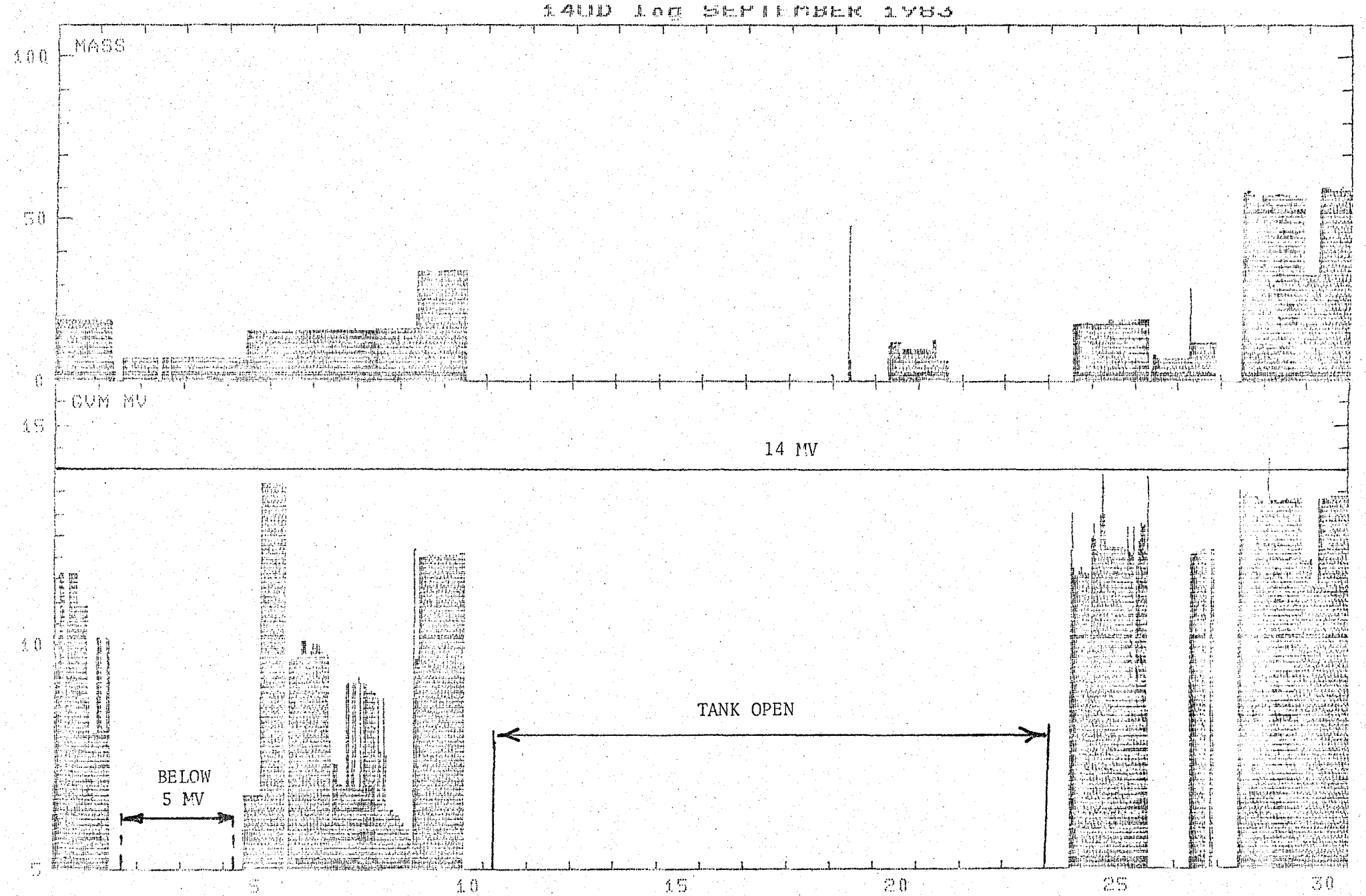


"HOURGLASS" LINKS

Solid line: proposed contour.
Dotted line: existing contour.


14UD 1oq JULY 1983
MASS
100
50
0
GVM MV
15
14 MV
10
5
< 5 MV
5
10
15
20
25
30


MASS
GVM MV
14 MV
3.04 to 3.8 MV
5
10
15
20
25
30


MASS
100
50
0
CUM MV
15
14 MV
10
5
BELOW
5 MV
TANK OPEN
5
10
15
20
25
30