AUSTRALIAN NATIONAL UNIVERSITY

DEPARTMENT OF NUCLEAR PHYSICS

14UD TANK OPENING REPORT No.43

Two Openings

6th - 9th February 1984 (4 days open)

15th February 1984 (½ day open)

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

REASON FOR TANK OPENING

To attend to problems with Chain 1 and general voltage instability.

PREAMBLE

The 14UD was last closed on 15th December 1983 following the tank opening during which we found a great deal of Vivalyme dust in the tank. For a while there were conditioning problems which appeared to be more closely associated with the inside rather than the outside of the tube; in other words, more likely to result from the tube being opened (42/3) than the Vivalyme dust (42/7,8).

Much of the running early in the schedule required only low voltage, but in the middle of January the machine was used at 13 MV. After about a week at this voltage we ran into a period of frequent sparks which led to troubles with Chain 1. The trace from the new capacitive pickoff (42/5) associated with this chain, changed significantly for a while and then settled down to an unsatisfactory, but not extreme pattern.

The new recirculator had not operated since the last closure in order that we could avoid repetition of the influx of Vivalyme dust (42/7). We had taken remedial measures, (42/8), but we were sufficiently apprehensive about their efficacy to avoid putting the recirculator into operation until just before the next tank opening. With an opening scheduled for 6th February the recirculator, with new Vivalyme and alumina loads in respective vessels, was opened to the tank and operated on 2nd February.

The next day, in an attempt to see if Vivalyme was being blown onto the column, someone went to peer in one of the upper viewing ports while light was shone in another further around. It so happens that the input from the new recirculator is at the lower ports about 38 feet further down the tank. The bright idea was not entirely without success because, while peering into the dimness for white powder, the observer saw distinct sparking on the column at Unit 7. Always willing, when feasible, to convert our mistakes into diagnostic triumphs, we shorted out Unit 7 and improved the stability of the machine. Back in the old days, at times of instability, we used to perch ourselves on the top rung of a ricketty wooden ladder; clutching for support on the viewing flange, we peered into the tank, looking for sparks. However,

2/...

since the installation of safe, steel ladders, with good handholds, the practice has fallen by the wayside.

The machine continued in use and the differences in charging efficiency persisted, with Chain 1 intermittently worse than Chain 2. We became convinced, into the bargain, that Chain 2 was not behaving with what we remembered as usual charging efficiency.

OPERATIONAL TIME

During the 53 days since the last closure, the 14UD operated for 767 hours. This was 78% of elapsed time, excluding the days for gas transfer and those of Christmas and the New Year break (total 12).

THE TANK OPENING

Exploratory tour

There was no Vivalyme dust to be seen anywhere in the tank. Cruising down the column we soon saw what was wrong in Unit 7. A ring was off and this had led to serious spark damage to adjacent electrodes with which the ring had been lying in contact, (photo). In Unit 14 there were three rings off with minor damage on the post. In addition, some post electrodes had been eroded at the point where the rings clip on. This plethora of dislocated rings troubled us very much, not only because of the damage which had been done, but also because it was abundantly clear that our supervision had been sadly at fault. The previous button-up had dragged on, following extensive cleaning in the tank to get rid of the Vivalyme dust. Our students did a more than usually heroic job, but after two or three cleaning runs over the wall and the whole column, plus putting back rings, then further runs of tacragging, it is not surprising that mistakes were made. Regrettably, no professionals toured the column to check rings and we endowed ourselves with the consequences.

The stain on the terminal was surprising: it was about the same colour as usual, but it was a completely dry, non-sticky dust which marked with the finger like chalk on a blackboard, and could be blown off with a good puff.

We examined the chains, pulleys, inductors, pickoffs, wires and every aspect of the charging system for both chains in the terminal. A d.c. idler had a bearing which had considerable play, but had not seized. The idler had good contact springs and rotated correctly when the chain was turned. In the bottom of the tank the entire charging system was in faultless condition, with all inductors correctly spaced, clean and free from sharp points.

And so to work!

Before attending to anything else we concentrated on the charging problems. Beginning with charging tests we established that there was still a difference in efficiency between the two chains. After cleaning wires and contacts of the cross-over system, checking the contact bands, the d.c. idlers and cleaning the insulators, we repeated the tests, taking photographs of the waveforms from the pickoffs. We realized that the waveforms were not particularly satisfactory, but didn't pay much attention to them because the devices have only been in the machine since we have been having charging problems. We disconnected the crossover system and established that efficiency was reduced without it. We then put a high impedance voltmeter on the inductors themselves, even though sparking at 8 kV in the bottom of the tank demonstrated that there were plenty of volts floating about. At 2 kV we read the correct voltage on the positive (suppressor) inductors, but not on the charging inductors. Higher voltages gave an intermittent reading and eventually we found that a resistor in series with the external charging cable, to protect it from sparks, was faulty. Eliminating the resistor we obtained normal voltages on the charging inductors for both chains. This could not explain the difference between the two chains, but, since nothing else explained it either, we comforted ourselves that under running conditions all might be well.

In order to convince ourselves that our memories of great charging efficiencies in the past were not just rose-coloured dreams, we looked up the values recorded for 25 charging tests, made with different chains, before our present problems began. While the values for individual chain positions varied in particular tests, there was nothing to suggest the one position was better or worse than the others. We lumped all the tests together and obtained average charging currents, in air, with newly oiled chains and well-set inductors as follows:

TABLE 1

Charging Voltage (kV)	Charging Current (microamps)	Efficiency (microamps/kV)
2	9	4.5
4	15	3.75
6	20	3.33
8	24	3.0

Having established the above table, it occurred to us to dig even further into the past to see if we had ever written down some definitive numbers given us by N.E.C. We found that Robert Rathmell told the older author in 1976 that, if inductors are properly adjusted, we should get about 3 microamps/kV for each chain; also, depending on humidity, we should get 15 to 20 microamps, in air, without sparking. The table is clearly a good yardstick for charging efficiency in air.

Chains

As usual, a thorough inspection of every link of both chains was made. Three cracks were found on Chain 1, two of them minute and the third was declared by our expert examiners to be serious. This chain was a composite one, put in last November when we removed an uninterrupted sequence of spark-damaged pellets (42/2). All three of the cracks found were in the older part of the composite chain, which had operated for 3,843 hours. No cracks were found in Chain 2 which had operated for 5,484 hours.

We replaced Chain 1 with a brand new "hourglass" chain (41/4). When we repeated the charging tests we found that the charging efficiency of the new chain was no better than for the one we had taken out.

Damaged post electrodes

Fortunately, the damage on the electrodes had occurred, in all cases, other than at critical stress points. The eroded spots were treated with emery cloth

4/...

to get rid of sharp edges. We put a high voltage resistance tester across adjacent rings for the whole of an undamaged unit to get a feeling for where breakdown generally occurred. We found that it was random on the four posts at about 9 kV. Rings with damaged electrodes appeared to stand the same voltage just as well as undamaged ones, with breakdown occurring in only two cases at a damage spot. We decided that what had happened would not impair the voltage-holding capabilities of the two units which had suffered. While the effect on electric fields of the spark damage was serious enough, we were even more concerned about erosion of the electrodes at points which give mechanical support to the equipotential rings. In several cases the lips of the electrodes had been eroded enough to prevent standard ring screws receiving sufficient support. In addition, we feared that the electrode material had become weakened to the extent that it might crumble under the tension of the rings. We took out the ring screws at these places and put in longer ones which held the rings satisfactorily in position.

Foils

The terminal foil changer was taken out and the Weisser valve once again held perfectly. The seal in this valve was last changed in June 1981 after a foil holder had been jammed in it. The valve has been operated under high vacuum conditions at least 12 times since then.

Shaft bearings

There was no evidence that any bearings needed to be changed.

Idlers

All stabilizing idlers appeared to be in good condition. The down d.c. idler for Chain 1, noted in the preamble to have a poor bearing, was judged to be good enough to leave in on the grounds that we've accepted bearings as bad as that before. This judgement, and its grounds, were hotly contested by another member of the judiciary who, on account of his age, was overruled; the idler stayed in.

Insulating gas

The outlet dust filter on the new gas recirculator was removed in order to repair a leak at the O-ring. Not a speck of dust was found on it and we concluded that we had effectively dealt with the earlier Vivalyme dust disaster, (42/7;8).

Cleaning

The column was blown with nitrogen and tacragged as usual.

Button-up

When charging tests were repeated we were again confronted with a poorer charging efficiency for the No. 1 position. We put extra lead blocks on the pivot of the new chain and left it overnight in order to stretch it. Next morning two links were removed and we buttoned up straight away.

We had volts on, and an experiment started, by 3 p.m.

Initial performance

We were soon to find that more was wrong with Chain 1 than charging efficiency. Within 24 hours of starting, a fluctuation in charging current appeared at an inconsistent frequency which was only about a third of chain rotation frequency. This eliminated such causes as a protruding chain rivet, a damaged pellet or defective shimstock contact bands.

It was Friday, and we settled for being forlorn and decided to see what things were like after running for the weekend at the relatively low voltage required by the experimenters. On Monday, things were no better. On Tuesday 14th, for which a higher voltage run had been scheduled, we turned Chain 1 off and then ran charging volts up to see what performance was like with only one chain. Charging current saturated at about 25 kV, (100 p.s.i.a. SF6). We cancelled the run and began to take the gas out of the machine. As the pressure came down we repeated the charging tests and found that the saturation effect had disappeared. The values for the three pressures are given as follows:

TABLE 2

100 p.s.i.a.		63 p.s.i.a.		27 p.s.i.a.	
kV	uA	kV	uA	kV	uA
13	36	10	28	8	25
18	41	15	42	10	30
20	42	20	54	15	44
25	47	25	65	25	74
30	46				
35	44				

The Second Opening

In the bottom of the tank the chains looked just as they had looked a few days earlier. In the terminal the poor bearing on the down d.c. idler, squabbled hotly about at the last opening, had seized and the tyre was badly worn. We concluded that the idler was intermittently stripping negatives and thus was causing the fluctuations we had seen. After the predictable quantum of resentful muttering by the frustrated individual who had wanted to have the idler changed, a new one was put in. The charging tests were then repeated with the mutterer observing at the terminal and we noticed a phenomenon that had never been reported before: there was a continuous arc from the down side of Chain 1 to its d.c. idler. Since there was an arc, there had to be a current. Since the idler was on a large insulator, which only fed an inductor on another large insulator, no d.c. circuit was involved. Something, somewhere, was not as it seemed. We put a 10 kV insulation tester on the cross-over system and found a dead short to local ground on the down idler insulator. We took the insulator out and put in one borrowed from the No. 3 position, which still has no chain. Charging currents for Chain 1 then assumed the standard values given in Table 1.

The 12 nylon cross-over insulators in the terminal have been in the machine since installation 11 years ago. They are examined regularly for dirt and are cleaned almost every time the terminal is opened. There were no marks on the surface of the faulty insulator which, among other things, we had gazed at blankly time and again while trying to fathom out what was wrong with the system.

Four screws on the top of the insulator hold the support electrode for the d.c. idler and four at the bottom hold the insulator to a plate which is, in turn, bolted to the floor of the terminal. We took the insulator to pieces and cut the nylon part in half, across the line of two of the screws. We found severe damage within the nylon between opposite top and bottom screws. Unfortunately, these screws had been located exactly opposite each other. The holes tapped in the nylon were 1 inch deep, though the screws entered only half this depth. There were 2 inches between the tips of opposite screws, but 1 inch of this was empty, tapped hole, the walls of which had become blackened. Breakdown "trees" were clearly visible in the nylon. The enclosed photograph of the halved insulator is almost exactly full scale.

We have often written in these reports how important it is to trust nothing and poke and pry and test the most innocent-looking things. We were quite right. There is very little more innocent-looking than a nice, clean, substantial insulator which has worked well for 11 years. Far from suspecting a simple insulator of the duplicity of concealing a short circuit beneath its surface, a few of us were biased into the conviction that the fault lay somewhere in the depths of the new-fangled pickoff electrodes, immediately following the installation of which things had started to go wrong.

We took 3 links out of Chain 1. This meant that it had stretched by 5 links since it was put in, at the correct aspect, only a week before.

We decided to short together the two rings in Unit 7 where adjacent post electrodes had been damaged. This was because we found a dark grey, powdery deposit around the damaged region of the electrodes.

Initial performance:

The charging efficiency of Chain 1 was excellent and better than that of Chain 2. Someone suggested that perhaps one of the cross-over insulators of Chain 2 was beginning to suffer from insulation damage. It was haughtily stated that not only had the Chain 2 insulators been tested, but also those in the chainless No. 3 position. However, this testing was done in air and was limited to 10 kV. The problems with Chain 2 commenced at 20 kV. To be on the safe side we put an order into our workshop for a complete new set of cross-over insulators. When we remove the remaining oldtimers, and cut them open, we shall report on their condition.

A few days after gassing up, and starting to run again, there was an instability on the H.E. column which we cured temporarily by shorting out Unit 27, after some rod tests. A while later we took out the rod and found that the instability had largely disappeared. We remembered a similar instance and looking back in the log we found that much the same thing had occurred in Unit 27 almost exactly a year earlier.

7/...

We then discovered that the new recirculator, on which we were relying for purification, had been off for at least part of the weekend while the machine was running. Regrettably, wiring of a warning light in the control room had not been completed. A measurement with the conductivity cell revealed a rate of 600 kilohms/hour. The recirculator was hastily put on and 5 hours later another measurement showed a rate of 130 kilohms/hour. The next day the reading was 16.5 and the day after that, 12. These measurements are consistent with a flow rate for the new recirculator 5 times greater than that for the original one and with known production rates. The figures imply that the recirculator had been off for about 70 hours; in other words, it went off some time in the afternoon of the previous Friday. Interestingly, the gas had no smell when the reading of 600 kilohms/hour was observed, nor was any lost charge evident.

THE NEW RECIRCULATOR

The essential elements of the new recirculator system are a Spencer Gas Booster and two vessels, 0.45M in diameter and 0.85M long, to contain purifying chemicals. The design goal of 135 ACFM (compared to 25 ACFM of the original system) was demonstrated by pressure differential measurements (42/6) and confirmed by the cleanup rate of gas described above. The cleanup measurement not only confirms the flow rate, but also showed that 100% removal was achieved with a single pass of the gas.

Pre-dried Vivalyme and alumina are contained separately in each of the vessels, such that the gas passes firstly through the Vivalyme to remove the breakdown products and is then dried by the alumina in the second vessel. Initially, the system introduced Vivalyme dust into the pressure vessel (42/7). This problem was overcome by baffling the entrance to the Vivalyme vessel and installing a restraining sieve on top of the Vivalyme. Provision has been made to monitor the pressure drop across the filter. No change has been evident thus far.

Seven days after the button-up we were confident of the efficacy of the new large recirculator. The Vivalyme and alumina were taken out of the older recirculator in order to dedicate it to drying only. It was filled with virgin alumina, then evacuated and heated to 250 deg. F for 4 days. Once in service the recirculator reduced the moisture level from an already satisfactory 40 p.p.m. to less then 10 p.p.m. This effect is significant in that it implies that the small dryer can further desiccate the large vessels of Vivalyme and alumina. There are two beneficial consequences of this: 1) The moisture produced by the chemical action of the Vivalyme is well catered for and 2) It will not be necessary to install reactivation equipment on the large system.

T.R. Ophel

T.A. Brinkley

5th March, 1984

As mentioned in the last report (42/8), David Weisser will work on the module for the whole of 1984 and Trevor Ophel will take over the position of younger author.

Enclosures:

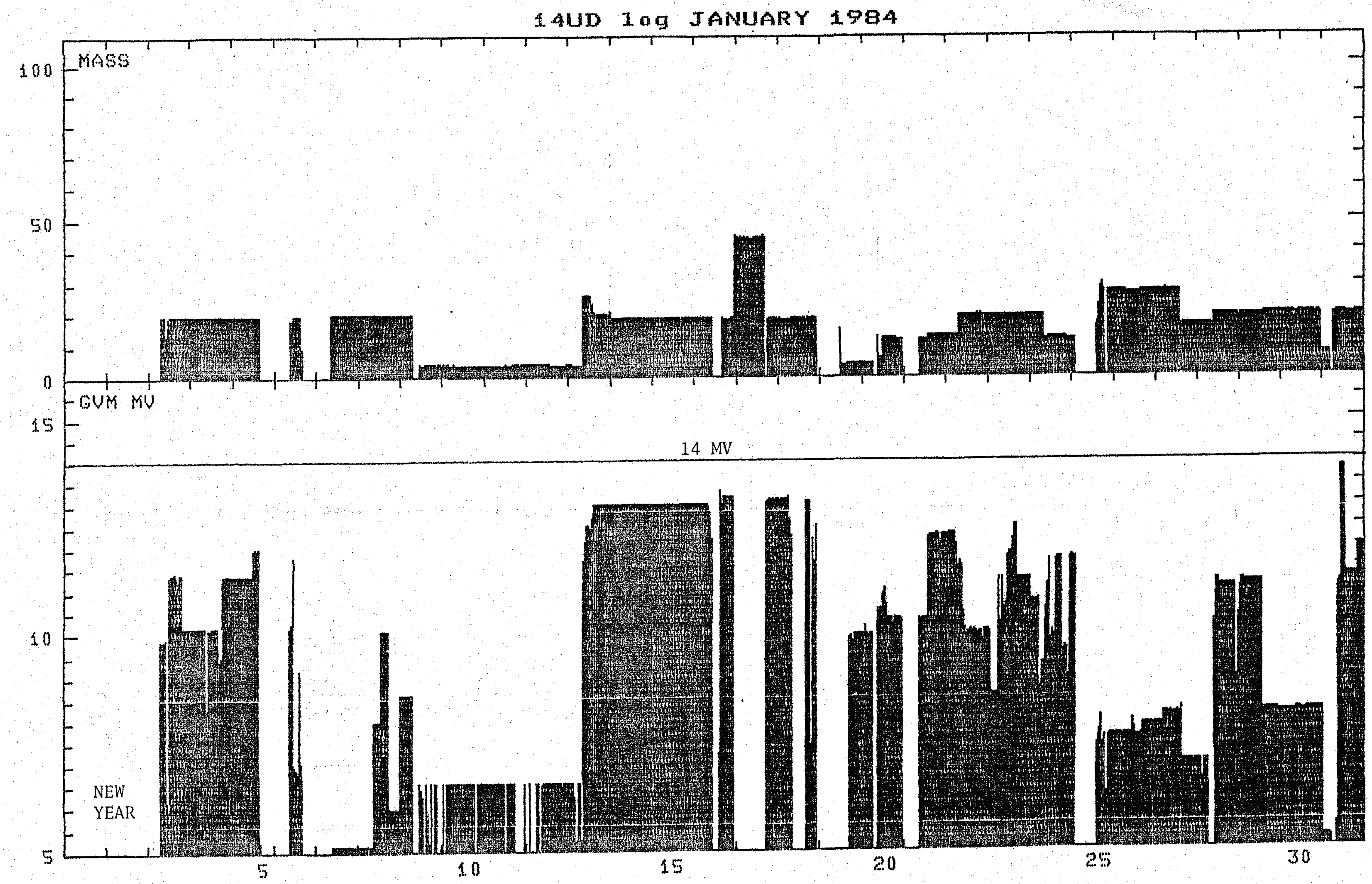
Plots of particle masses accelerated, and operating terminal voltages.

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:

1) Hole in post electrode caused by sparking from loose ring.

2) The two halves of the cross-over insulator, showing breakdown.


14UD log JANUARY 1984
MASS
100
50
0
GVM MV
15
14 MV
10
5
NEW YEAR
5
10
15
20
25
30

14UD log FEBRUARY 1984