/pp

PS / LP Note 91-20

March 1991

LIL Modulator Work done during the 1990/1991 Shutdown

G. Curri
M. Guillon
G. McMonagle
P. Pearce
G. Rentier

Preface

This note looks at the work done in the shutdown, starting in September 1990, and ending in February 1991. A checklist of work that must be repeated at each shutdown is noted, and comments are made on the timely requirement for services such as cooling water, controls and access to the machine to enable modulator power tests to begin.

Chapter 1

Modulator shutdown data

1.1 General work done

Once the machine was off, the modulators were electrically isolated and the high voltage components earthed down so that the faraday cage cleaning could start. This was done in September with a temporary labour person, and took two weeks. A special cleaning fluid and applicator was used, bought for this job from RDI. SA in Fribourg. The fluid type is called NETFASE, and is a solvent for disolving grease, oils and for eliminating residual carbon dust from components in high voltage installations. The product is safe, but must be used in a well aerated environment. It has an ignition point of between 50 and 60 deg C so therefore NO SMOKING whilst using it.

The high voltage charging filters were all dismantled to inspect the chokes and power resistors inside them. These resistors and their end mounting caps were changed during the last long shutdown and a new model was fitted. These have stood up to a years operation without any failures or end cap overheating, as was the case with the original design. The old filter assembly in MDK35 was modified to enable the inner filter chokes and resistors to be easily dismountable in the future. All filters now have fitted the insulated front end 200 μH coil to avoid interturn breakdowns. In addition all of the spacer disks in the filters have had the air ventilation holes enlarged to enable better cooling.

The end of line diode assemblies have now all been fitted with the sealed ROPEL capacitors since last October, and these were inspected during this shutdown. All assemblies were in a good state and will most probably not need opening again unless a fault develops in a unit.

The cotton air filters on the faraday cage doors were changed this time. In the same maintenance period last year these seemed clean enough, but now in retrospect after dismounting them completely one can see that inside the filter they must have been full of dust. This is another task that needs to be done on a regular basis yearly.

To improve the conditions of maintaining the equipment inside of the faraday cage, a door-switch operated light has been fitted inside at the ceiling level, on the thyratron assembly side of the cage.

The PO group planned to change the rotary 3 phase switch on the modulator MDK35 power distribution panel, but arrived to do this whilst we were setting up and testing the equipment at the agreed machine power levels. This was inconvenient at that moment in time, and so this work must be re-schedulede for the next short shutdown period in June. In addition to this, there is also a requirement for a regular inspection and tightening of all the modulator busbar connections that are in the 3 phase distribution racks, for each modulator installation.

Several modulators (MDK 35,25,13) have had changed the flexible water piping that connects up the focal coil cooling circuits to the water distribution manifold. These pipes were badly cracked, probably due to being close to the klystrons and getting irradiated by X-rays over a long period.

1.2 Klystron tanks

All of the klystron tanks were opened and inspected with the exception of MDK03. However all tanks had the Diala B oil changed for a good high voltage quality, regenerated oil, of the same type. Work done on the individual tanks is as follows, and it should be noted that all tanks were found to be dirty inside. This due to cracked oil on the surface of the hot components and water was also found on most tank bottoms.

1. *MDK35*

   The tank was emptied and cleaned. The heat exchanger pipe work was sealed and anti−condensation boxes were fitted over the exposed pipes in the tank. This tank has a Thomson klystron S No. 008 installed and the whole assembly was re−installed, after being filled with oil, into position MDK27.

2. *MDK25*

   Tank was emptied, cleaned and refilled with oil. The high voltage divider was changed since the plastic cover became fissured after cleaning with freon. A new cover has been ordered. the heat exchanger pipe work was upgraded as in the previous tank and the anti−condensation modification made. All electrical connection strips inside the tank have been remade with copper (as in the Valvo tanks). The HV socket on the tank side has been remade with a multi−contact strip connection and single, large earth strap, to improve the contact end connection and remove the multiple insulated wires from around this component. The end result is a good low inductance high voltage structure, similar to the Valvo tank, and with a better pulse performance. After we had made this modification to the HV socket the manufacturers sent to us drawings of their latest version of this assembly together with a quotation for replacement parts. It has an identical modification to the one we have made! During the inspection of this tank loose screws were found on the base connection of the klystron. A flexible metal strap connection from the pulse transformer to the HV socket was also designed and installed, inspired by the excellent Valvo tank layout. Finally some broken ferrite feedthrough filter cores were replaced, which were thought to be partly the reason for noise on the I/ V klystron signals. This tank has fitted the Thomson tube S No. 004 installed. The assembly was left in the MDK25 position.

3. *MDK27*

   This tank was also opened, emptied, cleaned and re−filled with oil. The heater connection multicontact sockets on the toroidal transformer screening can were changed to have a polarised socket pair, which eliminates plugging up in the wrong sense. Copper strap conductors were fitted to all electrical tank connections in place of the insulated cable used. The heat exchanger pipe work was upgraded and the anti−condensation boxes fitted. The klystron tube based was equipped with round head screws instead of cheese heads to reduce possibility of sparking. The HV socket was assembled with a new silver plated centre connection piece. The old connection showed signs of current arcing. The improved earthing strap and flexible pulse transformer connections to the HV socket were also fitted. A new insulating part was made and fitted to one of the isolating inductors in the tank. The only fault found was a loose earth connection (the second one) inside the toroidal transformer assembly. This was corrected.

4. *MDK31*

Again, this tank was emptied, cleaned and re-filled with good Diala B oil. Whilst the maintenance was being performed the focal coil set was sent to Valvo, and then to Bruker for remeasurement. This was to enable Valvo to complete the manufacturing information in order to quote us for getting made a spare coil set. It turns out that it is Bruker who do all the work, and so it is cheaper for us to order from them directly, rather than passing via Valvo. The magnetic measurements in any case are being done by Bruker, and the cost is in their quotation to us. The klystron in this tank also had cheese head screws fitted around its base, these have been changed for round head types. Several broken ferrite cores were replaced in the filters on the measuring cables. This tank has been made nearly vacuum tight by fitting O-rings to all components that traverse the tank cover plate, including the klystron itself. This is part of the programme to overcome the problem of condensation and oil degradation. The results of the work on this tank will be seen in the next inspection and should be felt operationally by a much reduced klystron fault rate. In addition to the tank sealing modifications a Silica-gel breather has also been mounted on this tank. This means that any air going into the tank should, in theory, pass only via this filter, which will remove any moisture. The tank is fitted with the Valvo tube S No 004 and is still in the position MDK31.

5. *MDK13*

The tank was emptied, cleaned and re-filled with regenerated Diala B oil. A broken rubber O-Ring was found at the bottom of the tank, and came originally from the seal around the inspection opening! The copper strap modifications were fitted as well as the anti-condensation boxes and renewed pipework to the heat exchangers. The heat exchanger circuits were pressure tested (at up to 40 bars) to see if there were any leaks. The test was made because it had the most cracked oil deposits and water on the tank bottom. It also has given some trouble (Dec 1990) during tests, and low breakdown strength oil was also found in the tank afterwards. The flexible water pipes connected to the focal coil units were also replaced. Nylon screws that were found to be holding the component plate to the metal support bars were not changed for steel ones. This difference was only communicated after the tank had been re-assembled. This should be corrected when the tank is next opened. This tank is fitted with a Valvo klystron, S No 003, and the whole assembly was put back into the MDK13 position for this run.

6. *MDK03*

The Valvo tank assembly with the klystron S No 006 is now installed in this position. This tube and tank was originally in the MDK97 position and before that it was in the MDK13 position. The tank was not opened for inspection during the shutdown, and only emptied and re-filled with clean oil. The modulator and PFN were set up for providing power to the new buncher, requiring only 3MW.

7. *MDK97*

This modulator, providing HF power for the CTF experiments, is now fitted with the klystron tank assembly that was in position MDK03. This is the Valvo tube S No 005. The tank was not opened during the shutdown, but the oil was emptied out and filled again with clean oil. At the present time this modulator is undergoing tests in preparation for the CTF experimental work.

1.3 Yearly work checklist

The following tests should be made on a yearly basis to enable a "trouble free" operation during the rest of the year. These checks will not cure equipment faults, but will ensure that the known failure areas are looked at regularly and preventive maintenance can be used to avoid major problems.

- CHECKLIST

Clean the Faraday cage, Thyratron and PFN assemblies.

Inspect the HV filter for burnt end contacts and/or resistors.

Inspect the HV Triaxial plug/socket for contact burning etc.

Take a sample of the Diala B oil and get it measured from each tank.

Empty each tank and clean, and inspect all connections/components.

Re-adjust pulse shape, working in diode mode at operational voltage.

Re-calculate klystron voltage to check calibration/scaling factor.

Check the klystron current calibration from CT signal.

Check the trip levels and timing of all dynamic interlocks.

Make a final power test into waterload or machine cavity loads.

Check the security RF protection system at each modulator.

Check the tightness of all 3 phase busbar connections(PO group).

After all maintenance and setting up has been completed the following data must be taken and entered into each modulators log book.

- Waveform photos with amplitude and timebase scales.
- Modulator operating parameters screen photo.
- Klystron/Thyratron hours run data.
- RF output power level from HP peak power meter.
- Calculate and note the klystron perveance.

1.4 Oil test values at start – up

The following are the measured breakdown strength values for the treated Diala B mineral insulating oil put into the indicated HV modulator tanks. These values should be taken only as indicators of the oil quality, since in the past, multiple sampling tests made from the same tank oil have given quite a wide dispersion of measured results. Nevertheless, when the values obtained drop to around 20kV, trouble is usually not far away. The oil in the tank MDK13 is completely new.

Table 1: Start – up oil quality (22/2/91)

MDK	Klystron tank	Strength kV
03	V04	60
97	V01	59
13	V03	71
25	T02	63
27	T03	42
31	V02	63
35	T01	57
Reserve	T00	58

1.5 Klystron status

The situation with the klystrons has changed a little since last year. Several tubes have been moved in the gallery to try and use the ones with highest perveance into positions requiring most output power. This is shown in Table 2 below.

Table 2: Klystron situation at 26/3/91

Modulator	Klystron	Heater hours	Perveance (E – 6)
MDK03	V/006	15461	1.87
MDK13	V/003	4789	1.87
MDK25	T/004	13974	1.52
MDK27	T/008	10866	1.874
MDK31	V/004	19571	1.8
MDK35	T/005	18338	1.6
MDK97	V/005	17583	1.75

Photographs of each modulators data display screen have been taken. These show the focal and PFN reference values being used. The modulator MDK35 was under test when the photo was taken, and hence the lower than usual reference voltage value. Normally this would be about 32.5kV and not the 31.7kV displayed. Secondly, the focal currents for MDK97 have been optimised for the tube to produce 30MW output power, with the minimum amount of input power and a klystron body delta temperature not exceeding 3 deg C. The photographs are shown in the next 7 Figures.

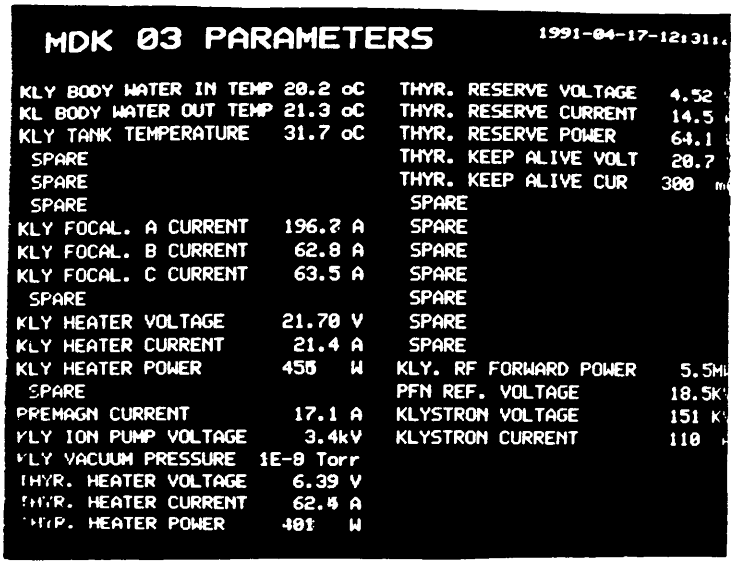

Figure 1: MDK03 display

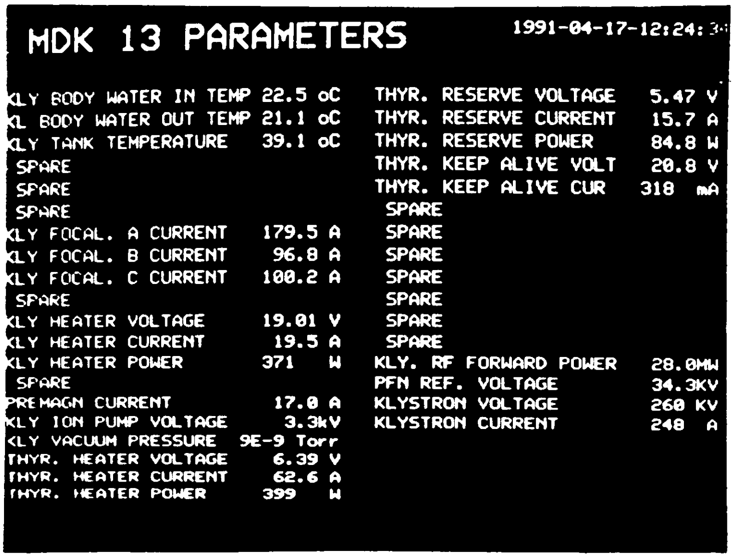

Figure 2: MDK13 display

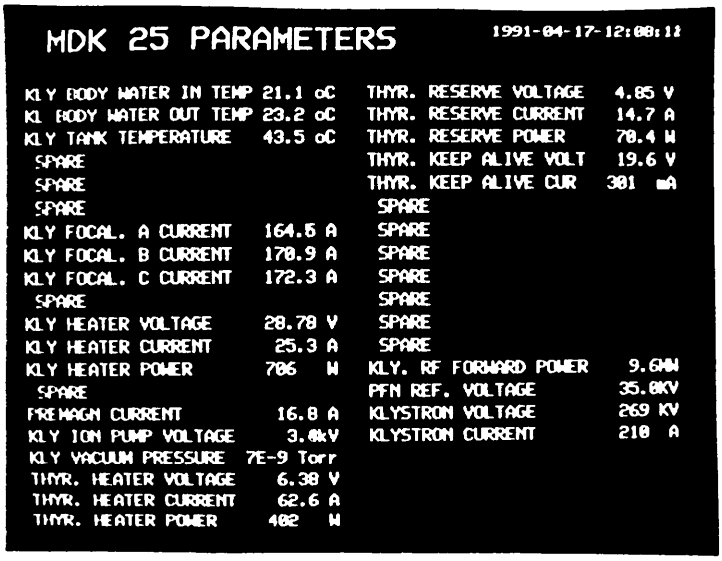

Figure 3: MDK25 display

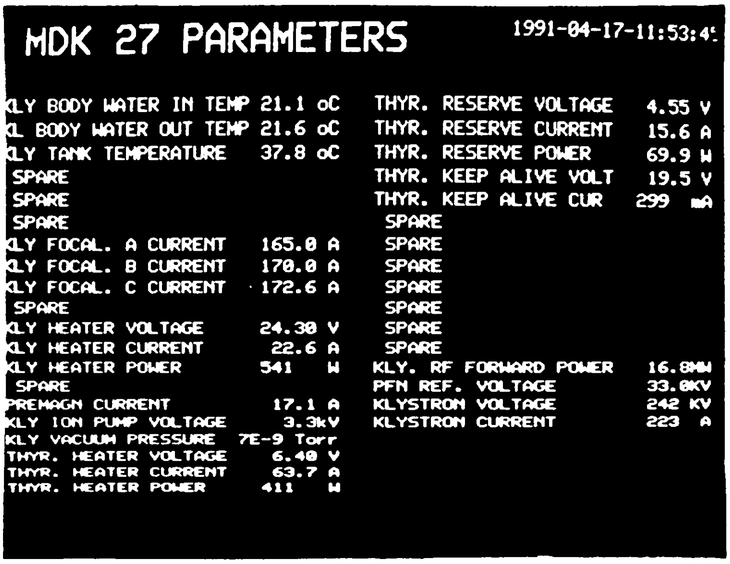

Figure 4: MDK27 display

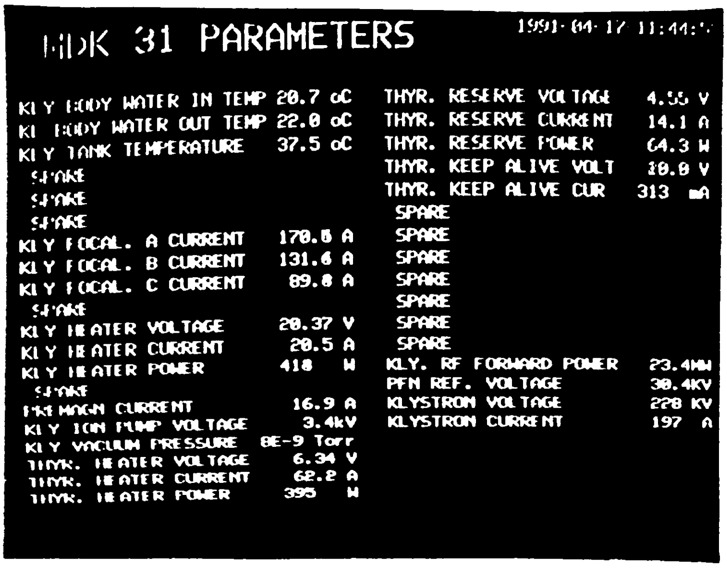

Figure 5: MDK31 display

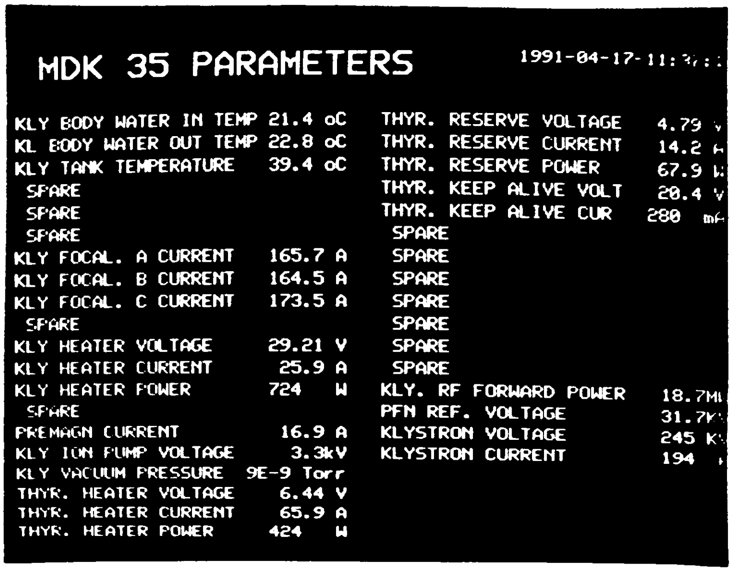

Figure 6: MDK35 display

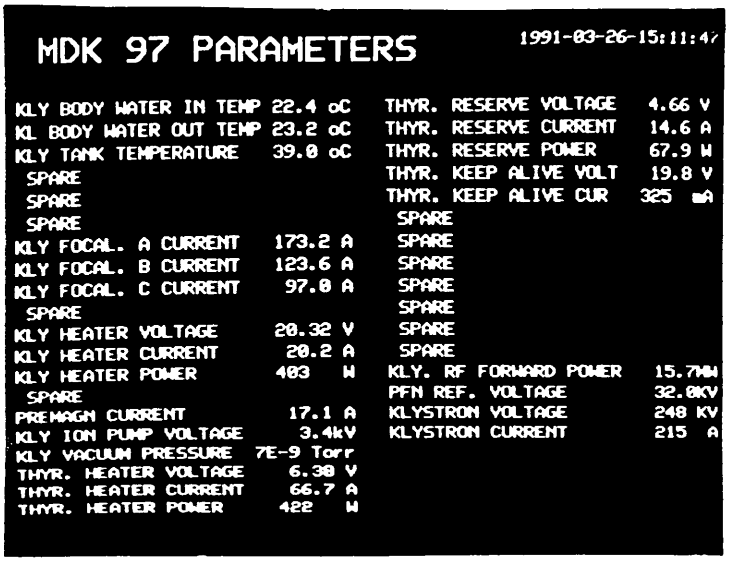

Figure 7: MDK97 display

1.6 Thyratron situation

The thyratrons in use in the LIL modulators (Type KU275C – ITT) have all been in use since the original start – up of the machine, giving in general excellent service. A few of these tubes have been replaced in the last year, but have usually been re – used in positions working at lower voltages. Also some of the said " faulty tubes" were later found to be good, and components on the thyratron assembly were diagnosed as the real source of the original fault. Nevertheless, it has been found absolutely necessary to "track" the reservoir voltages of the tubes in operation in order to reduce the incidence of transient faults. These faults are made when the thyratron ceases to conduct for a brief period during PFN discharge. This prevents correct recovery of the pulse system, and usually trips the modulator with EOLC or Thyratron current faults on the operators display. Increasing the voltage (and hence gas pressure) reduces this type of operational fault. As the hydrogen gas is used up during normal pulsing, it has been found that at the 100Hz rate we need to increase this voltage by about 0.1 volts every 500 hours or so to keep the system in good shape.

The spares situation for these tubes and assemblies is as follows:

- Doubtful tubes in B174....(3 off). S Nos 2169, 2170 and 2175.
- Maintenance assemblies in gallery....S Nos 2115 (old), 2356 (new).
- New tubes in stock......S Nos 2353, 2354 and 2355.

Since most of the operational tubes have now about 25000 hours use, and the best we can expect (according to SLAC) is 35000 hours, then during this year we should normally be replacing some of those in service. An order for 3 or 4 new thyratrons must be negotiated during the first half of this year in order to have them delivered by early next year. At that moment our stock will certainly be smaller than at present due to tube wearout, and faulty tubes being replaced from this stock.

1.7 Klystron perveance variation

The variation of each klystrons perveance during it's operational lifetime is plotted out below in Figure 1. The tube with the longest operational lifetime is the Valvo klystron V/004 in MDK31. The tube with the lowest value of perveance is the Thomson tube, T/004 in MDK25. This klystron has been hanging on for over a year now and would seem to be the next candidate for replacement. However, all tubes have a gradual degradation of perveance with lifetime, and some like the Valvo tube in MDK03, show how they can respond to increases in heater voltage. This has been demonstrated to give a temporary increase in performance at the expense of a overall lifetime. Also it has been noticed that as klystrons get older and their perveance drops, in some cases a retuning of the focal coil settings along with heater voltage increases can greatly improve performance. This was the case for the old Valvo klystron V/005 now in MDK97 for the CTF tests. The absolute values of perveance depend on the accuracy of the klystron voltage and cuurent measurements. This is taken to be in the range of 5%.

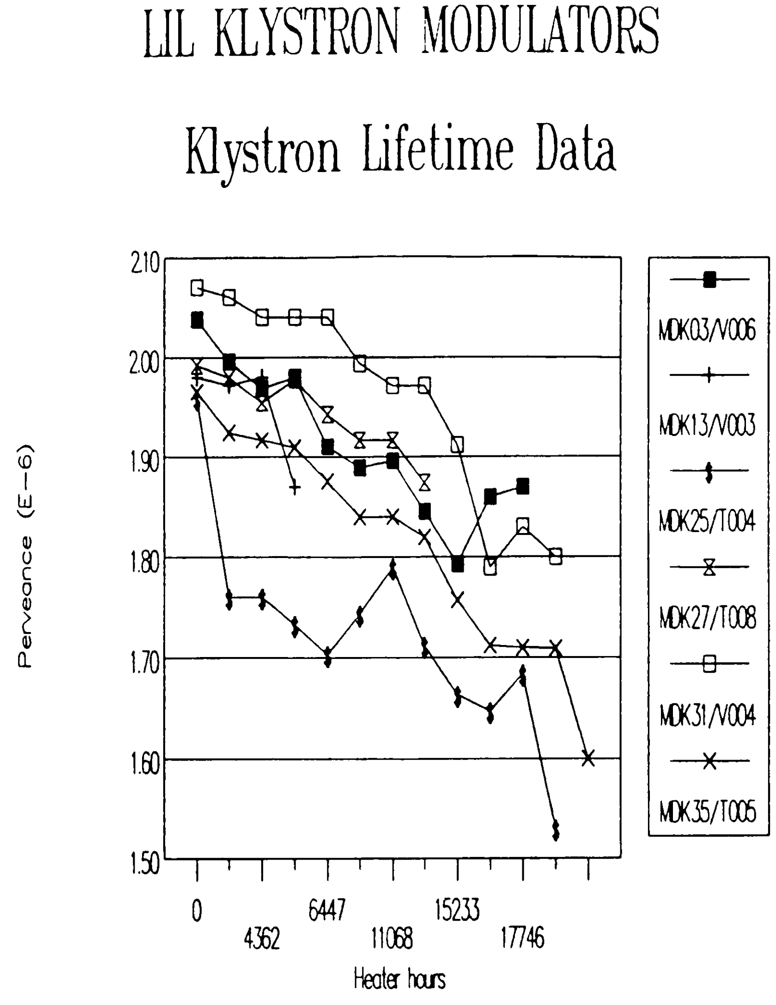

Figure 8

1.8 RF Power calibration

All of the seven modulators have been tested and calibrated with RF power using the water load and mobile power source. The power curves obtained from these tests are given in the following diagrams.

All of the tests with each modulator has been made at the 100Hz rate. The RF pulse width used was 4 microseconds and the peak power output obtained from calorimetric measurements and calculation. For each test the RF input pulse was synchronised to be in the centre of the high voltage pulse applied to the klystron.

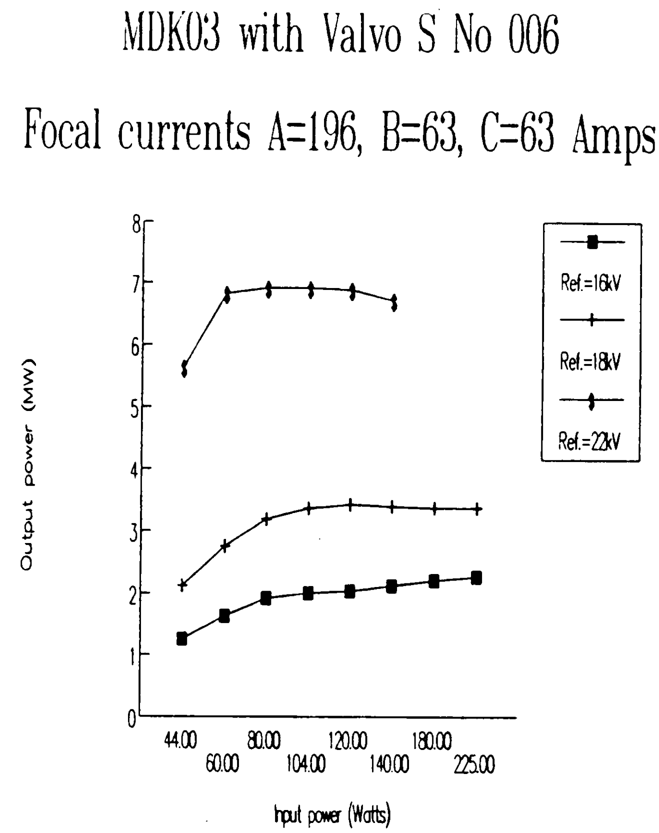

Figure 9

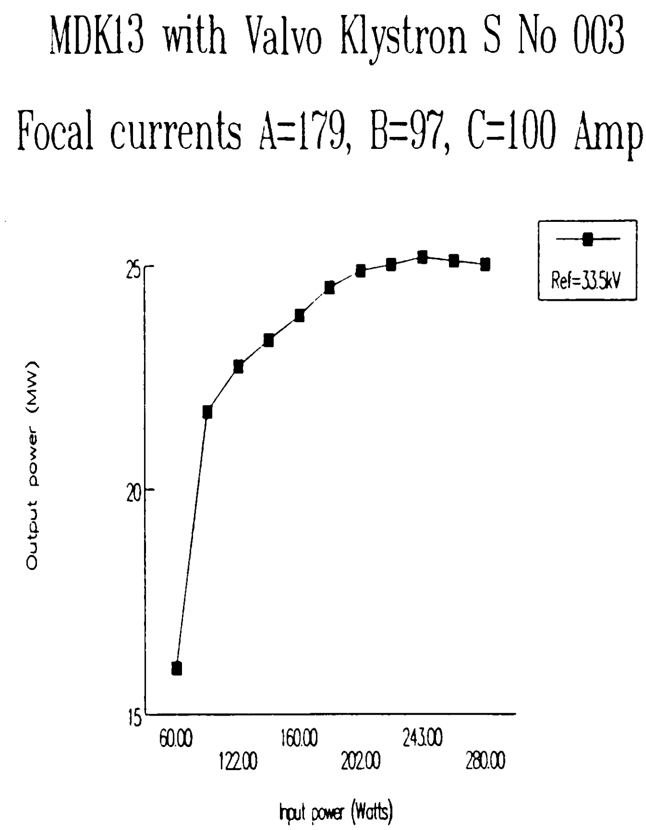

Figure 10

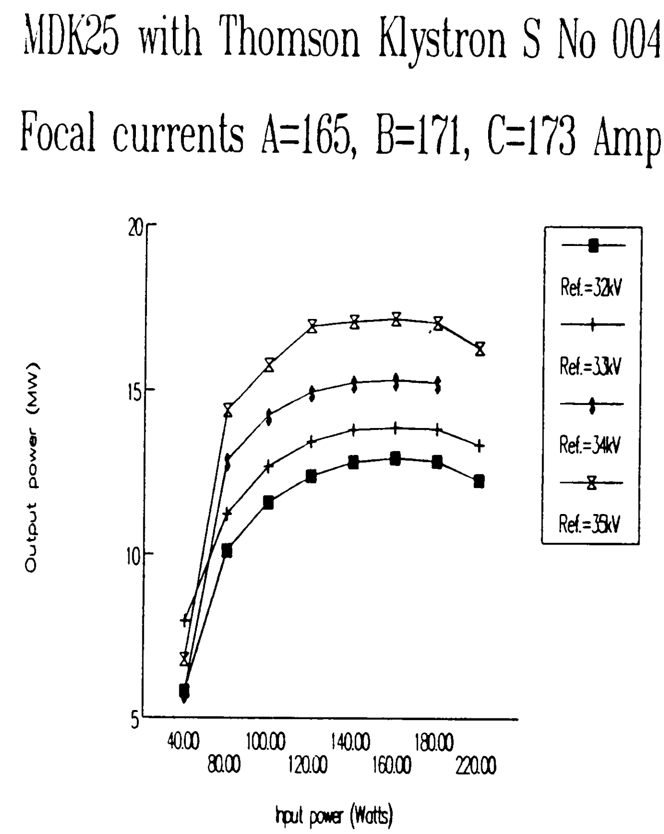

Figure 11

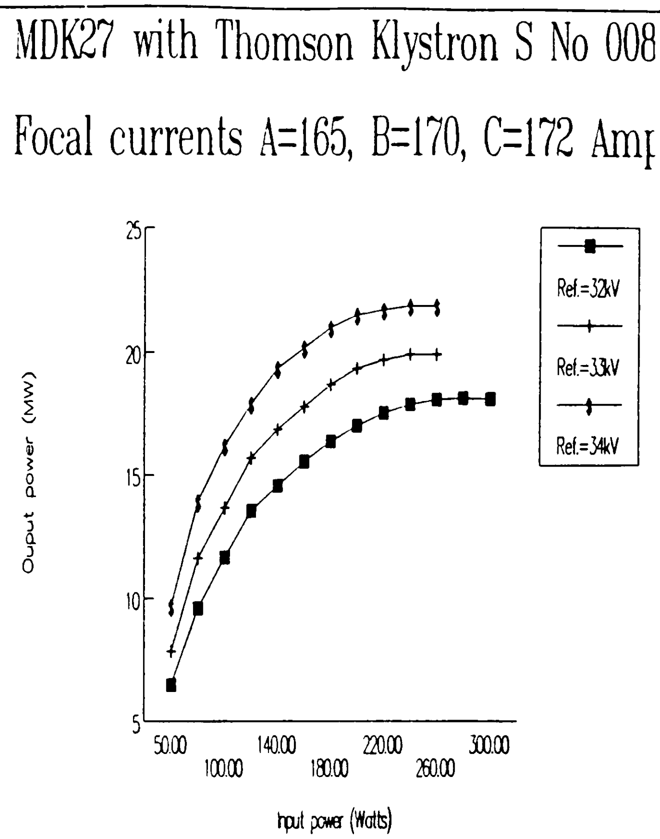

Figure 12

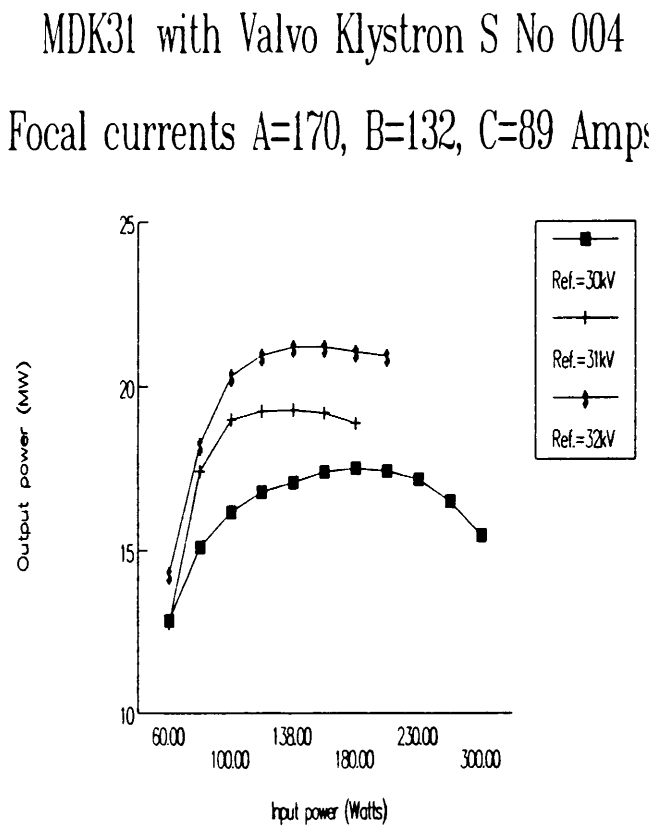

Figure 13

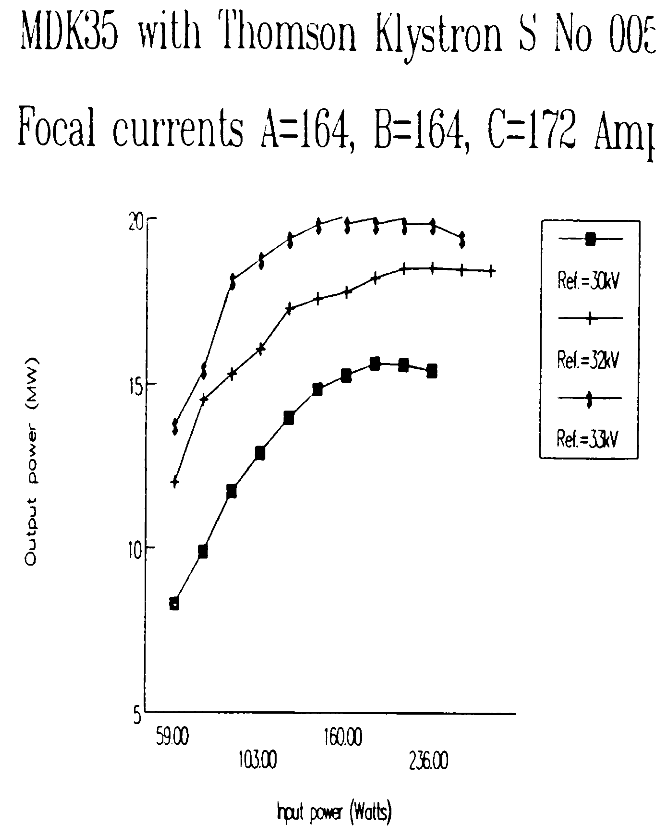

Figure 14

1.9 The CTF test modulator

The MDK97 modulator has been nominated as the RF power source for all the present tests in the CTF facility. For the tests actually being made now, the modulator and klystron have been optimised for an output power of about 30 MW. The tube in use is an old Valvo klystron that has seen battle in several other modulator positions. In order to get the 30 MW peak power it was necessary to retune the focal currents for maximum output with a minimum of extra heat being dissipated in the collector structure. The results of this setting-up is seen below in the MDK97 power curves. It should be remembered that all these calibration curves have been made at a rate of 100Hz (10ms). However the MDK97 for the CTF actually runs at 10Hz rate (or 100ms). This means that the PFN of the modulator remains charged for most of this time before being discharged and as a result the PFN voltage, that will determine the output power will have reduced. This is due to the high resistance measuring and protection components that are always in parallel with the PFN.

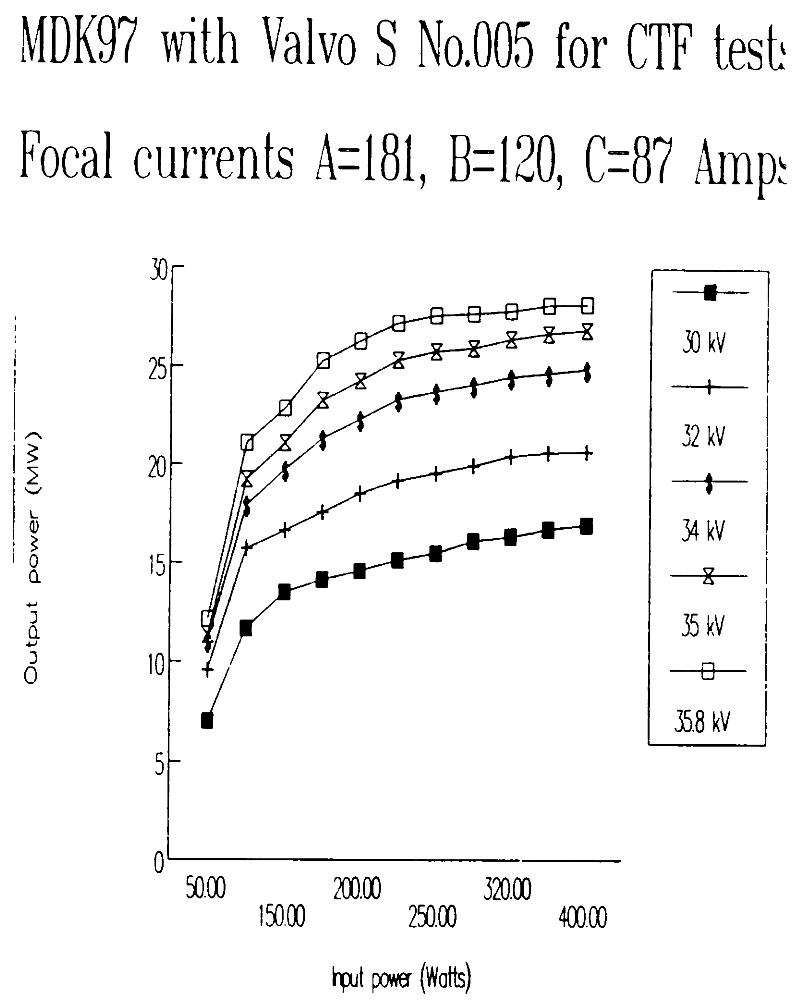

Figure 15

1.10 Summary

Obtaining a good performance from the modulators after the long shutdown and maintenance period was initially difficult. This was partially due to some of the necessary services not being available when needed, and partly due to public holidays falling at the same moment as start-up. However once these things became stable and the access to the machine had become one of request via the operator in charge, the process of setting up the seven modulators for machine operation became viable. This process which entails a complete voltage and current calibration as well as using a water load to establish the power performance of each klystron. The mobile 500 watt amplifier and frequency synthesizer are used for the power tests. In addition, all dynamic and static interlocks have to be tested, and if necessary, adjusted to ensure a proper protection. Finally the computer controls network and timing need to be available for testing via the consoles and into the machine. Sufficient time must be must be allowed for these tasks, as well as using the modulators to re-condition the accelerating cavities, after the modulator power tests are completed. In general, at least two weeks should be reserved for these setting-up and test activities at the end of a long shutdown.

15/5/91

PS/LP/mm - Liste de distribution "Groupe LP (+ Op.)" (17.04.91 - 42 personnes)

Aebi J.-J.	PS
Baconnier Y.	PS
Bellanger A.	PS
Bertolotto R.	PS
Blaha H.	PS
Bossart R.	PS
Canard B.	PS
Cherix E.	PS
Chevalley E.	PS
Curri G.	PS
Delahaye J.-P.	PS
Devlin-Hill P.	PS
Dupuy B.	PS
Durand J.	PS
Fernier P.	PS
Frammery B.	PS
Godot J.-Cl.	PS
Guillon M.	PS
Hutchins S.	PS
Kamber I.	PS
Madsen J.H.B.	PS
Marti P.	PS
Martin O.	PS
McMonagle G.	PS
Metral G.	PS
Noergaard L.	PS
Pearce P.	PS
Pincott B.	PS
Potier J.-P.	PS
Priestnall K.	PS
Rao R.	PS
Remmer W.	PS
Renaud Y.	PS
Rentier G.	PS
Riche A.J.	PS
Rinolfi L.	PS
Rossat G.	PS
Rück A.	PS
Ströde J.	PS
Suberlucq G.	PS
Wagner J.	PS
Wurgel M.	PS