Conditioning and Testing of 3 MW S-Band Pulse Tunable Magnetron

N, Kanagraj[1], S. Maurya[1], RK Verma[1], Prateek Chaudhary[1], M. Kumar[1], Vivek Yadav[2], Abhijit Tillu[2]
[1]CSIR-Central Electronics Engineering Research Institute, Pilani-333 031
[2] APPD, BARC Mumbai, INDIA
Email: nkraj86@gmail.com

Abstract – *A detailed method of conditioning and testing of the 3MW S-Band pulse tunable magnetron has been discussed. As the magnetron prototypes developed are not suitable for direct operation and use in the system, certain procedures are followed to make them rugged enough to operate at the full specifications. The cathode used is a triple carbonate oxide coated and application of required voltage at the initial level may cause inefficient emission from the cathode and even damage of cathode, resulting in the end of tube life. Also the vacuum level is to be maintained inside the tubes and sufficient time is required to pump out the emitted gases from the different surfaces inside the tubes due to heating of the surfaces by electron bombardment or resistive heating.*

I. INTRODUCTION

A magnetron is known as a high-efficient, high power and low cost device for generating microwaves from kW to GW-level at centimeter wavelength [1-2]. Because high power pulse magnetrons are important for the generation of X-Rays in the Liner accelerator research community, CSIR-CEERI, Pilani has been recently completed a Research and Development project on 3 MW S-Band Tunable pulse magnetron in collaboration with BARC, Mumbai. Under this project lab prototypes have been developed and tested with the HV pulse modulator developed by BARC, Mumbai [3].

II. EXPERMIENTAL SETUP

Conditioning of a tube requires the application of actual working high voltage to the tube in progressive succession so as to harden it in its entire operating range of voltages and get a completely aged vacuum tube. The conditioning and ageing system of magnetron can be understood into two major sections (a) pulse power input supply section and (b) measurement and characterization output section. The magnetron is placed in between these two sections. The electrical specifications of the major equipments used in the setup are detailed in Table.1 [4].

Table 1: Electrical Specification of HOT RF Testing Components

S.No.	Name of Equipment	Specifications
1.	Line type high voltage pulse modulator	Power: 6.0 MW Impedance: 416 Ohms Max. Peak Voltage : 50 kV Max. Peak Current : 120 A Pulse Width : 4.5 µsec PRF: 0 – 250 Hz
2.	Electromagnet	Max. Magnetic Field: 1650 Gauss Air Gap : 88.0 mm Pole Piece Face Dia.: 77.0 mm Max. Field Current : 28 A
3.	Electromagnet Power Supply	0 – 35 V, 0 – 35 A
4.	Spectrum Analyzer	9 KHz – 13.6 GHz
5.	Power Meter and Sensor	-60 dBm to + 20 dBm, 50 MHz – 40 GHz
6.	Oscilloscope	Bandwidth : 500 MHz
7.	High Voltage Probe	Attenuation Ratio 1000 : 1 Pulse Operation up to 60 KV Compatible with Oscilloscope
8.	Re-circulating Chiller Unit	Water Flow Rate: 5 L/min. Pressure: 3.0 Kg/cm^2 Input Temperature: 20^{0}C Output Temperature: 50^{0}C (Max.)
9.	Gauss Meter with Cross Field Hall Probe	Capacity : 3000 Gauss

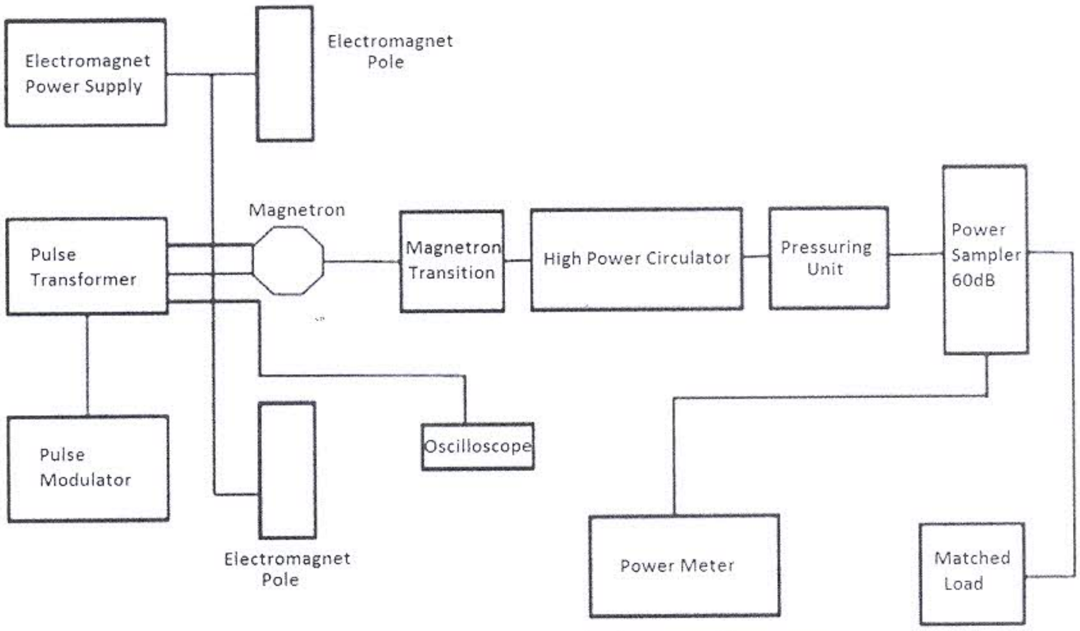

Figure 1: Hot RF testing and conditioning setup for magnetron

A line type modulator consisting of pulse forming network which generates a maximum of 12kV pulse of 4.5 μsec which is fed into the 1:5 pulse transformer creating a maximum of 60kV voltage pulse serving as the HV input to the magnetron. The electromagnet supply is a constant current supply having maximum voltage and current rating of 35 V and 35 A respectively. It generates required variable magnetic field for magnetron's operation. This variable voltage supply and variable magnetic field supply helps in conditioning the magnetron in its complete operational range. The output power from the magnetron is fed into a four port high power circulator, which is connected with power sampler and water and air cooled loads. The schematic of the experimental setup is shown in Fig.1.

III. TESTING PROCEDURE

For the HOT RF testing of the magnetron or ageing of the tube, the tube is first mounted in between the poles of the electromagnet and fitted with the test bench via its output coupler. The ion pump and its controller are connected to the tube's exhaust and the chiller water circulating pipes are also connected to the tube's cooling channels. The entire waveguide test bench line is pressurized with nitrogen gas to avoid high power microwave arching inside the waveguide system. The pulse modulator is now switched ON and the process of filament warm up is initiated. The warm up time for the present magnetron filament is around 5-7 minutes. When the warm up is completed the electromagnet is turned ON and a specific magnetic field is applied. Now the high voltage supply is turned ON and the high voltage is applied to the magnetron. The voltage and the current pulse of the magnetron is read via high voltage probe and rogowski coil respectively and are displayed on the oscilloscope. A sample of the generated RF power is sampled using a 60dB power sampler in combination with a 30 dB attenuator and is fed to the power meter and the spectrum analyzer.

IV. EXPERIMENTAL RESULTS

The application of operational voltage and the required magnetic field to magnetron results in the generation of output RF power which can be measured using power samplers. The applied voltage pulse of 48kV and 4.5μsec duration generated by the high power pulse modulator is shown in Fig.2. Each block on the oscilloscope is set at 10kV per division. The corresponding current pulse generated by the magnetron is shown in Fig.3. with 20 A per division on the oscilloscope. Maximum operational anode current of 108A is shown in the current pulse of Fig.3.

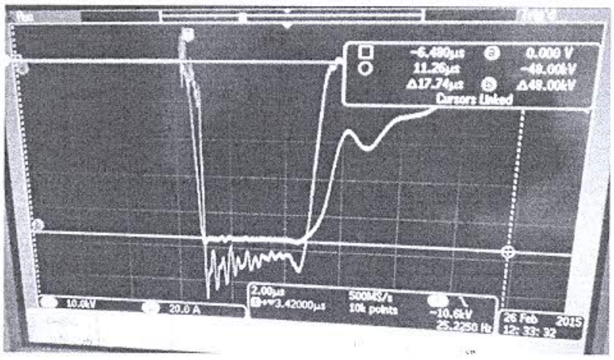

Figure 2: Maximum high voltage pulse waveform supplied by the pulser to the magnetron

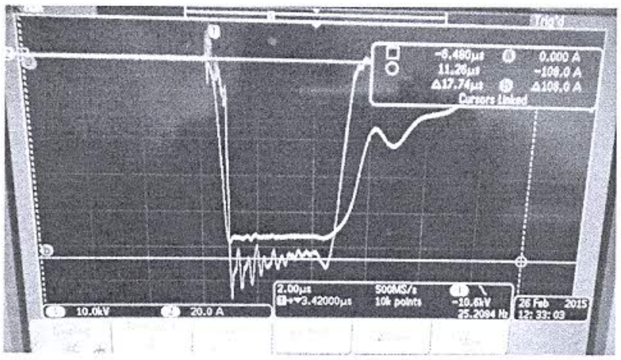

Figure 3: Maximum current pulse generated by the magnetron at full power operation.

The frequency spectrum of the operational magnetron is shown in the Fig.4. The pulse repetition frequency is 25 Hz and the resonant frequency is 2.859 GHz. The spectrum is clear in the span of 100 Hz with no spurious modes in the vicinity of operational π-mode.

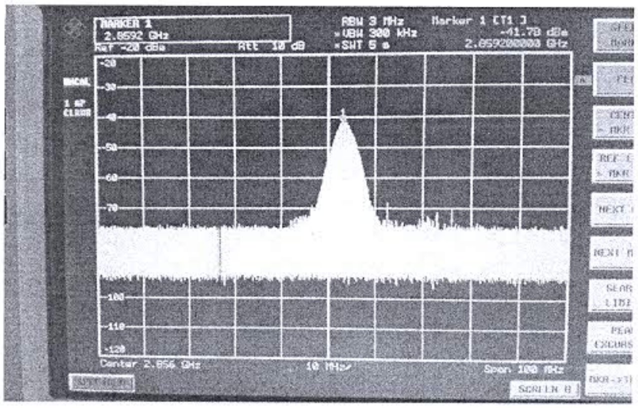

Figure 4: Frequency spectrum showing operational frequency of magnetron as 2.859 GHz.

The output RF power of 3.04 MW is sampled through the 60dB power sampler along with a 30dB attenuator, making a total of 90dB offset which is incorporated in the power meter. The output power pulse is a clear pulse of ~4.5μsec duration and is shown in Fig.5. The overall efficiency of the magnetron lab prototypes has been found to be ~52% with electronics efficiency of ~57%.

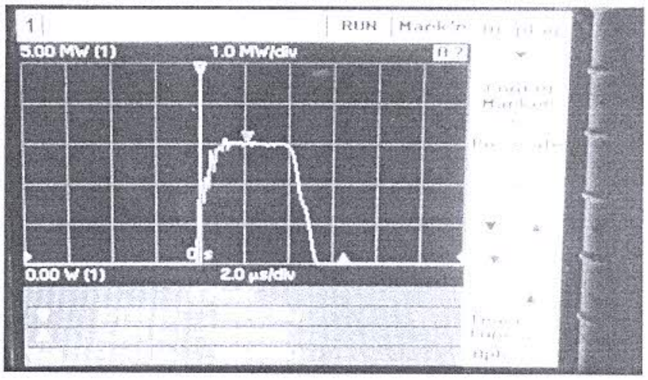

Figure 5: Output power pulse showing 3 MW RF power generation on the power meter.

V. CONCLUSION

Three numbers of 3 MW S-Band Tunable pulse magnetrons lab prototypes have been developed and conditioned/aged for long term operation using pulse modulator developed by BARC, Mumbai. The tubes have been operated in the range of 500-700 hours.

ACKNOWLEDGMENT

Authors are thankful to the Director, CEERI for granting permission to present this paper. They are also thankful to their colleagues of Project team for their supports.

REFERENCES

[1] James Benford, "High-Power Microwave Sources", (Artech House, Norwood, 1987), page 351-395.

[2] G.B. Collins, "Microwave Magnetrons", McGraw-Hill New York, 1948.

[3] Abhijit Tillu , Vivek Yadav et.al. " High power pulse modulator for Klystrons/Magnetrons/Electron Guns for Electron LINAC" BARC News Letter, Special Issue 2015.

[4] Rowdra Ghatak, " RF Measurement on 2.0 MW S-Band Tunable Pulsed Magnetron", Dissertation Report, 2002.