14UD TANK OPENING REPORT NO.5.

October 20th - November 26th (37 days total; 27 working days).

Since the tank was last closed the accelerator ran for 97 days until this opening which was scheduled to replace foils and to take the opportunity to install a major modification, several small modifications and carry out a major vacuum service; unexpected setbacks in the latter extended the open period beyond the time estimated.

In this report we are departing from the usual format which discusses only what was done during the tank-open period. We believe that there would be value in giving our assessments of the general performance of the 14UD and also commenting on the success, or otherwise, of changes and innovations which have now been operating long enough to justify firm conclusions.

It must be remembered that obviously the 14UD, as supplied by N.E.C., was known to be experimental in a variety of ways. There were aspects accepted as being imperfect in which we believe we have since made improvements; we emphasize that reports by us on deliberate changes from the N.E.C. original installation are a natural development. The accelerator, as it is working today, is giving very satisfactory performance, and experimental groups in the department, who take no part in maintenance or development, but merely use the 14UD, are impressed by its reliability and stability.

14 million volts on terminal is not reached under ordinary operational conditions; in fact this value is rarely achieved other than at the end of careful conditioning. The machine operates effortlessly for long periods at 12 MV and, with modest attention to conditioning, we operate at 13 MV plus as a matter of course. The final million volts will presumably come with extended conditioning and sealing a vacuum leak that has become monumentally hard to find.

TERMINAL POTENTIAL STABILIZER:

The N.E.C. stabilizer was abandoned entirely and the second version of an A.N.U. device has just come into operation. This unit incorporates a conditioning mode: we switch from "operation" to "conditioning", in which mode the terminal voltage is swung slowly plus or minus 150 kV of nominal voltage.

VACUUM PUMPS:

We discontinued the use of N.E.C. ionizers in our pumps and report that we are well content with the performance throughout, of A.E.I. 10 ℓ/s and a Varian 20 ℓ/s triode pumps.

SHORTING RODS:

On more simple matters we discontinued the original power-driven N.E.C. devices for handling shorting rods and replaced them with manually operated crank wheels. These devices require only modest effort to use, even when inserting a full load of steel rods at the H.E. (upwards) end at 80 psi abs. tank pressure. We are especially pleased that we have control, by simple feel, when rough spots are encountered in the various castings. Instead of the original requirement to screw an insert into each rod in order to remove it we have a gripping device adapted from vice grip pliers, which operates in a moment, and enables us to drag out a string of rods without damaging them. Both co-authors have had a shorting rod mishap, with escaping gas at high tank pressure, and each appreciates a non-power system which enables the operator to react quickly to warning signs. We take into account not only personal risk but also the huge financial consequences of a great or total loss of SF_6.

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PLATFORM CONTROL:

Since the heavy platform control cable was eroded by spark damage to a degree that compelled an alternative, the platform has been operated, at each tank opening, by simply dangling some control and communication cables through the upper door and down the inside tank wall. There is no intention of re-installing the spring-loaded commutator type control cable reel. A new 18-core cable was purchased, but has not yet been used. When there is time the new cable will be installed to deal with 18 circuits electrically more satisfactory than those which are in use at the moment, but the device will be a "dangling" type, not a spring-loaded reel.

LOW TERMINAL VOLTAGES:

The accelerator has recently been run at low terminal voltages without using any shorting rods. The following table is a guide to the results.

ANALYZED BEAM ON STOP	NO SHORTING RODS	
MV(Term)	Analyzed beam of $^{16}O_{4+}$	Analyzed beam of $^{16}O_{5+}$
7	70 nanoamps	225
6.5	58	175
6	60	145
5.6	60	115
5.4	38	92
5.2	40	78
5.0	56	---

There was no tube or column corona current at less than 7 MV.

The 14UD holds well at surprisingly low terminal voltages and has allowed satisfactory measurements to be made without shorting rods to evoke the tube and column corona currents considered necessary for voltage stability. The accelerator held steady without tube or column corona currents, during the experimental run tabulated above.

LITHIUM EXCHANGE SOURCE:

Using a 1 mm thick filament of coiled thoriated tungsten wire, and not a thoriated gauze filament, which has been assiduously avoided, a week's running, even when accelerating oxygen, is typical.

Experiments have been made with the lithium oven, and its condensers, and the best run on one loading so far has been 34 days, still going - in other words the oven was changed because an opportunity presented itself, not through necessity. Enough lithium remained in the oven to have run for a further day or so and the buildup on the condensers, though heavy, seemed as though it would not have blocked.

The oven has been loaded with 50 lengths of lithium wire, about 4 inches long and eighth inch in diameter; giving about 21 grams of lithium which has a total surface area of about 500 cm^2. We have just made our first loading with half inch thick lithium bar, four inches long. Five such bars will go in the same oven and this means about 34 grams with a total surface area of about 200 cm^2. The five bars are much easier to clean than fifty lengths of wire and the pump-down time is shortened, together with the desirable fact that the usual sudden bursts of solvent trapped in the tangle of melting wires did not occur.

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Returning now to the tank opening, and the conventional aspects of our earlier reports, we submit the following:

SHAFT BEARINGS:

Fifteen bearings needed replacement. Mobil has since "reneged" on their recommendation for Mobil 78 and now suggest use of the standard grease. Neither NSK nor Mobil offer any encouragement for lifetimes much beyond 5000 hrs of continuous operation.

CHAINS AND CHARGING SYSTEM:

The chains were run as first job when we went into the tank in order to note their behaviour before any work was carried out. Nos. 1 and 2 ran well and No.3 had a wobble in the stiff direction. Two pellets from No.2 and one pellet from each of the others were removed.

One contact spring in the down d.c. idler of Chain 2 was missing.

The rims of all pulleys were in good condition, likewise the shimstock contacts. The pulley rims were distinctly oily and the chains faintly so; this is the condition found to be optimum.

Before closing up a stroboscope was again used on the pulleys in the terminal. There was no significant slip; all three pulleys were running at about 660 rpm and all idlers at about 2250. These figures disagree with those given in Report No.3 where the pulleys ran at 600 and the idlers at 3700. We did not calibrate the stroboscope and attributed the lower idler speed to idler slip because the chain was more oily this time than at the original tests which were made before the new oilers had been operated.

The oilers appeared to have worked well. The reservoir for Chain 3 oiler had about 50 of its 100 or so cc of oil remaining; the rest was on the floor of the tank, implying that it had not discharged as a mist into the tank gas. The oilers were operated on four occasions during the 94-day operational period.

The barrier strip which carries the leads for the charging and H.E. corona currents had suffered spark damage, and was replaced after the connections on it were meggered and shown to still have high resistance to ground.

The usual charging tests were carried out after the inductors were checked and the behaviour of all three chains was very close in pattern. Sometimes one chain obstinately refuses to show sparking in the 4 to 6 kV inductor voltage range and holds off until 8 kV, but on this occasion onset sparking occurred at about the same voltage for all chains.

STRIPPER:

The foil change mechanism had to be modified by replacing the sprocket wheel at the stripper end with a flanged pulley because of trouble with the teeth on the driven pulley. Lateral alignment screws were also fitted. The entire stripper system was taken out of the terminal in order to install the new A.N.U. valve which was designed to enable both ends of the tube to be shut off from the stripper volume, enabling foil changes to be effected without letting the tube up to air. This was an extensive venture because the N.E.C. support framework had to be taken out and our own fitted in such a way that the additional vacuum components would all go together in the restricted space, allowing alignment devices to be adjusted. In the vacuum system we put on the input end of the upper stripper canal a tantalum collimated gold-faced beryllium plug which has

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a two and a half inch thick lead slug round it. The end of the lead cylinder was also shielded with tantalum. We expect this to reduce radiation, and ionization in the gas, significantly better than the lead sheet which has hitherto been wrapped as well as possible round the outside of the tube.

Before foils were loaded the tube and foil volume were pumped down with the new valve open. The tube remained like this for some days while leak chasing was carried out using the leak head which can now be fitted into the terminal plumbing. When the time came to test the new valve, and load foils, vacuum was watched at L.E. and H.E. ends and, at the same time, workers at the terminal could observe local vacuum because the 10 ℓ/s ion pump was running on a temporary 240 V supply, fed from a dangling mains lead; i.e. we were not dependent on shafts running.

The new valve was closed and the stripper volume let up to air. There was no detectable change in either L.E. or H.E. pressures, nor pressure indicated by the terminal ion pump.

The foils were changed, the stripper volume was roughed with the carbon-vane pump on a portable roughing system we had taken onto the platform, then the vacsorb was opened and left on the stripper volume for some 10-15 minutes. The vacsorb was then valved off and the new valve opened: in other words the stripper volume, newly roughed, was opened to both L.E. and H.E. tubes.

There was a detectable change in the terminal ion pump current and indicated L.E. and H.E. pressures increased from $\sim 10^{-7}$ to 10^{-6} torr.

While it cannot be predicted how many operations of the valve will allow this degree of sealing the performance under first operational test was very pleasing.

So far the method of counting foils has been an electrically operated counter on the console which counted impulses the foil changer was given, whether or not the changer responded to them. A simple mechanical counted was fitted on the panel in the terminal where the ion pump meter is located. This counter, which can be seen on T.V., is linked to the foil changing Geneva mechanism and we expect it to be completely reliable.

PNEUMATIC OPERATORS:

The foil changer, cuperture, terminal and midsection sublimer switches have been converted to pneumatic operation instead of a rod driven by a motor on top of the column. There has been incessant trouble with everything electrical inside the tank and we were driven to a non-electrical alternative; because pneumatic operators installed in the EN years ago gave no trouble whatsoever, we tested identical nylon tubes in the 14UD column (see Report No.1). When no damage was found to occur to them it was decided to convert all systems which do not require smooth variac operation; i.e. sublimer current control and terminal lens control. The operators are driven by SF_6 released by a solenoid outside the tank; the SF_6 is vented into the tank and therefore not lost. We concede that the principle is experimental in that, because impedances necessary to slow down operation have been incorporated, we may run into trouble if the SF_6 liquefies; At this stage we are not sure how carefully external SF_6 pressure must be set relative to the tank pressure; so far the setting seems to be fairly broad.

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VACUUM:

Because the stripper system was taken out entirely the opportunity was taken to chemically remove all the titanium from the terminal and midsection pumps. This procedure was carried out about two years ago and, since that occasion, we have larger cleaning tanks and better lifting facilities; also there has been success with different solutions. The three pumps were treated as follows:

1. Degreased in vapour degreaser.
2. A stainless steel vessel, containing hydrochloric acid (conc) in an equal volume of water was heated by being lowered into a vapour degreaser. When this acid solution had reached equilibrium with the vapour (i.e. was at about 80 degrees C) the pump bodies were immersed in the acid for 5 minutes. The result of this is striking: large flakes of titanium float to the surface of the acid, and it should be noted that, for all 3 pumps, there were no loose flakes on the pump bodies which could be removed by the basic approach of a clean, stiff wire brush; all bodies were brushed in that way and no titanium removed whatsoever. Titanium adhesion was complete.
3. The pump bodies were then lifted from the hot acid, lowered into a plastic tank of clean, cold tap water and "sloshed around" for a couple of minutes. An equal number, or perhaps even more, flakes came out of the pumps in this process.
4. The pumps were then returned to the hot acid bath, but the degreaser heaters turned off. They were left for 45 minutes, then again put into water and sloshed around; the difference this time being that the insides were rubbed vigorously with a rag in order to remove a residual grey sludge film.
5. The next step is immersion in a solution of 30% nitric acid (conc); 3% HF, made up with water. They were left in this for about 20 minutes, then washed, then rinsed in distilled water, then rinsed in alcohol and finally put in the vapour degreaser in order to dry them.

   Unless carried out in a very well-ventilated room, taking all the usual precautions for such noxious and dangerous solutions, for instance copious clean cold water must be on hand to deal with accidents, the process is thoroughly unpleasant and somewhat hazardous. Inexperienced persons should not be delegated to carry out the work.

There was evidence of etching on the sealing surfaces of some flanges, but it seemed more to have produced a matt effect than real erosion.

A new sublimer was put in the midsection pump and two new ones in each of the terminal pumps. The remaining sublimers were in very good condition.

After reassembling the vacuum system, and pumping down, we found a leak on the tube flange of the upper pump. This was due to etching the sealing surface, by the chemical cleaning, to a greater degree than seemed from appearance only. The pump was taken out and the flange machined. When put back another leak was found where the weld had been attacked by the cleaning solution. The pump came out again, was re-welded, and this new weld also leaked. Further and more extensive welding closed the leak. It was clear that different grades of stainless steel were used in the manufacture of the pumps. On the same pump only the tube flange suffered from the acid, not the sublimer flange. The midsection pump showed no sign of etching. While we are convinced that the pumps needed to be cleaned, the leaks which were caused set us back a long time.

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When the tube was roughed the former method of using mechanical pumps at each end was departed from and, for the first time, the entire tube was roughed by one carbon-vane pump attached at the inflection magnet. The tube came down to the base pressure of the carbon-vane pump (57 mm) in 4½ minutes. Then a single vacsorb was opened up at the same place. This brought the tube down to a few microns in 45 minutes; the L.E. and H.E. pumps were then opened and the ion pumps came on easily.

POINTS:

No points, tube or column, needed to be changed in the machine. The excellent performance of Type 2 points (soldered sewing needles instead of gramophone needles held by screws) continues.

MISCELLANEOUS:

When the gas recirculator was dismantled for routine servicing the fan was found to have been always rotating in the wrong direction. After some tests we concluded that it does not perform much better when running in the correct direction, therefore there will not have been much effect on the gas.

Two viewing ports were fitted at unused blanked flanges on the curvature of the bottom of the tank. These give a very good view of the column from opposite sides.

PYROTENAX:

This was exchanged for wires in Greenfield wherever practicable because of the troublefree results obtained from that which was installed at earlier stages.

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In the ten days since button-up the machine has behaved well electrostatically, and has been used for scheduled runs, however it was clear when the tank was roughed that a leak existed somewhere. The machine is running at the moment with pressures mid to high 10^{-8} at the L.E. and about 10^{-7} at H.E. It should be noted that while leak chasing in the terminal was very careful, and was repeated, the tube was not bagged in order to facilitate matters because there was no time available for this.

D.C. Weisser

T.A. Brinkley.

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Copies to:

Prof. J.O. Newton, C/- Manchester Univ.
Dr. R. Rathmell, N.E.C.
Chiaki Kobayashi, Japan Atomic Energy Res.Inst.
Dr. J. Ball, Oak Ridge National Lab.
Dr. C. Moak, " " " "
Dr. R. Voss, Daresbury Nuclear Physics Lab.
Dr. Kenji Katori, Tokyo University of Education.
Prof. G. Goldring, Weizmann Inst. of Science.
Prof. S. Skorka, Universitat Munchen.
Dr. T.R. Ophel, Dept. Nuclear Physics.