Why Magnetrons Fail
Understanding 13 Points of Breakdown for These Key Components Is Crucial to Maintaining ROI
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No component is more critical to an industrial microwave system than the magnetron, and none is more complex and, therefore, subject to failure from a variety of causes. The purpose of this paper is to help operators understand those vulnerabilities in order that they may guard against them. Doing so will ensure not only lower maintenance costs but also reduced downtime expense.

SOURCES OF FAILURE

While it sometimes is impossible for the purchaser of a magnetron to understand why the unit failed, most breakdowns observably fall into one of three circumstances:

1. Poor materials and/or workmanship
2. Improper use
3. Ordinary wear and tear, effectively taking the magnetron to the end of its lifespan

When magnetron tubes are rejected at the initial state of application, generally defects in materials or workmanship or rough handling during shipping can be blamed. Of course, it is also true that an intimate relationship exists between the viability of a tube and the surrounding operating conditions.

Improper use indicates problems in maintenance or operation of the microwave generator. Deviations in the operating conditions and environment can impact magnetron life. In this respect, it is very important for both operators and maintenance personnel to keep good records of hours of use and operating conditions, and to take corrective actions when operating conditions deviate from normal.

Sometimes, it is impossible to determine the failure cause with certainty. The magnetron is a consumable item. It can, over time, be expected to wear out, but when lifespans are unexpectedly short, the matter should be reported to the manufacturer. Appropriate materials
and methods for dud packaging and return shipment should be arranged so that the duds can arrive in an unchanged condition, as manufacturers will invariably reject warranty claims for any tube returned in other than original or otherwise approved packaging.

Regardless of the instigating cause, breakdowns occur generally owing to one or more of a well-defined set of 13 causes.

1. DAMAGE TO ELEMENTS

Damage to elements may be related to one of two causes: rough handling during shipping or installation or abuse in operation. Examples of the latter include: a dented anode jacket, punctured vacuum seals, misaligned filament due to handling by the cathode / filament (stem), operation with incorrect voltages / currents or insufficient cooling (air and water).

2. BROKEN FILAMENT OR HEATER

In general, the filament or heater has almost no chance to break before termination of life. Instead, vibration or shock is often attributed to broken rejections. Due to the particular fact that, for directly heated cathodes, thoriated-tungsten wire is used. The surface of which has been specially treated (known as carburization) in order to ensure good electron emission. The filament or heater has poor mechanical strength against shock. The tube manufacturer, therefore, pays careful attention to the packaging and the shipment. The user also has to handle magnetrons with identical care (including reusing the original packing materials for reshipment of the tubes). Handling should be free from a sharp shock as a result from falling, impact, etc. When installing a tube in the microwave generator, special care should be taken.

The filament connections are subject to a large amount of current required to heat the cathode. Poor connections can also cause problems. This phenomenon is often mistaken for a broken filament or heater. Poor mechanical contact in the wiring raises the temperature and accelerates oxidation of the contacts. In case the filament or heater does not light during the operation, it is necessary to check the connections.
3. DAMAGE TO CERAMICS

Ceramic material is used for both parts of the cathode and the MW antenna of the tube. The temperature of the cathode stem becomes extremely high due to the thermal radiation of the heater. For this reason, certain types of magnetrons specify the maximum temperature of the stem and the lead wires in the specifications, and special care for cooling of those parts must be taken. An unusual increase in the temperature may cause damage to ceramic parts.

The slight heating of a MW antenna (dome) due to MW energy radiated by the antenna is acceptable as long as the tube is operated under normal conditions. Under the influence of the increased reflection from the load (increased VSWR = voltage standing wave ratio.), however, the ceramic of the MW antenna may overheat and crack.

When the anode temperature exceeds the maximum rating, the ceramic part will break down because of overheating. The anode cooling, therefore, must be carefully maintained.

In handling magnetrons, care must be taken to avoid damage to the ceramic parts.

4. DEFORMATION AND ASSYMMETRY OF THE FILAMENT

The thoriated-tungsten filament is generally coiled in shape. Therefore, it is easily deformed and/or can become asymmetric, when it receives a series of heat cycles exceeding the maximum ratings. The higher the temperature in operation, the more failures might take place. This potentially leads to a drop in power, an increase in filament current, moding, etc.

5. BURN OUT OF ELECTRODES

When the cooling system of the microwave is able to maintain tube temperature below the maximum ratings, it will not cause burn out of the electrodes. In order to avoid damage to tubes due to trouble in the cooling system, it is always necessary to check the protective circuit (temperature and flow switches). Special care should be taken to insure proper cooling of the filament and antenna of the magnetron. This is accomplished by forced air via the magnetron blower.

6. POOR VACUUM
Various rejections like poor emission, poor insulation at high voltage, etc., as a result of the degraded vacuum of tubes, are mostly caused by two reasons: discharged gas from the inner electrodes and/or the insulation materials; and air leakage (intrusion of the atmosphere). When sealing rejections, like cracks in the ceramics are observed, the leakage progressively leads to glow or internal arcing. Proper cooling minimizes the potential failures due to decreased vacuum in the magnetron.

7. POOR EMISSION

Rejection due to insufficient electron emission from the cathode will show a sharp drop in the output power and moding during operation. Poor emission is due to residual gas in the tube, improper cathode temperature, etc.

An increase in the residual gas contaminates the cathode and quickly deteriorates emission quality. Too high cathode temperature also contributes to poor emission by reason of excessive evaporation. Too low cathode temperature, on the other hand, not only produces insufficient electron emissions but also represents temporary degradation of the thoriated-tungsten filament.

The filament or heater voltage must be maintained within the specifications. As emission rejection actually includes such deceptive reasons as poor contact and increased resistance of the filament circuit, care must be taken.

The electric power supply voltage must be carefully monitored. Variation of the supply voltage leads to excessive anode current (greater than the maximum ratings), which shows the same phenomenon as emission failure It is advisable to minimize any potential changes in the supply voltage greater than 2.5%.

8. DROP IN OUTPUT POWER

The cause of this rejection is not always related to the drop in the emission, because secondary electrons ejected from the cathode by back bombardment also contribute to the emission during operation.

The major reason for the drop in the output power is in the decrease of efficiency due to the increased surface loss in the cavities as a result of the deposits from the cathode or other parts.
Also, the deformation and asymmetry of the thoriated-tungsten filament, the structure of which is easily deformed, results in a disturbance of the interaction space. The higher the temperature, the more evaporation, deformation, and asymmetry of the cathode are observed, and care must be taken.

9. MODING

Moding occurs when the MW electric field inside of the tube can no longer maintain the oscillation in $\pi$-mode because of the disturbance by the reflected waves from the load, resulting in an unusual oscillation.

Insufficient electron emission from the cathode also discontinues the $\pi$-mode oscillation, which gives rise to moding.

In order to avoid moding, the operator of the microwave is advised to check the operation of the circulator. Additionally, the manufacturer’s advisement should be sought regarding the load impedance, reflection from load, load variations, etc.

10. RUNAWAY

Generally, when a magnetron is operated with a larger reflection in the off sink phase, the tube can no longer control the electrons in the interaction space because of the increased temperature in the electrodes. This causes the anode current that does not contribute to the oscillation to be increased. The phenomenon is referred to as “runaway”. Large magnetrons are protected from reflected power by a circulator and water load.

In order to avoid “runaway,” care must be taken so as to suppress the increase in cathode temperature. Note that change in the load impedance of the microwave oven has a pronounced effect on this phenomenon.

How to Get Maximum Service from Your Magnetron

1. Purchase magnetrons only from a recognized and reputable vendor.
2. Inspect all magnetrons for obvious damage immediately upon receipt.
3. Place new magnetrons in service immediately to obtain the full benefit of the warranty.
4. Have basic knowledge of the magnetron operating parameters (these are provided on the manufactures data sheet).
5. Understand the operation, maintenance and calibration of the microwave generator in which it is used.
11. ARCING INSIDE THE MAGNETRON

Arcing, the phenomenon that represents high voltage breakdown between electrodes inside of the magnetron has complicated causes. Generally, sparking that is not repeated is not cause for concern, except that the potential failures caused by poor emission, excessive application of voltage and poor vacuum must be watched for carefully.

Application of high voltage at low electron emission due to too low filament voltage or insufficient preheating of the cathode occasionally gives rise to sparking and may destroy the surface of the cathode. The sparking also might take place because of the unusual high voltage generated as a result of transient phenomenon or parasitic oscillation and by the momentary deterioration in the vacuum due to the excessive loss in electrodes.

12. MAGNETIZATION OF THE ELECTROMAGNET

Due to the fact that the electromagnets of the magnetron have to be precisely controlled, they do not perform properly once the magnet current supply fails to provide the right magnetizing current. Adjoining or attaching to the ferromagnetic materials to or nearby magnetrons might change the magnetic field. The electromagnet should be separated from the ferromagnetic materials and kept to a distance as indicated by the manufacturer.

13. SURGE VOLTAGE

Although this is not considered a cause for rejection, this phenomenon is associated with magnetron operation.

When the high voltage and the filament voltage are excited in the magnetron simultaneously, or when the high voltage is applied before the cathode achieves its thermal equilibrium enough to emit electrons, surge voltage is occasionally observed in the power supply circuit. Moding also sometimes contributes to surge voltage.

Although, the magnetron will not generally be damaged by surge voltage, the breakdown voltage of the power supply should be such to withstand the surge voltage, and proper operation of the high voltage filter/protective circuits should be checked.
CONCLUSION

Fatal damage to magnetrons can occur as result of manufacturing defect, shipping damage, misuse or poor operating conditions. Regardless of the source, however, failure is likely to occur in association with one or more key components of magnetron operation. Operators who are familiar with these vulnerabilities are better able to prevent failure from occurring, and better able to take advantage of manufacturer warranties if they occur.

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 assist manufacturers throughout the world to get the most from RF and MW technology.