Product User Manual

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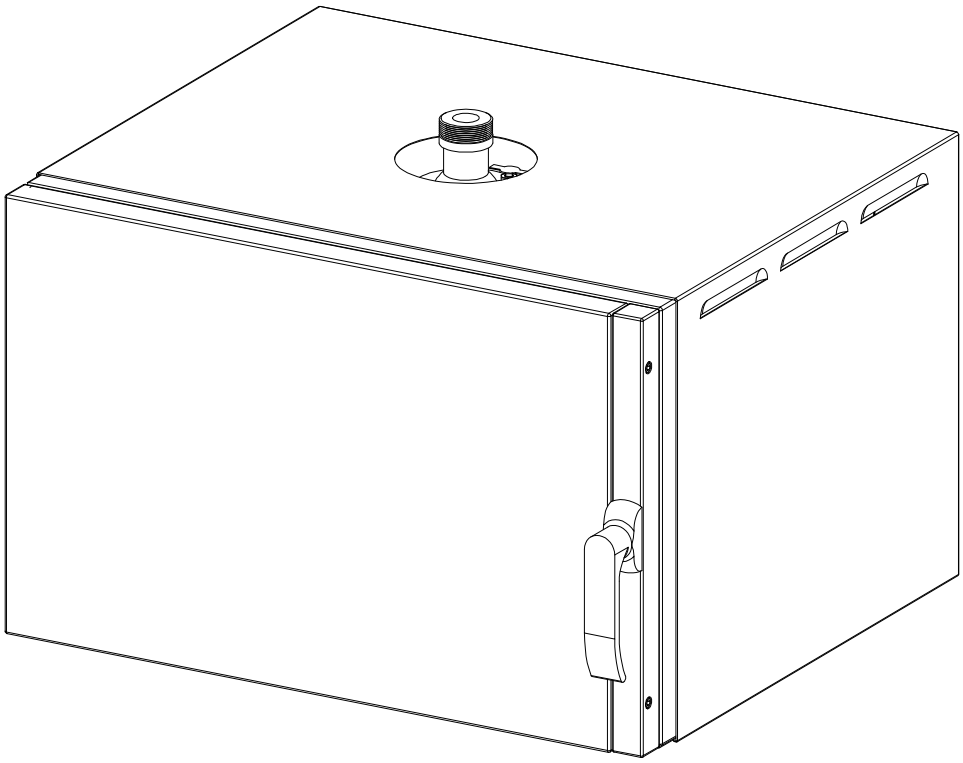
Multimode Microwave Applicator



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GERLING

Gerling Applied Engineering, Inc.
P.O. Box 580816 ♦ Modesto, CA 95358
www.2450mhz.com

REVISION HISTORY			
REV.	**DESCRIPTION**	**DATE**	**APPROVAL**
1	PROTOTYPE RELEASE	20JUN08	JFG

WARRANTY

Products manufactured and sold by Gerling Applied Engineering, Inc. ("GAE") are warranted to be free of defects in materials and workmanship under normal use and service for a period of twelve (12) months from the date of original shipment. GAE's obligation under this warranty is limited to repairing or replacing, at GAE's option, all non-consumable component parts. Consumable parts are specifically excluded from this warranty and may include, but are not be limited to, magnetrons, fuses, lamps, seals, o-rings, v-belts, and fluids. All warranty repairs are to be done at GAE's facility or as otherwise authorized by GAE. All shipping charges for warranty repair or replacement are the purchaser's responsibility unless otherwise agreed to by GAE.

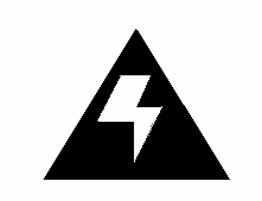
This warranty supercedes all other warranties, expressed or implied. No warranty is given covering the product for any particular purpose other than as covered by the applicable product specifications. GAE assumes no liability in any event for incidental or consequential damages, financial losses, penalties or other losses incurred in conjunction with the use of GAE products.

DOCUMENT CONVENTIONS

NOTE: *Means the reader should take note. Notes contain helpful information, suggestions, or references to other sections, chapters, or documents.*

CAUTION: *Means the reader should be careful. You are doing something that might result in equipment damage or loss of data.*

WARNING: *Means danger. A situation exists that could cause bodily injury or death. All personnel must be aware of the hazards involved with high voltage electrical circuitry and high power microwave devices.*



WARNING

The microwave applicator described in this manual is used with a microwave energy source capable of producing a microwave field that is potentially hazardous to operating personnel. The unit must never be connected or operated in a manner that allows a field in excess of 10 milliwatts per square centimeter to be generated in an area accessible to operating personnel. Contact GAE, Inc. for technical support prior to installation and/or operation of these units if there is any question or concern about microwave leakage.

All electrical cable connections must be secure prior to operation. Never operate the microwave oven without a properly rated absorbing load inside the oven cavity. To ensure safe operation and prevent microwave leakage, the equipment must be periodically inspected and maintained as required or recommended.

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EQUIPMENT DESCRIPTION

The multimode microwave applicator (MMA) is designed for laboratory research in high temperature materials processing at 2.45 GHz. While similar to a conventional microwave oven cavity, the MMA is used with external microwave power components (available separately) and thus allows greater flexibility with regard to microwave power control and delivery than is possible using a conventional microwave oven. Standard features include ports for gas delivery and sensors, a mode stirrer for enhanced cavity field uniformity and interlock devices for the cavity door and temperature. Optional features include a gimble mount for an IR camera, cavity environmental sealing, internal cavity insulation and customization of gas and sensor ports.

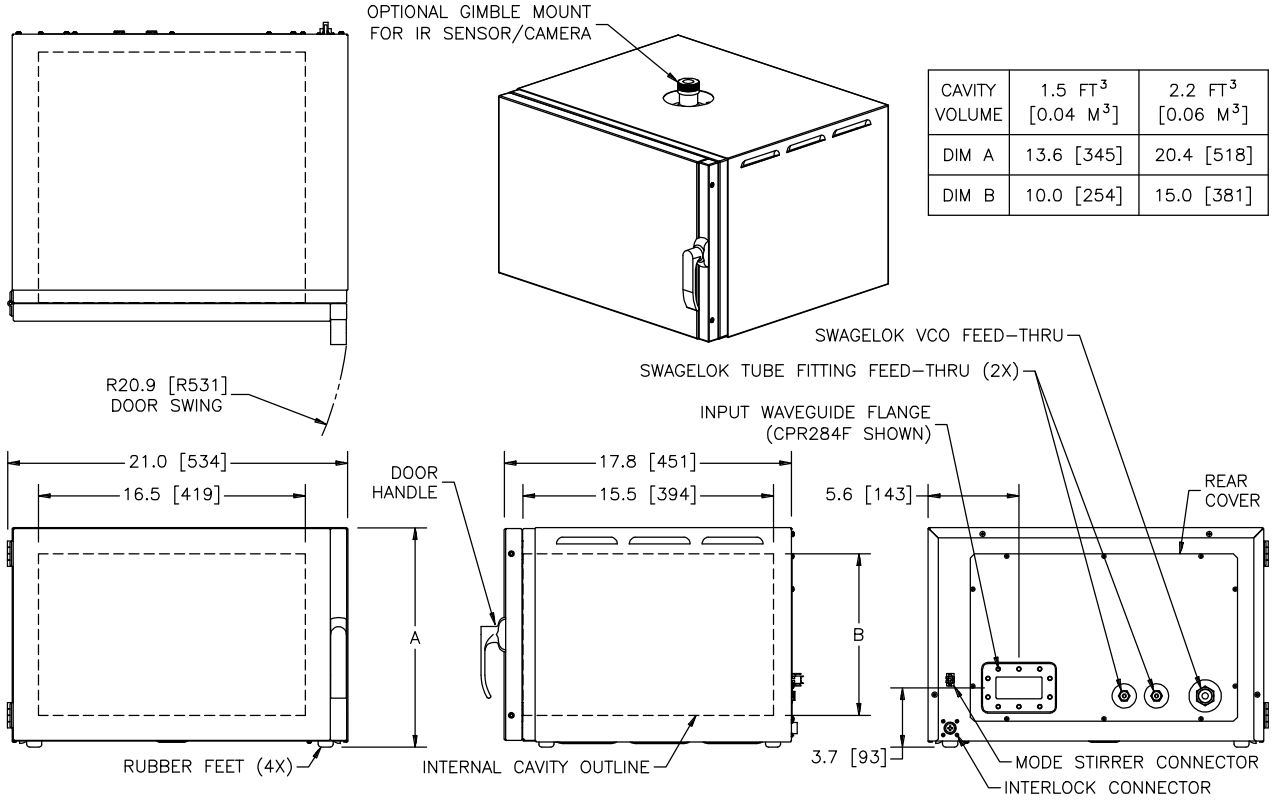
The MMA is constructed almost entirely of stainless steel for rugged durability and high temperature operation. The applicator cavity is thermally isolated from the chassis and insulated to minimize heat transfer to external surfaces. Microwave leakage from the cavity door is nearly eliminated by the use of a dual sealing system consisting of a reactive choke and RF gasket. A removable panel at the rear of the MMA allows access to the rear of the cavity to facilitate the addition of ports or other features that may be required for processing. Two cavity sizes are available to accommodate a wide range of loads.

General Specifications

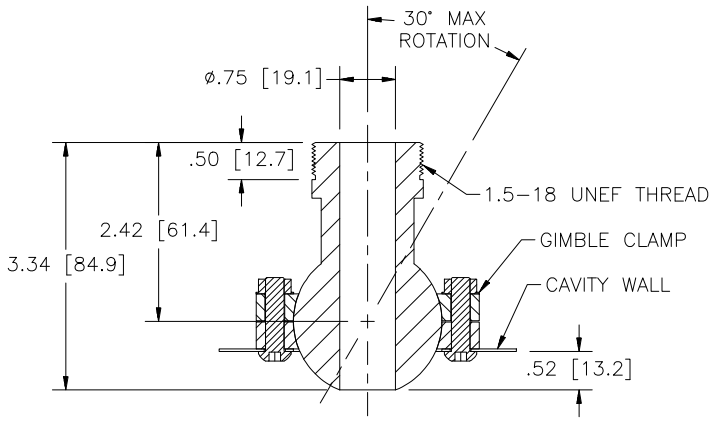
Operating Frequency	2.45 GHz nominal
Microwave Power Input	3 kW continuous maximum with high loss cavity load 1.5 kW continuous maximum with low loss cavity load
Input Flange	CPR284F (UG-1725/U) with ¼-20 tapped holes
Operating Temperature	250 ºC max continuous, 500 ºC max intermittent, 1600 ºC max with optional internal cavity insulation
Interlocks	Cavity door, cavity over-temperature
Mode Stirrer Power	24 VAC +/- 20%, 50/60 Hz, 30 mA
Electrical Connections	Interlocks: 4-pin “CPC” style connector Mode Stirrer: 2-pin “MR” style connector (mating connectors supplied for both)
Feed-Thru Ports	Swagelok VCO Fitting, size 8, SST (one port) Swagelok Tube Fitting, ¼”. SST (two ports)
Dimensions	(see outline drawing)
Weight	50 lbs (23 kgm) approximate (standard configuration)

Options	Gimble mount for IR sensor/camera Cavity environmental sealing Custom ports (specified by customer)

Outline Drawing



CAVITY VOLUME	1.5 FT^3 [0.04 M^3]	2.2 FT^3 [0.06 M^3]
DIM A	13.6 [345]	20.4 [518]
DIM B	10.0 [254]	15.0 [381]



IR SENSOR GIMBLE MOUNT

INSTALLATION

Preliminary Inspection

Upon arrival at the installation site the MMA should be thoroughly inspected for damage or wear caused during shipping. Any visible damage to the packaging material or the magnetron head itself should be noted and reported immediately to the shipping company in accordance with standard claims procedures.

The following items are supplied with the system:

1. Multimode Microwave Applicator, p/n 912691
2. Mating interlock connector, 4-pin “CPC” style
   Housing plug p/n 371303-04 (1 each)
   Socket contact p/n 371361-2 (4 each)
3. Mating mode stirrer connector, 2-pin “MR” style
   Housing plug p/n 371202-02 (1 each)
   Socket contact p/n 371203-2 (2 each)
4. Product User Manual (this document)

Mounting Position

The MMA must be mounted upright on a level surface capable of supporting its weight. Clearance must be provided at the top, sides and rear of the oven to allow adequate ventilation.

Sensor Mount (optional) Installation and Adjustment

The MMA may have been shipped to the customer with the optional sensor mount removed to facilitate packaging and protection from damage. Figure 1 illustrates installation of the sensor mount assembly.

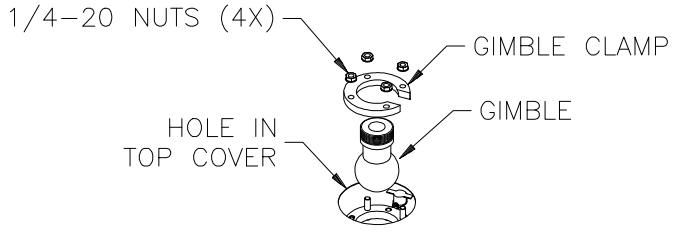


Figure 1, Installation of the sensor mount assembly.

The IR sensor mount is designed to allow adjustment of the sensor aim by rotating the mount in a gimble socket. To adjust the sensor, loosen *but do not remove* the four screws securing the gimble

clamp and gently rotate the gimble. Tighten the screws securely to fix the gimble in the desired position.

WARNING: *The IR sensor mount gimble and clamp must be properly installed and all fastener nuts tightened securely prior to MMA operation. Improper installation can cause hazardous levels of microwave radiation resulting in severe injury or death. Do not adjust the gimble while microwave power is being delivered to the MMA.*

Interlock Connections

The MMA includes internal interlock devices associated with the cavity door and cavity temperature. Two separate interlock circuits are provided as shown in Figure 2. Both circuits consist of multiple series-connected dry contact switching devices that are open when the interlock function is not satisfied.

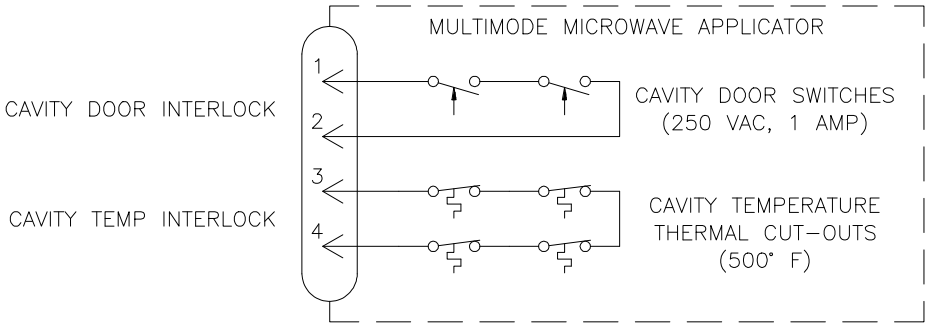


Figure 2, Connections to internal interlock devices.

Connections to the internal interlock devices are made to the 4-conductor circular plastic connector located on the rear panel of the MMA.

WARNING: *To ensure adequate protection from exposure to hazardous levels of microwave radiation, the cavity door interlock circuit MUST be connected to the microwave generator such that microwave output power is disabled when the cavity door is open.*

Mode Stirrer Electrical Power

The mode stirrer motor requires 24 VAC +/- 20%, 50/60 Hz, 30 mA power for operation. Connections are made to the 2-pin “MR” style connector located above the interlock connector on the MMA rear panel as shown in Figure 3.

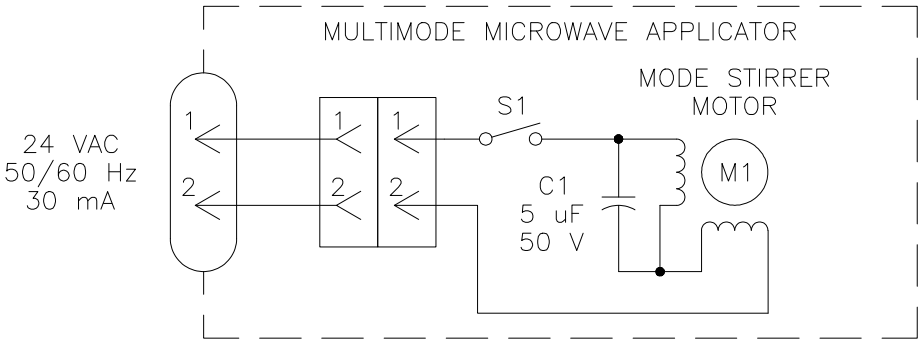


Figure 3, Mode stirrer schematic diagram.

Waveguide Connection

Microwave power is delivered to the MMA through a waveguide flange located at the rear panel. This flange has a ¼-20 UNC tapped hole pattern and opening compatible with standard CPR284 (UG-1725/U) flanges. The waveguide flange of the mating waveguide component must have clearance holes and be the same standard type and size. Bolts and nuts must be installed at all flange bolt holes and tightened securely prior to operation.

Figure 4 illustrates typical configurations of waveguide components for delivering microwave power to the MMA. Depending on the nature of the load to be heated, not all components shown are required for satisfactory performance. If an impedance tuner is used, it should be connected as close as practical or directly to the MMA.

Microwave Leakage – Regulatory limits for microwave leakage relate to standards for human safety and interference with other electronic devices. Standards for human safety as adopted by OSHA, the International Electrotechnical Commission (IEC) and other regulatory agencies limit leakage to 5 mW/cm^2 measured at 5 cm from the leakage source under normal operating conditions, and 10 mW/cm^2 at 5 cm from the source under abnormal operating conditions. The U.S. Federal Communications Commission (FCC) has established regulations limiting the emission of energy at frequencies outside the ISM bands. All GAE waveguide components meets these requirements when properly connected to another waveguide component.

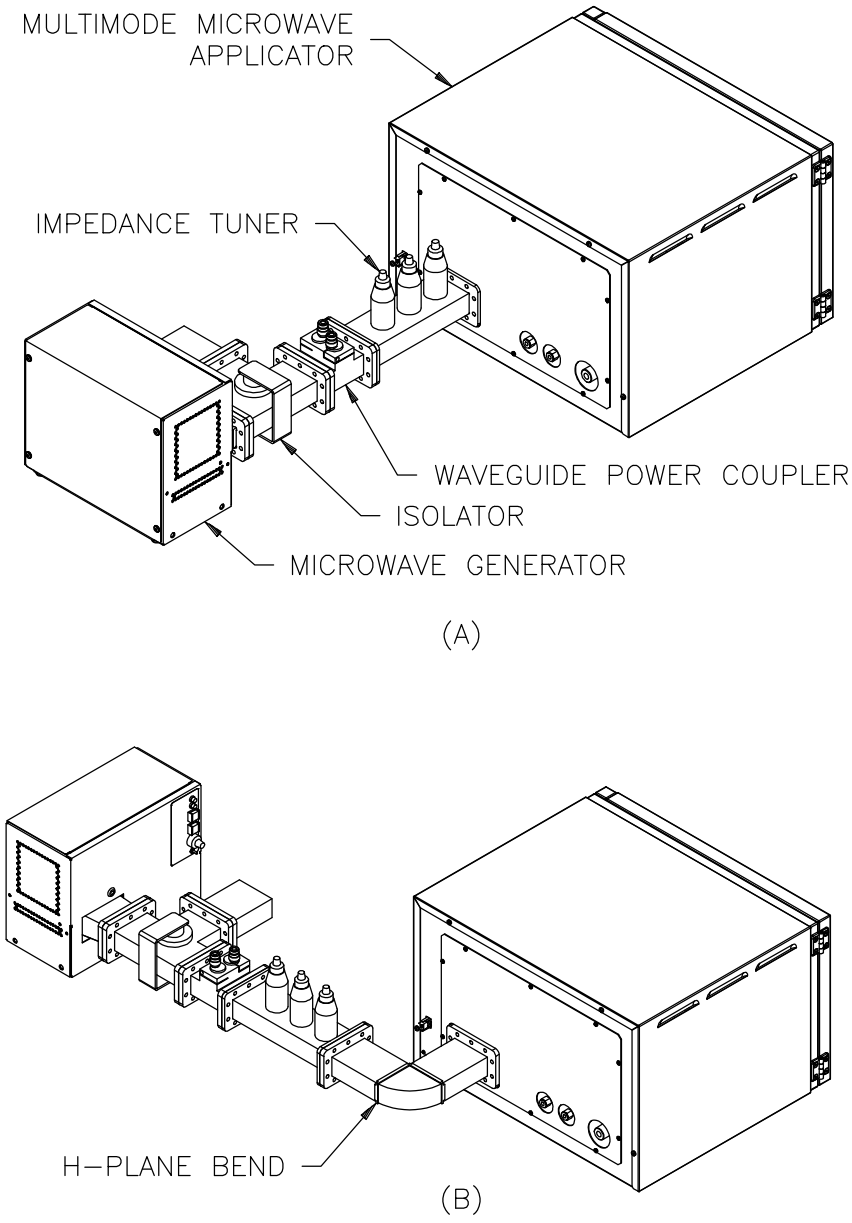


Figure 4, Typical waveguide component configurations for microwave power delivery to the MMA. (A) With impedance tuner directly connected to MMA, (B) With additional H-plane bend for bench top convenience.

Feed-Thru Port Connections

Three fittings are provided at the rear of the MMA for delivery and/or extraction of fluids and/or gases. These ports can remain open without causing excessive microwave leakage, or the user may connect any type of hose or tubing that is compatible with the fitting. However, connections inside the cavity and the associated user-provided apparatus must be compatible with use inside a microwave field. Consult GAE for advice and/or design assistance.

CAUTION: *Careful attention must be given to the design and installation of user-provided apparatus within the MMA cavity. Improper design and/or installation of user-provided apparatus can result in equipment damage or injury.* ***GAE ASSUMES NO LIABILITY WHATSOEVER FOR DAMAGE OR INJURY THAT MAY RESULT FROM THE USE OF USER-PROVIDED APPARATUS.***

WARNING: *Do not insert metal objects such as wires or rods through the feed-thru ports into the MMA cavity. Inserting metal objects through the feed-thru ports can cause hazardous levels of microwave leakage that can result in injury or death.*

OPERATION

Basic Operation

The MMA is a passive device having no features designed for control of the heating process. Control of microwave power delivered to the MMA must be provided externally by the user (e.g. as provided with the microwave generator).

Similarly, other than the cavity over-temperature interlocks, there are no displays or indicators on the MMA that provide information related to the process. Care must be taken when opening the cavity door to prevent exposure to process related hazards. The use of equipment to monitor heating process parameters such as load temperature is strongly recommended.

Cavity Door Interlocks

Interlock switch contacts associated with the cavity door are closed when the door is properly closed. The RF seals around the cavity door will prevent hazardous exposure to microwave radiation when the door is closed. A very slight rotation of the door handle will cause the switch contacts to open well before the door itself begins to open. When the door interlock switch contacts are properly connected to the microwave generator (see previous section), microwave power will be turned off before the door opens, thus preventing hazardous exposure to microwave radiation.

WARNING: *To ensure adequate protection from exposure to hazardous levels of microwave radiation, the cavity door interlock circuit MUST be connected to the microwave generator such that microwave output power is disabled when the cavity door is open.*

WARNING: *The cavity door must be properly closed before delivering microwave power to the MMA. An improperly functioning door can cause excessive microwave leakage which can result in severe injury or death. Do not operate the MMA if:*
a) Objects are caught in the door frame,
b) The door does not close properly,
c) The door, hinges or latches are damaged.

Mode Stirrer

The mode stirrer inside the MMA cavity is a rotating metallic blade that continuously perturbs the microwave field in a periodic pattern. A toggle switch located at the rear of the MMA is used to turn on and off the mode stirrer motor. When the mode stirrer is off, the microwave field pattern inside the cavity remains fixed (except due to changes in the cavity loading during heating).

Cavity Load Placement

Materials to be heated may be placed anywhere inside the cavity. However, placing the load materials directly in front of the microwave input waveguide can result in undesirably high and/or non-uniform absorption of microwave energy. Also, for obvious reasons, the load materials should not be placed in such a location that they interfere with the mode stirrer rotation.

Placing load materials directly on the bottom surface of the cavity can have undesirable heating non-uniformity due to the absence of a strong microwave field near the metal surface. It is generally recommended that load materials are placed on a microwave transparent stand-off accessory that provides some space above the cavity bottom surface, although the required amount of stand-off space depends on many factors such as the shape, thickness and properties of the stand-off accessory and load material.

Microwave Power Delivery and Impedance Tuning

The efficiency of coupling microwave power to the load material depends largely on the characteristics (size, shape, material properties, etc.) of the load and how well the loaded cavity is “tuned” for resonance (i.e. reflected power is minimized). A large load having a high dielectric loss factor might heat very efficiently without any tuning required. Similarly, a small “low loss” load can also be heated efficiently if the cavity is tuned for minimal reflected power.

A conventional microwave oven is designed with an integrated microwave power source and does not have any means for tuning the cavity to resonance. Thus, its microwave power coupling efficiency may be limited when heating small and/or low loss loads.

In contrast, an important characteristic of the MMA that distinguishes it from a conventional microwave oven is that the MMA does not have an integrated microwave power source. When connecting an external microwave generator, an adjustable impedance matching device is typically installed between the generator and MMA (see Figure 4) and used to enhance the power coupling efficiency by tuning the cavity to resonance.

However, this advantage of the MMA can also be a hazard. When microwave power is introduced into the cavity, an electric field is established inside the cavity that can lead to arcing and/or microwave leakage if allowed to become very strong. The electric field strength depends on the size and dielectric loss factor of the load, the level of microwave power and how closely the cavity is tuned to resonance. Table 1 shows the relationships between these factors and the propensity for arcing and leakage.

Table 1, Relative effect of controlled process parameters on the propensity for arcing and microwave leakage.			
Controlled Process Parameters			Propensity for arcing and leakage
Load Size / Loss Factor	Reflected Power	Forward Power	
High	High or Low	High or Low	Low
Low	High	High or Low	Low
Low	Low	Low	Low
Low	Low	High	High

For example, large, high loss loads can be heated at the maximum rated input power of the MMA without resulting an electric field strength high enough to cause arcing or leakage regardless of cavity tuning. Similarly, small, low loss loads heated at low power levels may not result in arcing or leakage even when the cavity is critically tuned to resonance.

At the other extreme, arcing and/or microwave leakage may indeed result when heating small, low loss loads at high power while the cavity is tuned for minimal reflected power. An example of a process during which this might occur is when attempting to rapidly heat a small amount of pure alumina without any other load materials (e.g. silicon carbide susceptors). The user will naturally attempt to operate at a high power level and adjust the cavity tuning to minimize reflected power. Under certain circumstances, the reflected power can suddenly drop as the tuning achieves critical coupling to the cavity. In this case, arcing can suddenly occur if forward microwave power is already at a high level. As safer approach is to tune for low reflection at low forward power and then slowly increase forward power.

WARNING: *Heating small and/or low loss loads at high power can cause hazardous levels of microwave leakage which may result in severe injury or death. Always use a microwave leakage detector to monitor microwave leakage. Turn off the microwave generator immediately if excessive microwave leakage is detected.*

MAINTENANCE

The MMA is designed to be maintenance free under normal operating conditions. No calibration is necessary and no internal devices or components are user-serviceable. In the event of damage due to improper operation or mishandling, the MMA should be returned to GAE for repair. Contact GAE for information on repair services.