



# 1600°C Microwave Assist Furnace



MRF 16/22/3508P1

## Microwave Assist Technology

Microwave Assist Technology (MAT) represents a furnace system that combines free radiating heating elements with a microwave field. Traditional heating elements heat material from the outside in, and microwave energy heats volumetrically. A unique technology of combining these two heating techniques was first developed and patented in 1993 by C-Tech Innovation, a UK company. In 2005, Carbolite Ltd. established a licensing agreement with C-Tech to manufacture furnaces utilizing microwave assist technology. The benefits of microwave assist technology have today been proven from laboratory scale systems to large production equipment.

### Key Advantages of MAT over Traditional Radiant Heating

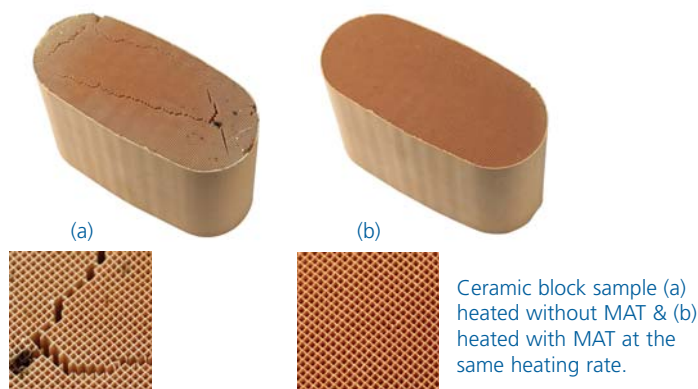
- Greater energy efficiency
- Faster sample heating
- More uniform heating
- Improved material properties

Each of these specific benefits can result in considerable cost savings when compared to standard radiant heat treating furnace systems. In addition to the direct savings in energy and time, indirect savings result from the quality improvement of material properties.

### Radiant or Microwave Heating Only

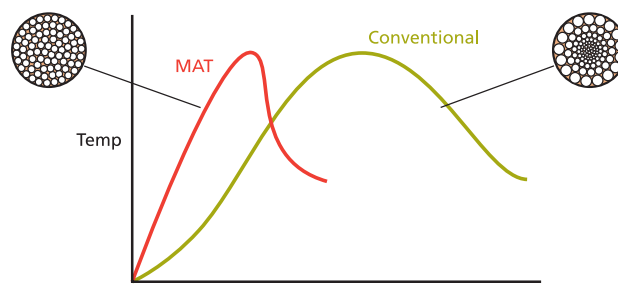
Conventional free radiating elements heat the outside of a sample, with the deeper inner areas heating more slowly through conduction. This temperature difference will be magnified if the sample is large or a poor conductor of heat. Microwave only heating methods initially heat the susceptible components of a sam-

ple throughout its volume, but heat is then lost from the surface to the surrounding atmosphere. Without any external source of radiant heating, a temperature gradient is created between the sample's hotter internal temperature and the outer surface. In both cases these thermal gradients can put the sample under stress, and cause damage during heating and cooling.



Ceramic block sample (a) heated without MAT & (b) heated with MAT at the same heating rate.

Traditionally, a practice used to reduce thermal gradients when heating with radiant heating systems, has been to extend the process time, so that the heating rate remains slow. The disadvantages of this are that not only are cycle times extended and more energy required, but because the exterior surface is heated for a longer period of time, unwanted physical and chemical changes can be produced. This can result in sintered materials developing a coarser less desirable crystalline structure on the exterior before the desired densification takes place in the interior. This phenomenon is illustrated in the following graph.



Comparison of Conventional and MAT Sintering

Microwave Assist Technology (MAT) provides the ability to balance radiant and microwave heating effects, offering the potential to heat susceptible materials faster and more uniformly, with consequential savings in energy consumption and the production of materials properties that cannot be achieved by other means.

## 1600°C Microwave Assist Box Furnace

Furnace Model	Max. Temp. (°C)	Internal Chamber Dimensions Inches (mm)			External Dimensions Inches (mm)			Max. Power (kW)	Radiant Heating (kW)	Micro. Power (kW)	Micro. Freq'y. (MHz)	Furnace Voltage	Shipping Weight (lb.)
		Height	Width	Depth	Height	Width	Depth						
MRF 16/22	1600	9.00 (232)	9.50 (245)	15.50 (396)	43.00 (1090)	36.00 (910)	36.50 (925)	12.0	9.0	1.8	2450	208/240*	324

Specify voltage at time of order.

Contact Carbolite for optional stand.

\* 3 phase delta electrical design.



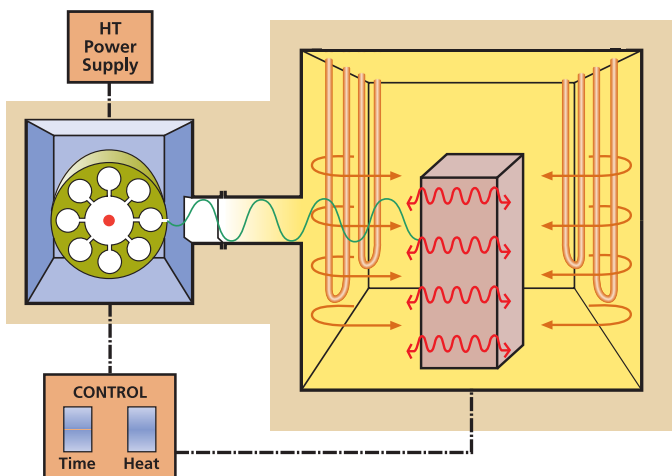
## The Carbolite MAT Furnace

The Carbolite Model MRF 16/22 1600°C MAT furnace makes microwave assist technology available to any researcher. Prior to the introduction of the Carbolite furnace, benefiting from the unique advantages of combining radiant heating and direct sample heating using microwave energy, has only been available through single custom-built hybrid devices. Now, for the first time, having a standard commercially available MAT furnace allows consistent repeatable results to be achieved between users in different locations.

The Carbolite MRF 16/22 insulation design improves the furnace energy efficiency through the use of high temperature, high strength hot face insulation, and graded low thermal mass insulation. Long-life molybdenum disilicide heating elements and a 1.8 kW air-cooled magnetron are the heat sources that provide rapid uniform chamber and sample heating.

## General Features

- 1600°C maximum operating temperature.
- Excellent chamber uniformity.
- 20 segment programmable temperature control.
- Separate over-temperature control instrument.
- Side swing door design.
- Double safety interlock cuts power on door opening.
- Meets industrial and commercial safety limits for microwave containment.
- Fan cooling provides low temperature outer case.



Schematic representation of a MAT furnace with radiant and microwave heating.

## Temperature Control of the MRF 16/22 Furnace

Some materials are more susceptible to microwave heating than others - an effect determined by their dielectric potential. A sample material's dielectric potential may also be temperature dependent, with the result that requires radiant heating to the point where the material becomes susceptible to microwave energy. The highly flexible temperature control system of the MRF 16/22 MAT furnace is invaluable to balance the combined effects of radiant heating and microwave heating.

The radiant and microwave heat sources are independently controlled through a Carbolite 3508P1 programmable temperature control. This instrument represents the highest sophistication in today's temperature control instrumentation. It has exceptional accuracy, and incorporates advanced functionality and features. Each heat source may be run manually for continuous operation, or combined into an automated program with up to 20 segments. One has the ability to independently control the element temperature and microwave power per segment. The program may be run once or cycled repeatedly, and within each segment, the microwave energy level can be set to either pulse or be applied continuously, at any percentage of the maximum output. If required, more advanced control options are available to allow the storage and recall of multiple programs.

## The MRF 16/22 Safety Features

Operator safety is emphasized with a side swing pivot door design that keeps the hot face insulation facing away from the operator, and a positive safety door switch that cuts power to the heating elements and magnetron when the furnace door is opened. The MAT furnace mechanical design assures that microwave emission containment exceed all industrial and commercial standards. Low temperature outer case and critical components are provided though fan cooling. A separate independent over-temperature protection controller is provided as standard.



Carbolite has partnered with Ceralink Inc., the North American MAT licensee, to offer Carbolite MAT furnaces in the U.S., Canada and Mexico. Ceralink Inc., located in Troy, NY, is a company that has specific expertise in materials science with a focus on ceramics, microwave and microwave assist technology. The Carbolite Ceralink relationship can benefit Carbolite customers with technical support, and process development in the testing and evaluation of materials fired in the Carbolite Model MRF 16/22 furnace, located in Ceralink's laboratory. This support can prove very beneficial during the initial planning stage of purchasing a MAT furnace. A Ceralink engineer can also assist Carbolite customers in the commissioning and training on a new Carbolite MAT furnace. Carbolite would encourage this service be purchased at the same time as the furnace.