Magnetrons 101
The Key Facts and Attributes of the Heart of a Microwave

10501 Bunsen Way
Louisville, KY 40299
(502) 493-1299
www.thermex-thermatron.com
Magnetrons 101
The Key Facts and Attributes of the Heart of a Microwave

Any business dependent on microwave heating technology is dependent on the magnetron, but despite the ubiquity and core role of the device, few executives are aware of its existence, let alone the key role it plays in the larger technology. This paper will provide a basic, introductory look at what magnetrons are and how they work.

THE MAGNETRON

A magnetron is a high vacuum electronic device consisting of a hollow copper anode incorporating a resonant microwave structure. A permanent magnet or electromagnet (depending on the type and size of the magnetron) surrounds the anode. At the center of the magnetron is an electron-emitting cathode (filament).

The anode has a set of vanes projecting inward forming slots between them, which are approximately $\frac{1}{4} \lambda$ deep. Therefore, they are resonant at the operating microwave frequencies. The slots are mutually coupled via the fringing field at their open ends and the whole structure forms a resonant circuit. When the filament is heated, a cloud of electrons is formed around the cathode. When the anode is supplied with high voltage DC, these electrons travel from the cathode to the anode.

The permanent magnet or electromagnet installed outside the anode provides a strong magnetic field that changes the path of these electrons. Since the field lines are parallel to the axis of the anode and perpendicular to the electron path, the electrons are forced to travel in a quasi-circular path around the cathode.

By increasing the DC anode voltage or decreasing the magnetic field, some of the electrons travel on a path closer to the anode, reaching the anode cavities where they generate a resonant microwave field. The microwave power generated is extracted from the cavities using an antenna that then is connected to a launcher. The launcher is connected to the circulator and then to the oven by the waveguides.
The filament and the anode components are insulated with a special ceramic material. This material is joined with the anode and filament structure with a “ceramic-to-metal” seal, capable of maintaining the high level of vacuum inside the magnetron.

The most important characteristics of the operating parameters of a magnetron are shown on the following diagram:

![Magnetron Typical Operating Diagram](image)

The anode voltage-current characteristic shows some peculiar features of the magnetron. On raising the anode voltage from zero at fixed magnet field, very little current flows until a specified voltage is reached (called the $\pi$ - mode voltage) when the outermost electrons reach the anode. Thereafter, the anode current rises very rapidly reaching its maximum rated value with further voltage increase of only 3-8%. It is essential that the generator is connected to a stable power source to prevent unacceptable changes in power from the magnetron due to fluctuations of the incoming voltage.

A change of the magnetic field produces similar changes in the anode current, except at different $\pi$ - mode voltage, increasing magnetic field giving proportional increase in $\pi$ - mode voltage. This feature makes it possible to control a magnetron with an applied magnetic field.
This technique is commonly used for high power magnetrons with electromagnets as only a low power adjustable supply is needed to energize the electromagnet. Low power magnetrons usually have permanent magnets and are controlled solely by adjustment of anode voltage.

It is important to note that:

- The power output rises with the increase of applied anode voltage since more electrons are attracted to the anode whereby increasing the anode current.

- The power output increases with the decrease of the magnetic field. Reducing the magnetic field allows the electron path to extend further and further from the cathode, when the outermost electrons reach the anode, anode current starts to flow.

For more information about magnetrons and microwave heating technology, visit www.thermex-thermatron.com.

About Thermex Thermatron

Thermex Thermatron LP is a trusted developer and manufacturer of industrial microwave and radio frequency equipment, including batch ovens, generators, presses, heat sealers, welders, and other custom engineered systems. The company also provides extensive services to help manufacturers throughout the world get the most from RF and MW technology.