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MODULATOR DEVELOPMENT AT LOS ALAMOS SCIENTIFIC LABORATORY*

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Modulator Requirements

The design objectives for the hard tube modulators for the Los Alamos meson facility were:

- 40 kV positive pulse output
- 100 amperes
- 20 microsecond rise and fall time
- 12% duty factor
- 1000 microsecond pulse length
- Output pulse must be regulated by the switch tube control grid for all output voltage and current levels
- Maximum average switch tube plate dissipation required for beam variation, beam loading, fine regulation, and capacitor bank droop should not exceed 60 kW
- Switch tube may be used as high voltage disconnect to clear high voltage faults in the rf system
- Minimum maintenance, cost, size

The above requirements were for testing the RCA coaxitron. The Raytheon Amplitron required a negative pulse be generated.

Modulator Switch Tube Development

The key component in modulator design is the high voltage switch tube. Two years ago existing modulator tubes in the required power range either had reverse grid current regions during which the grid lost control of the anode current or the grid current requirements were excessive (20 to 35% of the anode current.) Machlett Laboratories proposed the development of a magnetically focused triode as shown in Fig. 1. The development type was LPT-14. The final version is the ML-8618.[1] The electrode structure is in parallel planes with the cathode wires intermost, two arrays of grid wires on each side of the cathode, and the anode on the outside. The anode is water cooled and will dissipate 80 kW continuously. The heavy molybdenum grid wires also support and align the cathode wires. The grid wire, in contrast with fine, closed spaced grids used in tubes for rf service, will withstand arc back without damage.

The magnet, anode water jacket, and complete assembly are shown in Fig. 2. Early in the development we requested Machlett to leave the VacIon pump installed on the tube so we would have a better grasp on switch tube vs circuitry problems. This has been invaluable during high voltage and peak power aging of the tubes. Recent tubes have no internal getter and have come to full power in as short as 45 minutes after installation.

The switch tube mounted in the modulator is shown in Fig. 3. The VacIon pump is shown attached to the top of the tube. The 7.5 volt ac 340 ampere filament transformer is to the upper left of the tube.

The external magnet around the anode forces the electron flow to remain normal to the anode surface. Since the grid wires are not in line with the cathode wires, the percentage of anode current intercepted by the grid is greatly reduced.[2] Without the magnet the grid will intercept about 25% of the anode current. With the magnet the intercept current will run from 0.5% to 2% depending upon the power gain desired. Actual power gains in excess of 500 have been achieved with good stability.

Modulators in Operation

Three modulators are now operational. The first modulator was constructed entirely of surplus components except for the switch tube. It has been in regular operation for the past 18 months with zero maintenance during the past year. This modulator was tested at 42 kV at 115 amperes for 6% duty factor into a video load. This modulator provides the anode pulse for the RCA coaxitron test stand.[3] The second modulator was designed for one or two switch tubes, positive or negative pulse output, either side of load grounded, and for testing several methods of transferring the control pulse across the high voltage interface to the grid of the 5CX1500. This tube drives the control grid of the switch tube. A simplified drawing of the modulator is shown in Fig. 4. This modulator was tested to 40 kV at 115 amperes at 12% duty factor.[4] Rise and fall times were 6 microseconds each. Tests were also made at - 30 kV at 16 amperes at 6% duty factor, the limit of our negative supply. This modulator was used to test the Raytheon Amplitron. With the addition of a second ML-8618 switch tube, it will be used on the 7835 201.25 mHz test stand at 30 kV at 250 amperes.

The driver deck in this modulator was modified to permit rise and fall times of less than 2 microseconds. This permits clearing high voltage faults in the rf amplifier by removing drive to the modulator only. No clamping of the switch tube grid is necessary. The front view of the modulator is shown in Fig. 5. The high voltage interface occurs between the primary and secondary of the 115 V ac isolation transformer, the 5 kV switch tube bias supply, the 3 kV driver anode supply, and the 7.5 V ac filament transformers. Capacitance between secondaries, to electrostatic shields and primaries are limited to an average of 100 μμfd per transformer. The transformers are cast epoxy construction. The units have been tested to 50 kV ac by the manufacturer, Elma Engineering. They have been tested to 70 kV dc at LASL. The rectifiers for both the switch tube bias supply and the driver anode supply are solid state units manufactured by Unitrode. They are mounted directly on the transformers.

A third modulator was constructed for the mock up building. It is currently being used for negative output to modulate the Raytheon Amplitron. This modulator was designed for one switch tube only, and all contactors, control circuitry and regulator have been transferred to the control racks for integration in the computer control system.

Crossing the High Voltage Interface

All modulators in operation use a 5 mHz amplitude modulated signal to transfer the drive signal across the high voltage interface. Rise and fall times of 5 microseconds are typical for this unit. A coherent image light pipe using a gallium arsinide injection, luminescent diode and a pin diode was tested to 10 kV with 5 microseconds rise time. Mr. A.R. Koelle has developed a unit with 0.5 microsecond rise time and fall time. To date no satisfactory 50 kV light pipes have been received from vendors. The design of a pulse transformer to cross the high voltage interface directly with the control pulse was undertaken by Mr. T.F. Turner. One transformer is ready for testing. A 43 mHz amplitude modulated rf transmitter with associated rf transformer and demodulator is also under test. Response times approaching 0.5 microsecond look feasible.

Conclusions

The modulator has met all initial design objectives. The switch tube has met all design objectives. Changing programmatic requirements of 40% correction of output voltage in 1 microsecond seems within reach. The switch tube may be used as a high voltage disconnect during faults to prevent crowbarring capacitor bank. Size (6 ft. square), maintenance, and cost ($8,000.00) are reasonable.

References

[1] Peter, E., and Langer, H., "The ML-8618 Triode-A Magnetically Beamed General Purpose Power Tube," Cathode Press, Vol. 22, No. 4, 1965.

[2] Randmer, J.A., "Magnetic Beaming in Power Tubes," Cathode Press, Vol. 22, No. 2, 1965.

[3] Freyman, R.W., "A 40-Kilovolt, 125 Ampere Hard Tube Modulator for Accelerator Service," IEEE Transactions on Nuclear Science, Vol. NS-12, No. 3, June 1965.

[4] Freyman, R.W., "Hard Tube Modulators for the Los Alamos Meson Facility," Proceedings Ninth Modulator Symposium, DOD Advisory Group on Electron Tubes, May 1966.

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DISCUSSION

R. W. FREYMAN, LASL

KEANE, BNL: Two questions: When the "passing" tube was delivering 150 A output current, what was the grid current? And, by what means did you view the signal between the cathode and grid of the "passing" tube?

FREYMAN: Do you mean the switch tube when you refer to the pass tube?

KEANE: Right, yes.

FREYMAN: We look at the grid-to-cathode signal with a Tektronix 422 scope floating on the high voltage deck. When the "pass" tube draws around 150 A, the grid draws about an ampere. An unusual thing about this switch tube is that as you go to higher voltages, it does require more grid current. We and Machlett have both observed this , and have not, so far, explained it. There is some non-linearity, but it doesn't seem to be serious. We have swept this tube with sine waves, and triangular notched waves, going from 10 kV to 2 kV and back, several cycles per pulse, and there was no indication of any major perturbations in the response of the tube.

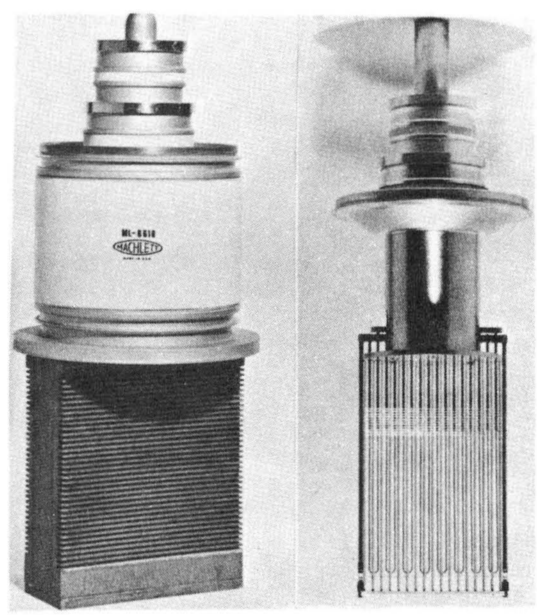

Fig. 1. Complete ML-8618 tube and filament-grid internal structure.

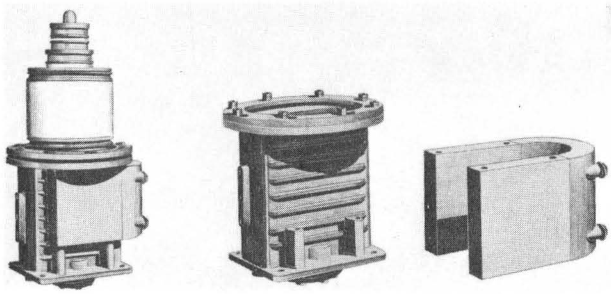

Fig. 2. ML-8618 magnet, anode water jacket and complete assembly.

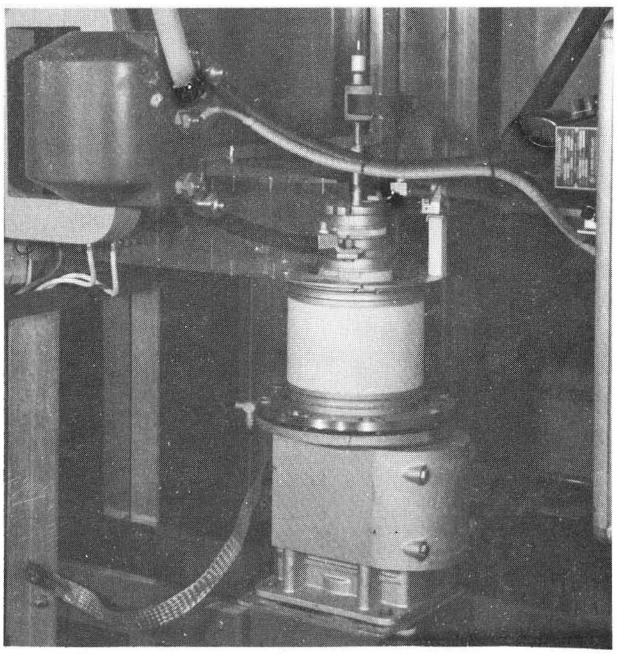

Fig. 3. Switch tube in modulator.

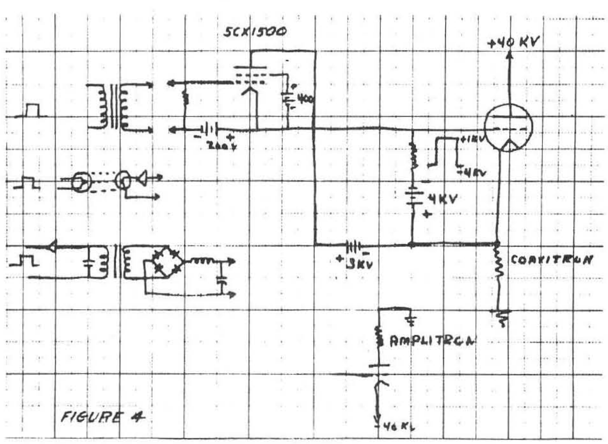

Fig. 4. Simplified modulator drawing .

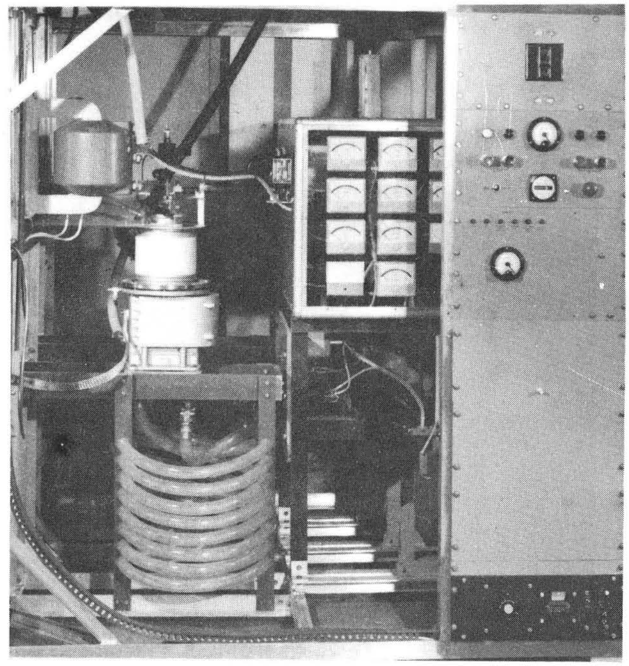

Fig. 5. Modulator - front view.

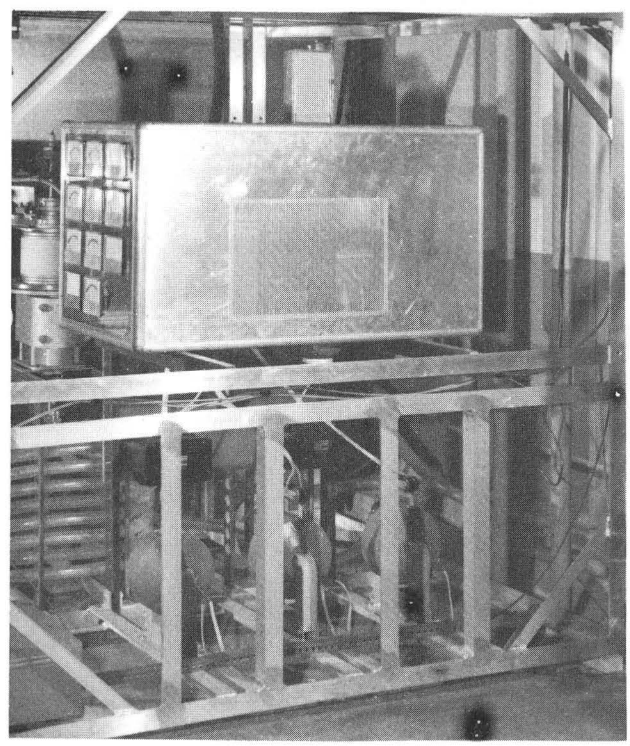

Fig. 6. Modulator - side view.