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14UD TANK OPENING REPORT No. 59

Two Openings.
29th June to 22nd July 1987
(24 days open, 18 working days.)
4th to 5th August 1987
(2 days open.)

D. C. Weisser **T. A. Brinkley**

REFERENCES: Earlier Tank Opening Reports are referred to by the notation (38/4) etc., meaning Report No. 38, page 4.
A glossary of terms and abbreviations is given at the end of the report.

Reason for the tank opening:

It was a scheduled opening, the main purpose of which was to put in the first stage of the compressed geometry tubes mentioned earlier (58/5).

Preamble.

The 14UD was last closed on 28th May. It was soon running at 13.6 MV and continued at high voltages for as long as it was required. Half way through June we ran into trouble with Chain 2 which was putting up only about half the charging currents of the other two chains. The pickup trace was very poor and we turned the chain off. With only two chains we were still able to run happily enough near top voltage, with a spell at 13.8 MV.

Lost charge annoyed us on occasions, more than anything because we were never sure what was causing it. We investigated the lost charge metering circuit and realized that, with 50μA of lost charge, 1 volt was developed across the 20kΩ series resistor, which is virtually in the cathode of the stabilizing triode; since the triode runs with a bias of -8 volts the effect of the developed voltage pulls it down to a situation in which it does not control effectively.

The machine was shut down on Friday, 26th June, when we took out the gas and left the tank unopened over the weekend.

Compressed Geometry Tubes.

The idea of increasing the voltage holding ability of an accelerator by increasing the insulator length of the accelerating tube was reported by Michel Letournel at the 3rd International Conference on Electrostatic Accelerator Technology in Oak Ridge, 1981. By that time, as well, there was evidence from the Canberra 14UD, that continuous operation of the heated tube apertures was not essential to the tube's voltage holding ability. The possibility was mooted, of eliminating the six heater plates in a pair of units to allow space for additional live accelerator tube. Clearly the space existed; the more difficult question was whether an electrode structure could be designed which "compressed" the electron trapping region without the dead length of the heater plate. Calculations and tests performed at Munich, Oak Ridge and NEC, demonstrated that such a compressed geometry was possible. The compressed geometry tubes produced for ORNL grew from this history. The equipment being installed for test at Canberra benefits from this previous research.

Units 1 through 4 are being used to test the compressed geometry tube. There are three main aspects of the Canberra installation which differ from that used at ORNL.

1. The "V" shaped decoupling electrodes will have a 45° angle with respect to the equipotential planes in contrast to the 30° and 0° apertures tested at ORNL.

2. Our tubes will not be shot blasted and only the six electrodes at each end will be replaced. The remaining six electrodes will not be touched; however, the new 8-gap tubes sent by NEC have undergone the standard shot blasting technique.

3. The new electrodes in Units 1 and 2 will be processed to try to reduce low field electron emission observed when similar tubes were tested at ORNL.

The Treatment Process:

Three days before the tank was to be opened for the tube upgrade dress rehearsal, involving four units, we received a telex from ORNL reporting that electrodes which had been mechanically polished in order to reduce their electron emission, were worse than unpolished electrodes. The symptom of the electron emission is the production of continuous x-rays. This radiation differs from conditioning x-rays in that 1). There is no threshold gradient. 2). The flux increases rapidly with gradient, and 3). It does not come in the usual approx 20 ms pulses, but is continuous in time.

The observation that buffed or polished electrodes were more potent electron emitters than unpolished ones is consistent with electrons emanating from foreign body inclusions at the surface of the electrode. Polishing, using high speed cloth wheels and some unknown compounds, melts and redistributes the surface and so could introduce such foreign bodies and partially bury ones which were present before polishing.

We proposed to rid the electrode surfaces of contaminants using an adaptation of the oxidation-reduction cycle we have developed for RF superconducting resonators. Its application is based on the assumption that some of the contaminants may contain carbon (cloth) or other substances which could form volatile oxides.

"Throw another prawn on the barbie".

The electrodes were oxidized by heating in air to about 700°C for a couple of seconds using an RF induction heater, (see photo No.1).

The titanium electrodes could not then have the non-volatile oxides reduced in a hydrogen atmosphere because of the danger of hydrogen embrittlement. The other normal reducing option is >1200°C heating at ultra high vacuum, $<10^{-9}$ torr. This method was rejected because we didn't have such a furnace and the electrodes would have softened and warped, anyway.

We chose to remove the oxidation residues by sputtering them away in an argon-magnetron sputtering device. This was adapted from our Nb sputtering effect on superconductors, (photo No. 2). Robert Rathmell told us that the first tubes at Munich had been argon sputtered and continued to bleed argon into the tube for years. We eliminated the implanted argon by baking the electrodes in a 10^{-7} capable oil free vacuum system to ~550°C for half an hour, (photo No. 3).

The ANU treated electrodes were installed in Units 1 and 2, while polished electrodes were installed in Units 3 and 4. The voltage test on the day that gas was put into the machine showed that the units with compressed geometry tubes rapidly conditioned to 1 MV/U, while the old tubes started to condition at 0.83 MV/U. As well, there was only minor conditioning activity in the compressed geometry units; thus the 45° apertures were a success.

X-rays >0.33 MeV were monitored opposite the terminal when only Units 3 and 4 and then 1 and 2 were live. Units 3 and 4 produced 300 to 400 counts/sec above background while no radiation above background was seen from Units 1 and 2. (See Figure 1).

These experiences have encouraged us to request that NEC should develop an oxidation-sputtering-baking cycle for the new electrodes to be used in the full machine compressed geometry upgrade scheduled for November 1987.

Operational time.

During the 28 days since the last closure, the 14UD operated for 493 hours. This was 73% of elapsed time, excluding the days for gas transfer (42/2).

The Tank Opening

Exploratory Tour

There was dust on the column and the familiar gritty feeling that we have become used to on the rings. A few tube points were out of alignment, but there were no serious displacements.

No further evidence of snail tracks or rivers was seen on the perspex shaft sections.

In the lower terminal we discovered the cause of the anomalous performance of Chain 2; its 'down' inductor was lying on the deck with a broken nylon support stud. We assume, and hope, that the stud failed because of excessive mechanical tension and not because of the effect of bdps and the dry environment which would, of course, affect our nylon chain links.

There appeared to be little or no chain stretch since the chains were last adjusted. Our chains have certainly stretched less since we reduced tension (57/2).

And so to work!

The Tube.

We began straight away on the tube conversion dress rehearsal. There was a lot to do and, with much forethought, we had organized ourselves into teams, carefully planned so that dismantling, disassembly, electrode treatment, clean room work, reassembly, alignment, etc. would be smoothly dovetailed together. Plans are one thing and reality another; sometimes events were crowtailed instead, with correspondingly ruffled feathers.

We first measured up what we already had: this, in order, was a long bellows immediately inside the tank; next came an empty beam profile monitor manifold, the intestines of which had long been surgically removed so as not to confuse us by getting the way of the beam; next, the entrance slit system; then the tank cup and finally the manifold for a 300 litre/sec pump which connected onto a blank nipple, a few inches long, then directly onto the first element of the accelerator tube.

We finished our designs for support for the slit system and bellows to fit between the cup and the accelerator tube, (photo No.4).

Low energy tube sections were removed down to, and including, the first section in Unit 5. This exercise yielded an interesting discovery: one of the thin tubular feedthroughs which enclose the high current heater leads, had a very bad twist which would have been caused when tightening the screws at some remote time in the past. The twist was close in and could not be seen between the adjacent tube flanges. That it did not break is remarkable; that it hung on in secret for so long without leaking is one of those beneficences which confide to accelerator people that all is not interminably stacked against them, (photo No.5).

The tube sections were disassembled outside the machine and given additional protective covers as needed, (photo No.6). The tapped blind holes on the tube flanges, where the corona point assemblies are fitted, were drilled right through and tapped in a smaller size. This was necessary because, now that the tubes were no longer separated by heater plates, the original arrangement for fixing tube end corona points could not continue. When working on the tubes we discovered, inside one of them, some bits of ceramic from the tank cup metering insulator which we found broken a long time ago.

The next step was to put the individual tube sections into the one tonne press which we had built in order to reset the sealing surface to ceramic distance.

We discovered large concentrations of particulate bdps on the sealing surface outside the previous gasket position. In addition, there was similar stuff all over the flanges as well as sand caught in the flange bolt holes. In order not to contaminate the gloves of the clean room tube assemblers, the flanges were thoroughly cleaned with water, alcohol and chlorothene. The tube nuts were cleaned in an ultrasonic agitator. All threads were coated with molybdenum disulphide anti galling compound.

Electrode treatment was being developed concurrently. As soon as tube sections for units 3 and 4 became available, they were fitted with new untreated electrodes. Three element assemblies were sealed together in the clean room and then removed for helium leak testing, (photos 7 and 8).

Charging system

Chains.

Chain 1 persisted in its odd behaviour by suddenly dropping in charging current when charging voltage reached about 6 kV. The younger author, who had been overseas when the fault cropped up (58/3,4), spent some time examining everything associated with the chain that his elders had already looked at without success. He found some sharp rivet heads and an accumulation of oil and grime around them which he felt could be causing breakdown to the inductor. He cleaned the chain himself and the matter was put aside until the charging tests; the fault was still there, as impudently as before, and as helplessly as before it was allowed to remain. We justified this permissiveness by telling ourselves that we knew there would be no problem when the tank was gassed up, and we had too many far more important things to get on with.

Idlers:

Conducting d.c. idlers, newly arrived from NEC, were put at the 'up' positions of all chains. Here it might be appropriate to say that what we call d.c. idlers, NEC calls 'pickoff pulleys'. Our name was invented in the very early days by the older author, who had to think of something to call them; he chose the fact that they ran on the chains like stabilizing idlers, but made a d.c. connection to the terminal inductors. We are unlikely to change our habits now; anyway, it doesn't matter, because when we order d.c. idlers, NEC sends us pickoff pulleys.

Strippers.

Foils:

Foils were renewed in both strippers.

The column

Posts.

Four reconditioned posts were put in Unit 20.

Pumping the Tube

On Saturday, 18th July, the tube was carefully roughed from the inflection magnet by the younger author himself. Finding no first order leaks, he started the various pumps. Remembering how many seals had been broken, we crossed our fingers and began to sit out the slow process of getting a tube, long opened, down to a comforting range.

We put on a residual gas analyzer to look for pressure sensitive SF6 leaks and to be used as a helium leak detector. We noted that we still see hydrocarbons from the bad old days when roughing was by rotary pumps. Units 1 through 5.1 were heater taped to 140 to 160^{0}C for 24 hours. The flanges were retorqued and helium leak tests were satisfactory. No sublimer pumps in the machine were baked, but existing exhausted pellets were used to outgas the sublimer pump bodies.

Miscellaneous

The entire entrance slit assembly had to be taken out because, when the slits were fully wound out to assist optical alignment, one of them jammed and could not be freed in situ.

In order to reduce the magnetic pickup in the GVM, steel shielding was improved near the sensing blades.

Electron suppression in the Tank Cup was improved by reducing the distance between the collector and suppressor from 5.5 to 2 mm and moving the collector slightly.

During the tube conversion the younger author had an idea about the four rods which precisely position and stabilize the tube at each casting. It occurred to him that adjustable wires in tension might be more suitable. The idea will be thought about further, when there is time.

Button-up

After blowing the column with nitrogen, tacragging and having successful charging tests, the machine was closed.

Initial performance

At full tank pressure, no leaks were detected. We were very pleased with ourselves because a number of seals had been opened and remade. Furthermore, when we tried to put beam straight through the machine, it went through. This was a little surprising since we had just done a careful alignment, a procedure which has a habit of leaving you worse off than you were if you undertake it when things aren't too bad.

The younger author then did a series of tests, following which he proclaimed exultantly that the ANU sputtering technique was nothing short of brilliant. A sodium iodide detector at the terminal saw no x-rays above the background level of 200/sec with Units 1 and 2 live at 2 MV. With Units 3 and 4 live there were 400 to 600/sec.

On 27th July, 5 days after closing the tank, instabilities led us to look through the windows where we found sparking in Unit 20, just below the second stripper. The unit was shorted out and we planned to open again for a quick investigation and fix.

THE SECOND OPENING.

The sparking in Unit 20 was immediately explained by finding that the top two column corona points had been interchanged so that the blank disc was the second assembly down. Apart from a piece of Gladwrap between the rings in Unit 18, there was nothing else to complain of.

The compressed geometry tubes had been fitted out with used ANU tube points. This arrangement did not allow sufficient current to flow along the tube corona path in parallel with the 17 gaps on the column. New sharp NEC points were installed in Tubes 1 and 2, Unit 1, with an average current of $120\mu A$ at 5 kV and new ANU points were installed on the remaining compressed geometry tubes, giving an average current of $100\mu A$ at 5 kV.

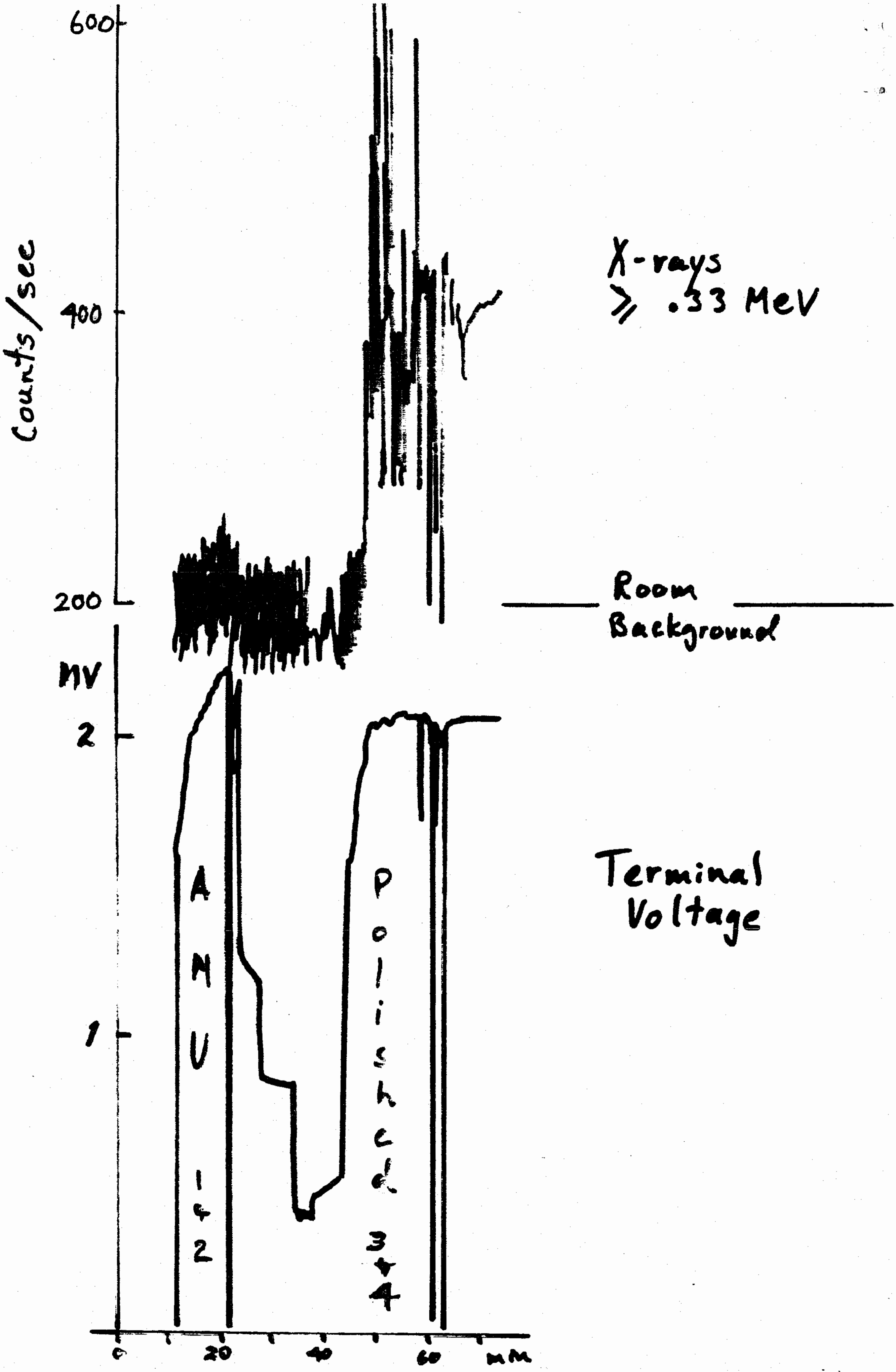
Initial performance

The 14UD worked well after all it had suffered and was soon running at 13.5 MV without effort.

A.N.U.
3rd September 1987

Enclosures
Photographs as numbered in the text. Photography by Gavin Gilmour.
Figure 1. Plot of x-ray counts from Units 1 to 4.

Our usual computer plots of mass and terminal voltages are not included. Logging has been transferred to a new computer and there has not been time to complete the plotting programs.



600
400
200
Counts/sec
X-rays
≥ .33 MeV
Room
Background
MV
2
1
Terminal
Voltage
AMU
1+2
Polished
3+4
0
20
40
60
mm

Figure 1

Glossary of terms and abbreviations:

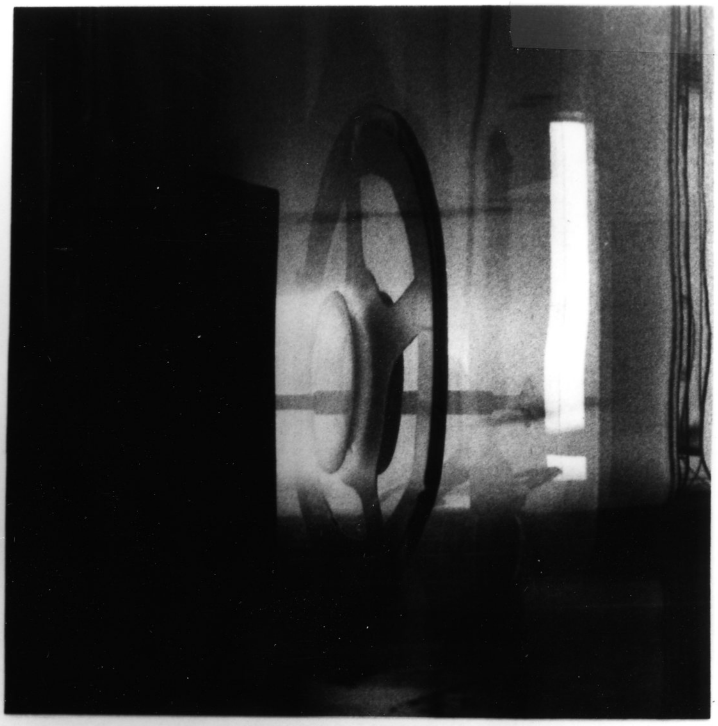
The order in which an accelerated particle passes positions in the machine is used to number them, thus Unit 1 is the first unit and units 14 and 15 are each side of the terminal, Unit 28 is the last. Tube electrode 19/2/7 is Unit 19, tube section 2 and electrode 7.

- BDP or bdp - breakdown products.
- Conductivity cell - the breakdown product detector described 37/10.
- Vivalyme - assumed to be soda lime, CaO + NaOH

Operational time: We subtract tank opening time from elapsed time and quote the percentage of the remainder that the machine has volts on terminal. Sometimes, when the source is down, the column is voltage conditioned, leading to an overestimate. Comparison of the source and terminal plots shows that the difference is rarely noticeable.

Finally, to avoid confusion, David Weisser and the older author often eat lunch together.

1



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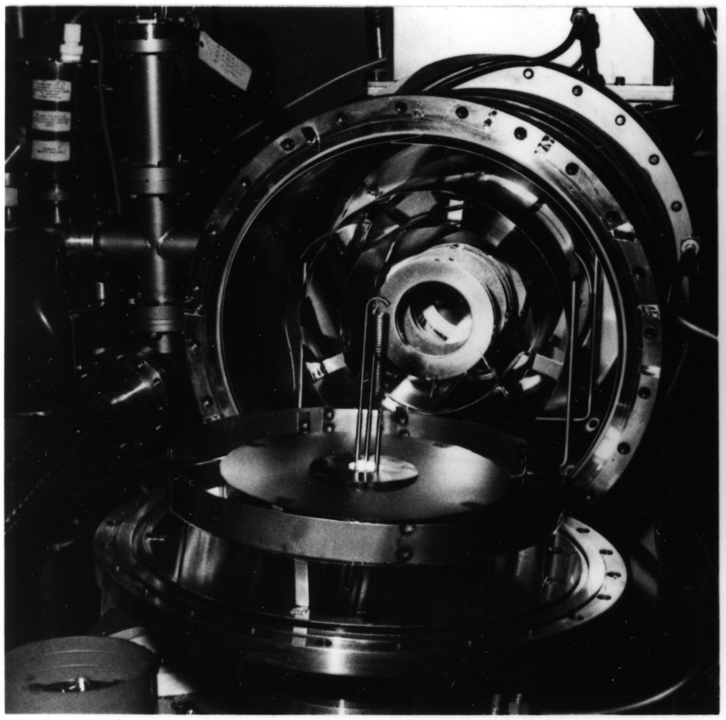

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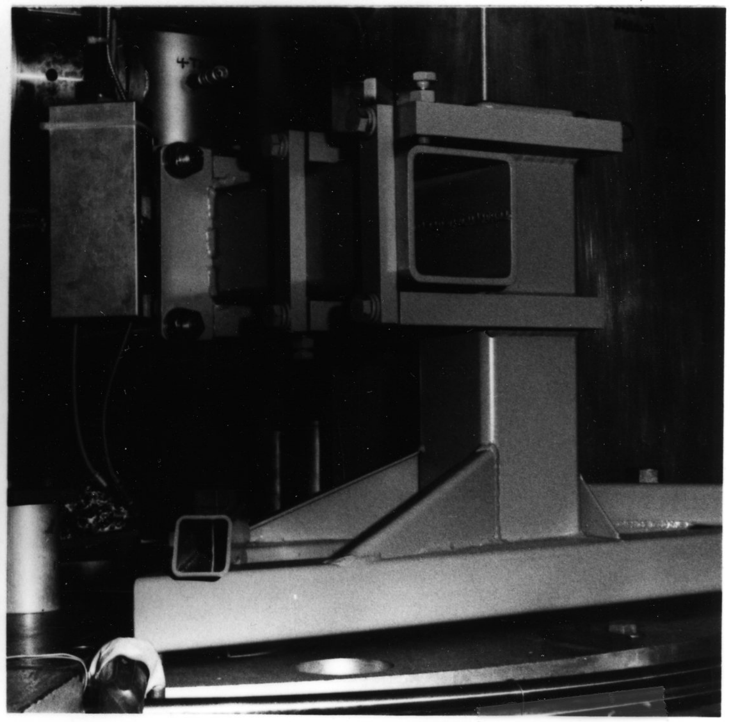

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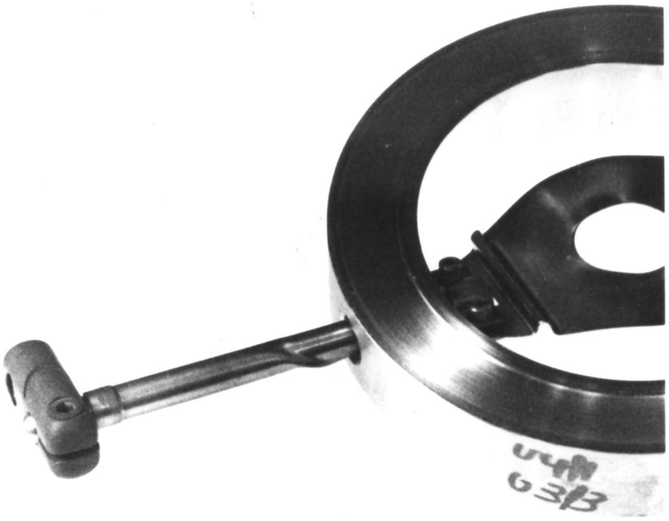

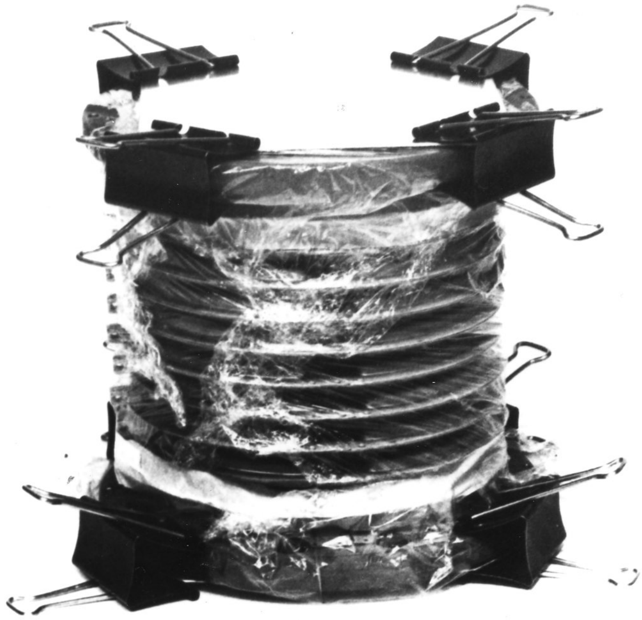

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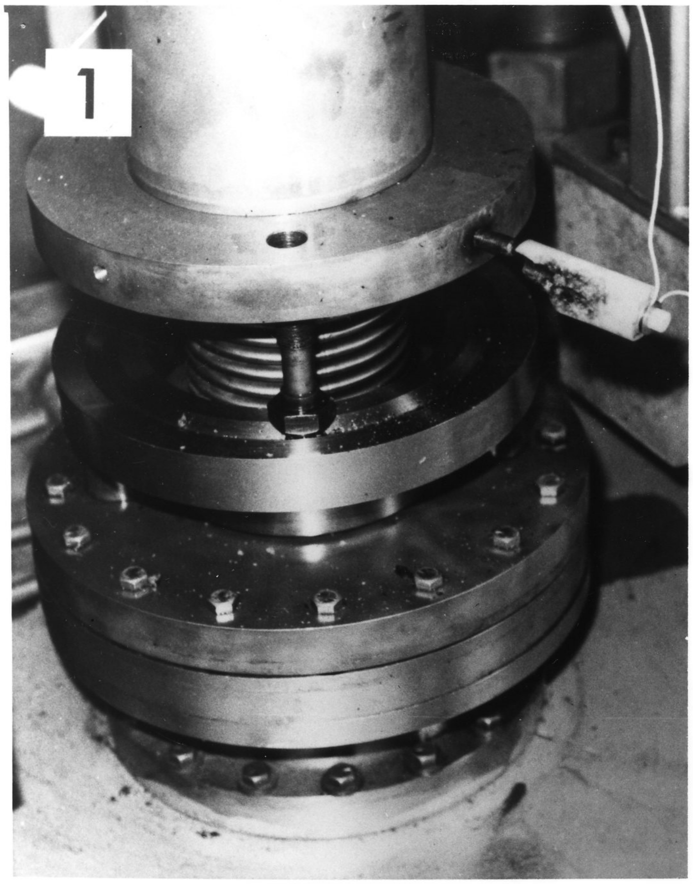
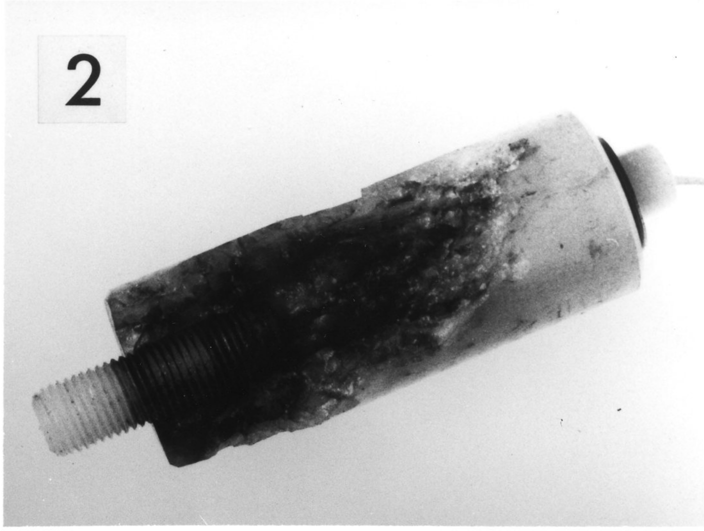
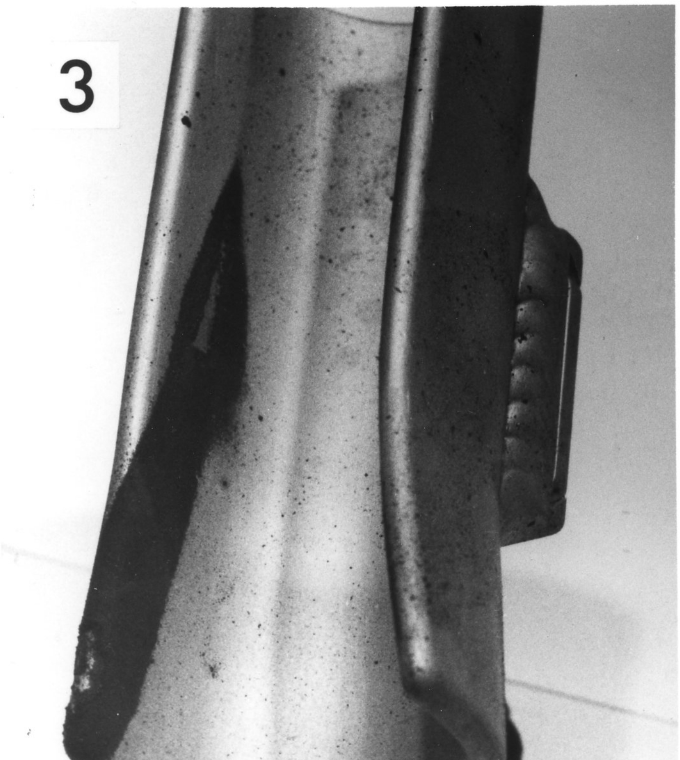
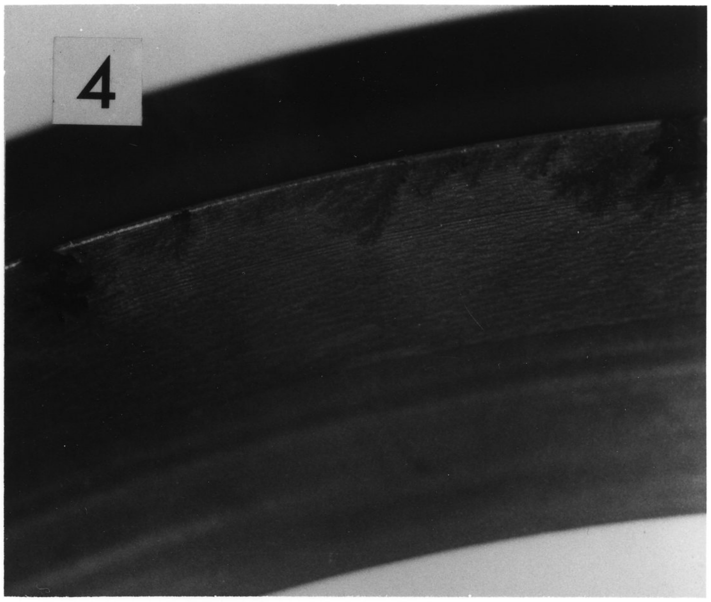
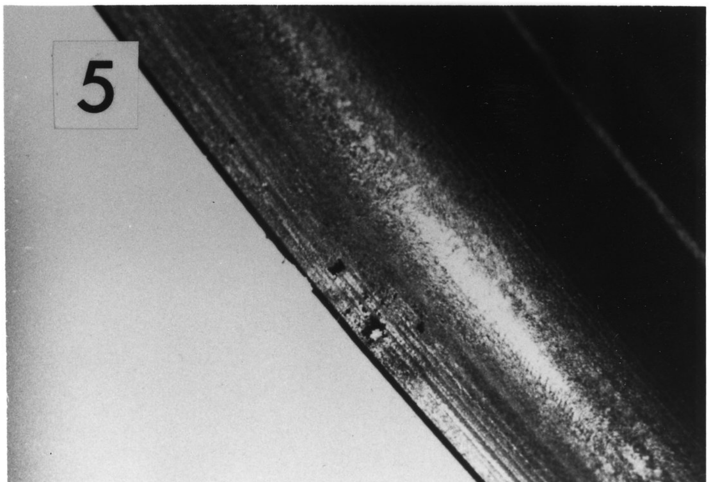
T059











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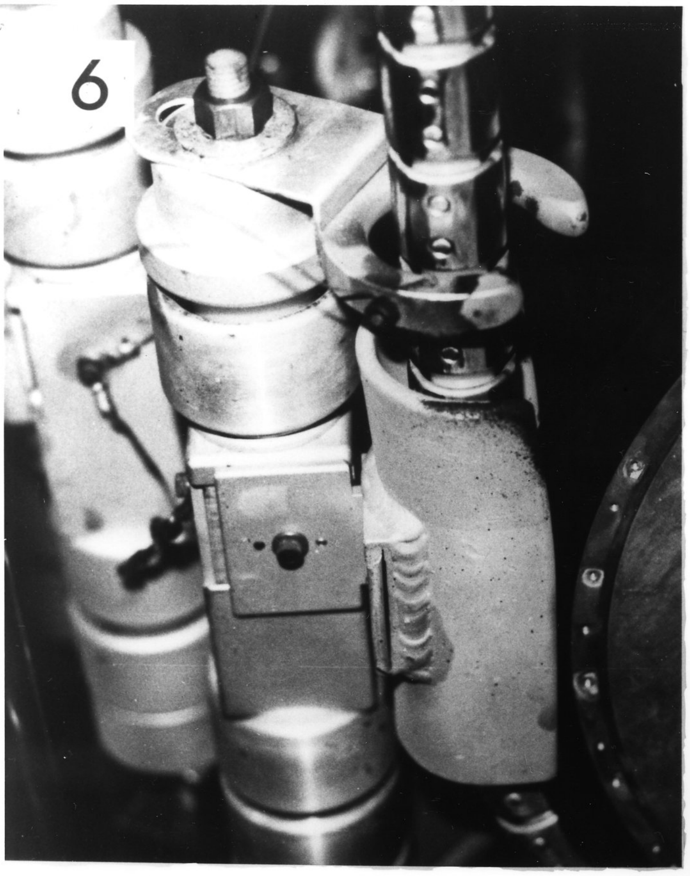
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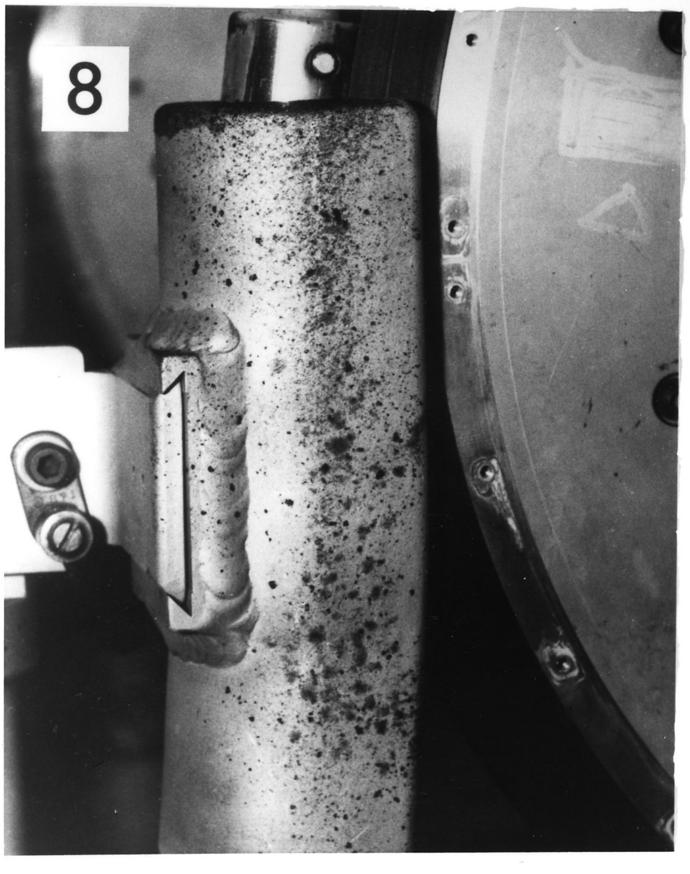
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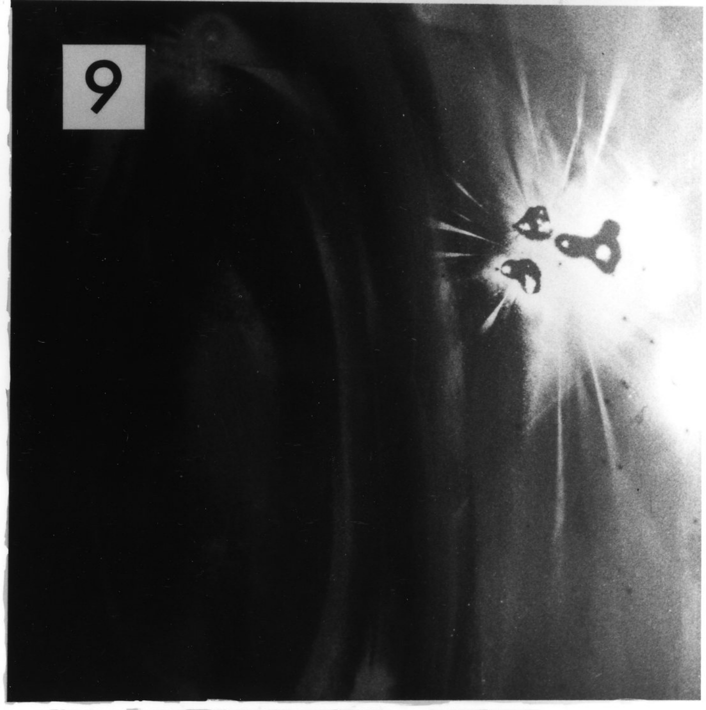
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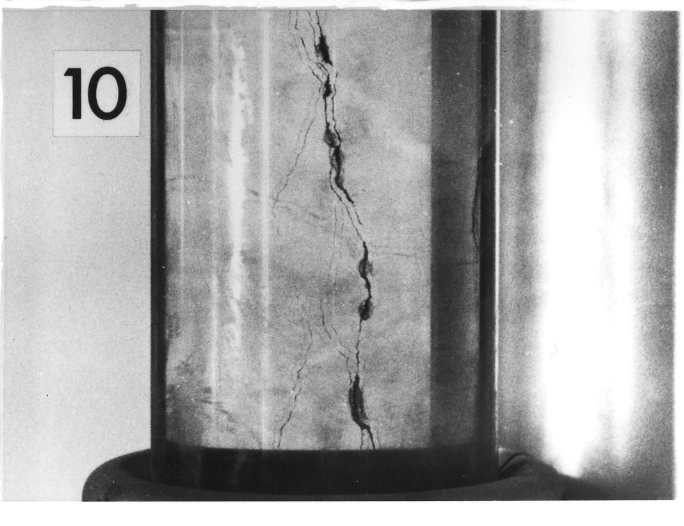
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