

2450MHz 30kW MAGNETRON DEVELOPMENT

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ABSTRACT

BURLE INDUSTRIES, INC. has been developing a high power 2450MHz CW magnetron (S94610E) for industrial heating applications. This paper covers the development of this device from the initial design to the finished product. Future plans for this device will also be presented.

INTRODUCTION

At the 31st Microwave Power Symposium, George Solomon of BURLE INDUSTRIES, INC., introduced the development criteria for this device in his paper "High Power S Band Magnetron". To review, the initial goals of this program were the development of a 2450MHz 25kW device with output to a WR-430 waveguide, along with the associated accessories. Since that time, BURLE changed the design goal from 25kW to 30kW.

As a starting point, BURLE chose the existing 915MHz 66kW magnetron as the initial mathematical model to develop the 2450MHz prototype. BURLE's engineering staff had over twenty years of experience with the 915MHz device. The scaling and modeling techniques used to achieve 2450MHz were useful to a point, but it was soon learned that the relationships between the magnetron components were so complex that a number of modifications were required after the first prototype was manufactured. BURLE's engineers were able to use a number of parts common to the 915MHz device, in order to minimize the unit costs.

FILAMENT ASSEMBLY

The cathode was found to be the most complex and difficult component to design. It is directly heated with helically wound tungsten wire supported at both ends. Critical design criteria for this assembly were the turns per inch (TPI) and the diameter of the pure tungsten wire.

In order to achieve the required current density, stand-by emission, and supply sufficient plate current, the TPI was varied from the initial model. It was discovered that the higher TPI filament presented a larger target surface and saw considerable back-bombardment. These first designs could not achieve a stable operation at any power level. The TPI was reduced to provide a smaller back-bombardment target surface.

After theoretical calculations and extensive experimentation, the correct TPI and wire diameters were determined. The amount of back-bombardment and thermionic heat now generated, provided stable performance throughout the operating range of the device.

Another design concern was the inherent resonant frequency of the filament assembly. Initial designs showed that the resonant frequency of the assembly was close to the frequency of the system, and caused distortion. BURLE's network analyzer was an integral tool in successfully evaluating the output frequency, resulting in a modified filament structure.

ANODE - RESONANT STRUCTURE

The anode - resonant structure is a vane and strap design. It was scaled and modeled in MATHCAD. In order to produce at least 30kW of output power and achieve an efficiency of at least 70%, the anode had to dissipate approximately 10kW. Like the BURLE 915MHz devices, each vane was water cooled across the anode surface. The required cooling is 5GPM with a pressure drop of 28psi.

Alternating vanes were connected by the use of two copper straps. When this structure was modeled as a parallel resonant circuit with the vane as an inductor, interstitial space between the vane tips as a parallel plate capacitor, and the straps as a distributed cylindrical capacitor, the resultant frequency was 2452MHz. Once the anode was constructed, the actual frequency was 2470MHz. With additional refinements, the fundamental PI mode frequency was 2458MHz. With the Pi-1 mode at 3039MHz, the device has excellent mode separation.

INTERNAL MAGNETIC FIELD DISTRIBUTION

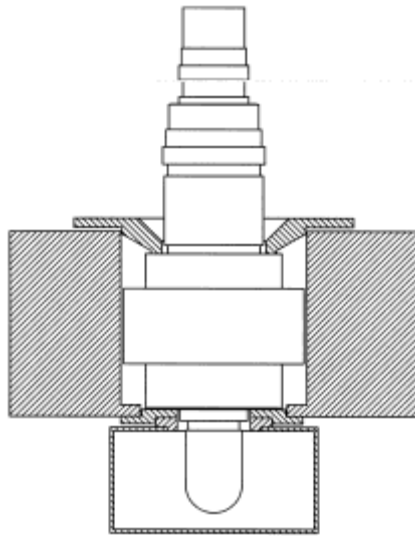
The internal magnetic path of the magnetron consists of a bottom magnetic plate, top magnetic plate, filament support adapter, and external pole piece. The function of this magnetic path (or circuit) is to produce a fairly uniform magnetic field over the extent of the interactive space. This magnetic field should be focused and tilted at the ends of the interactive space. The distribution of this magnetic field is difficult to measure.

Prototypes were constructed with varying components that altered the magnetic path. Tube performance was then measured. After test, the tube was cut open and examined to check for melted spots on the internal pole piece or any other internal damage. Any damage indicated that electrons escaped from the interactive space. After several attempts with varying geometries, the best results were attained. The maximum power output to a VSWR 1.5 : 1 was 35kW. Efficiency was measured at 74 - 78%. This uniform magnetic field reduced the back-bombardment on the filament and prevented melting of internal components such as the pole piece and choke.

ACCESSORIES

This magnetron uses a WR-430 waveguide and newly designed electromagnet. A magnetic pole piece holds the magnetron in the electromagnet with the dome extending into the waveguide (Figure 1).

The filament connectors are the same ones successfully used on the 915MHz devices. These connectors use integral plenums for air cooling of the contacts.



Assembly Drawing
Figure 1

TESTING

New testing facilities were design and built for this device. BURLE presently has the capability to test up to 60kW at 2450MHz. Over 100kW can be achieved at the 915MHz test stations.

In order to determine the performance range of this new device, testing was conducted over a wide range of operating parameters. BURLE's engineers have found that this device can operate well over the 30kW design goal at efficiencies greater than 74%. The device has also performed well at 35kW with a mismatched load of 1.5:1.

CONCLUSIONS & PLANS

Each magnetron component presented its own set of challenges both individually and together in the circuit. Mathematical modeling & scaling proved to be a useful starting point in the magnetron design. However, only actual construction and practical experimentation can produce a reliable device that will be accepted by the market.

BURLE has a number of the new devices in the field, under a variety of operating conditions. The performance of this device has exceeded the original design goals. As the data is collected and further testing is performed, BURLE will be able to determine the upper limit for the operation of this device. Future developments will be presented at subsequent International Microwave Power Symposiums.