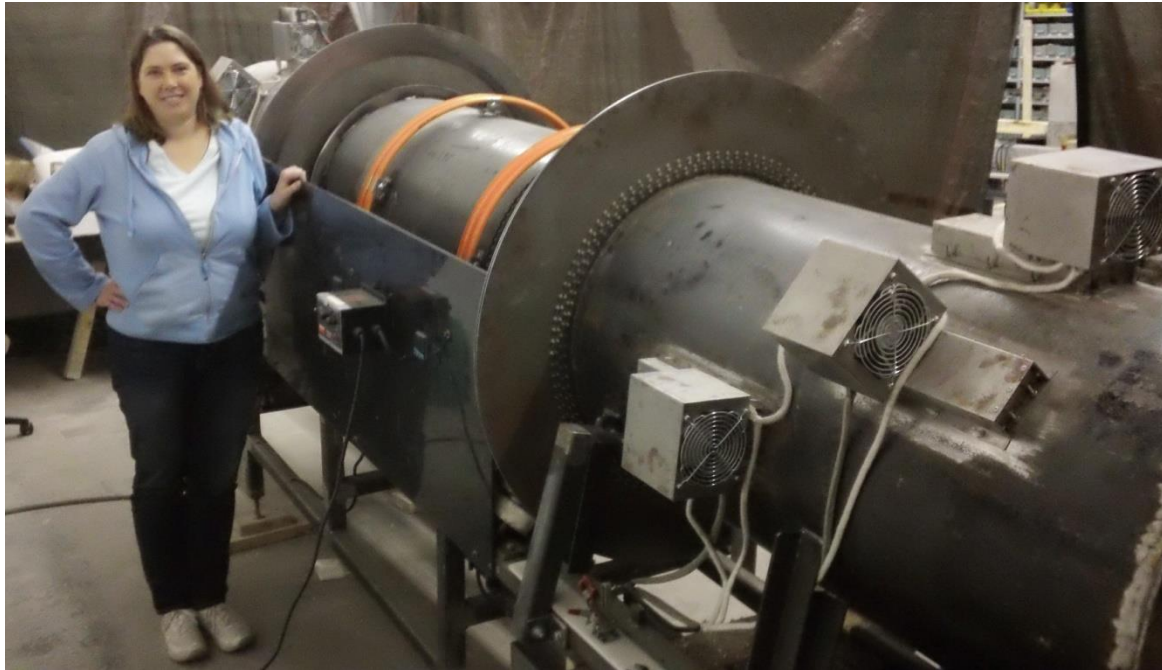


## The Microwave Sand Reclamation System



### Introduction: From the Kitchen to the Industrial Production Plant

Since the 1960's, starting with the Amana Radarange, most people have enjoyed the use of microwave ovens in their kitchens, using them in tasks from reheating a cup of coffee or tea to reheating meals and even cooking. The microwave oven has long been a staple of the modern kitchen for its ease of use, speed, safety and overall convenience in processing food.

The same attributes that have made microwave ovens a kitchen mainstay, have also been realized by the industrial processing of various products, raw materials and intermediate components.

Industrially, microwave has been used successfully in drying applications, ink printing, polymer resin curing and resin synthesis applications, drug synthesis and screening in pharmaceutical applications and in protein hydrolysis, among other applications.

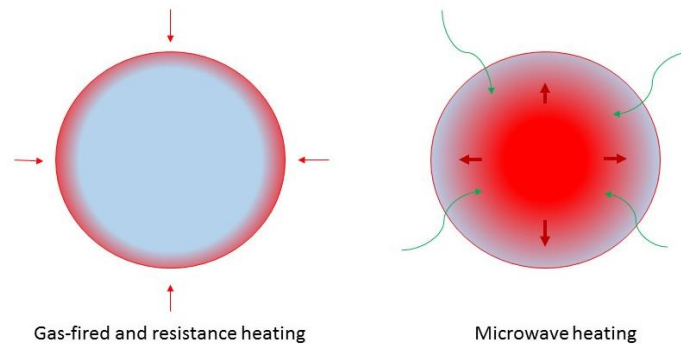
The primary benefits of microwave processes are significant decrease in process times for materials, as well as increased energy efficiency, and this is accomplished without generation of greenhouse gases as NO fossil fuels are needed for microwave operation. Microwave processing is generally more ecologically friendly.

### The Concepts:

Using microwave for sand reclamation for No-bake resin sand, furan-resin sand and green sand shows many advantages over other reclamation methods. Microwave, unlike conventional thermal processes, is a volumetric technique. Microwave energy is capable of penetrating various materials and throughout that material, and in most cases regardless of how much of that material is present. Conventional thermal methods work by conduction of energy from the surface of a material to its core, and in the

case of large amounts of a material or a bed of material, from the surface of the bed of material to the core of the bed depth.

For sand reclamation, not only does microwave work by penetrating and heating the entire bed of sand during the reclamation process, it also does not heat the surrounding kiln so the process is energy efficient simply because the energy targets only the resins and clays on the sand. Figure 1 shows the difference between conventional thermal heating and microwave processing in a large mass of material.



**Figure 1:** Comparison of thermal gradients within conventional heating methods and microwave sand reclaimer systems. Conventional systems heat from the outside surface, whereas microwave systems penetrate the waste sand and heat throughout the entire body of sand.

#### Cost of microwave sand reclamation

Because of this “targeting” the microwave power need not be on all the time to keep the waste sand up to temperatures. Basically, the better insulated the kiln, the less microwave power is required for processing.

And unlike gas-fired systems, when the microwave power isn’t on, the unit isn’t drawing any energy at all, so electrical costs for operation can be as low as \$3/ton using a cost basis of \$0.08kwh for electricity using a microwave sand reclaiming system. Gas-fired systems are generally 40-50% efficient and must remain “on” consistently during processing, and typical costs for a gas-fired system is between \$9-11/ton of sand.

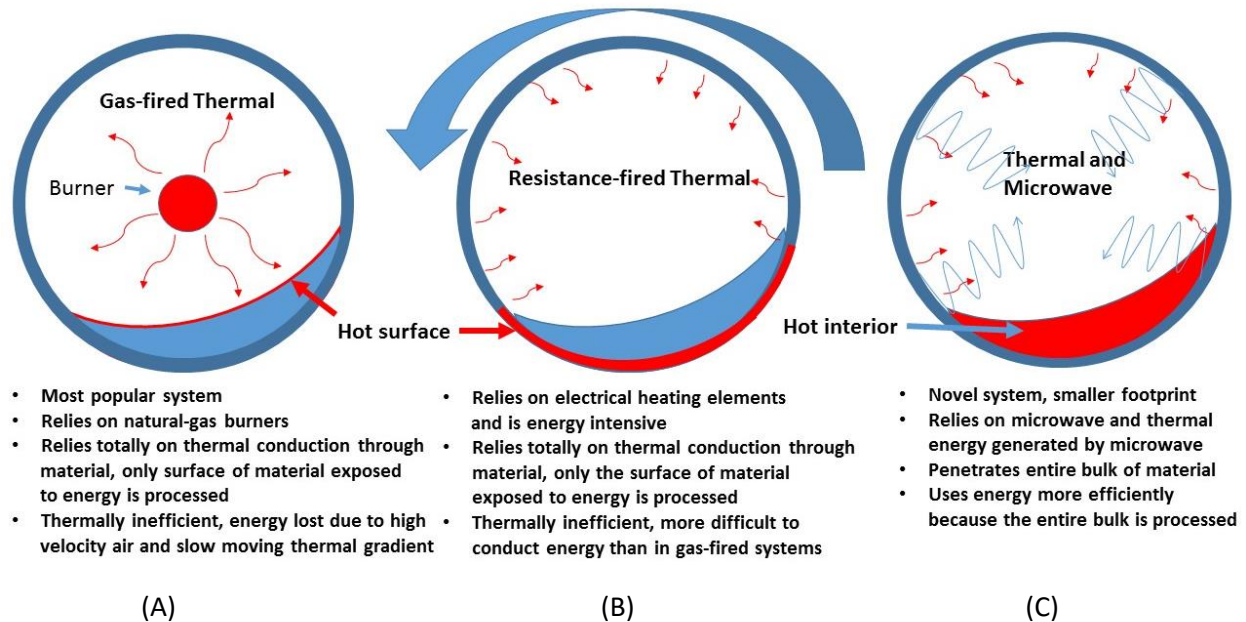
The microwave systems described within this document use ceramic components that are transparent to microwave energy but are very good thermal insulators, so overall, microwave based reclamation systems are more cost effective to operate compared to thermal gas-fired reclaimers.

#### Concept to Practical Application

The below figure compares the cross-sections of some standard rotary kiln formats, which are (A) the gas-fired kiln (direct or indirect fired), (B) the resistance-fired kiln and (C) the microwave sand reclamation concept.

The biggest advantage of any rotary system is it’s arguably the easiest large-scale industrial processing concept to operate, maintenance and understand. The simplest rotary design can be a hollow tube or cylinder balanced on a bearing ring around its circumference with a gear motor to turn the entire

construction. The construction is typical tilted 3-5 degrees towards the product output end and, as the construction turns, the product material moves towards the end of the cylinder where it is discharged into a bin or other collection system.



**Figure 2:** Direct Comparison of the rotary kiln systems and concepts, rotation direction in this figure is counter-clockwise as show by the arrow over example B.

However, the biggest disadvantage of conventionally-fired rotary systems in general is that they are inefficient. Most of the energy, whether it be from a directly- or indirectly-fired kiln, must also heat the surrounding structures, as well as the product material. If the surrounding structures (usually the kiln walls) are not as hot as the product material, the product material can cool itself when it comes in contact with the surrounding structures. So these systems need to supply larger amounts of energy to heat both the product material as well as the surrounding structures to accomplish processing of the product material. Convective/forced air, which is itself inefficient, in a typical rotary system helps in distributing energy but that air also needs to be near the processing temperatures.

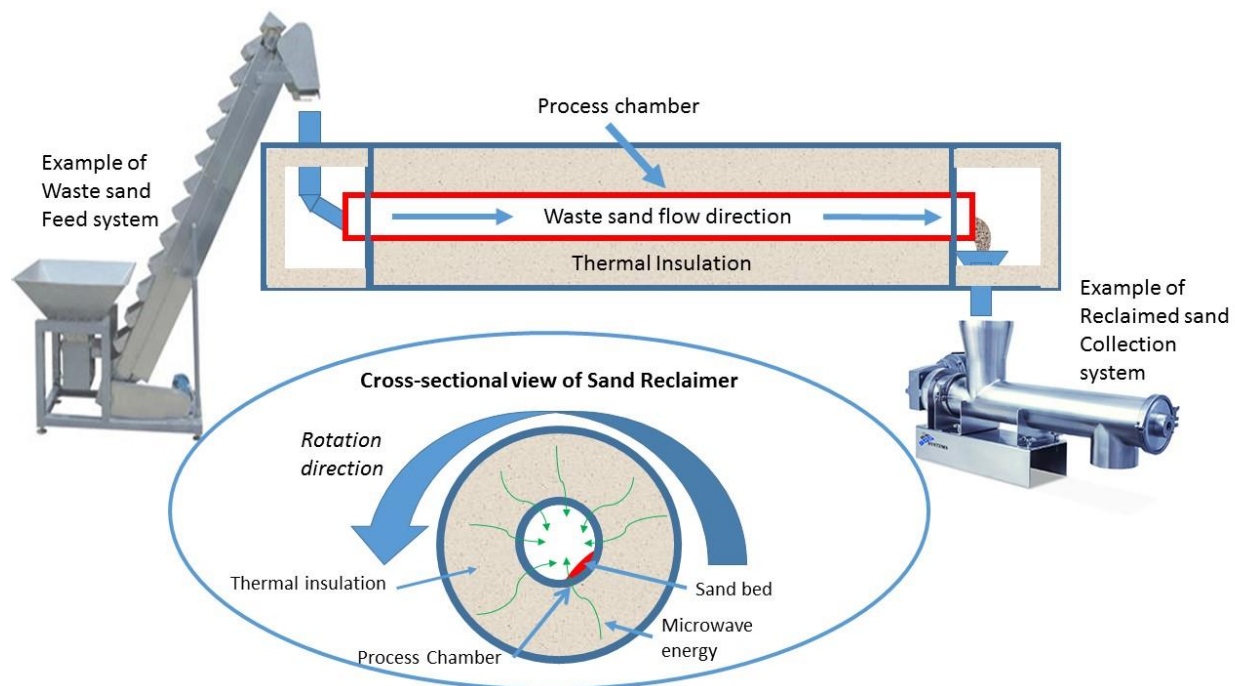
What the microwave rotary sand reclaiming concept does is significantly reduce, nearly eliminating, the inefficiency typically associated with rotary systems by heating ONLY the “target” area, and NOT the surrounding structures, so all of the energy is directed at the product material. Since the product material absorbs microwave energy it can remain hot throughout the process and all the surrounding structure needs to do is contain that heat generated.

**What makes the microwave rotary kiln superior to other foundry sand reclaiming concepts is that it combines the operating efficiency from being a microwave process, with the design simplicity of the rotary kiln system, making operation and maintenance more straight-forward and easily serviceable.**

## Offerings and Options in Microwave Sand Reclaiming Systems:

These patented and patent-pending units can be built for nearly any throughput size, the microwave power is the only consideration, as greater desired throughputs can require more power.

The below figure (Figure 3) shows the general concept of the reclaiming system.



**Figure 3: Overview of The Microwave Foundry Sand Reclaiming System**

The reclaimer is shown in this diagram (Figure 3) in between typical methods of loading waste sand and recovering discharged reclaimed sand from the system, a cross section view is provided showing the rotating section with thermal insulation surrounding the processing area. In the processing area the waste sand is shown interacting with microwave energy.

Figure 4 shows a picture of input sand traveling through the actual processing area. For the purposes of taking this picture, sand reclaiming was stopped during the process while the unit was still hot. Waste or “pre-reclaimed” sand can be observed near the entrance of the processing area as it is beginning to travel through the system. Sand reclaiming occurs immediately as waste sand begins burning off resins to give reclaimed sand. The sand stream, or sand bed, can be seen developing after the initial loading as the process chamber is rotating.

Figure 4A shows the system totally open to the atmosphere while sand travels through. The view shown is through a microwave-safe viewport designed to allow the operator to look directly into the system. The combustion of resins on the sand can be clearly seen within the process chamber while the system is in operation. The system controllers reduce the microwave power once the system achieves resin decomposition temperatures.

Figure 4B shows the sand output (as was shown in Figure 4A) but with part of the thermal insulation baffle system in place.

During normal and typical operation the system views that are presented in Figures 4 and 4A cannot be seen by the operator or any foundry personnel. The photographs for Figures 4 and 4A were taken with the system open.

Figure 5 shows the before-processing and after-processing photos of the sand. The starting waste sand contains both black and red iron oxides, accounting for the resulting reddish color. Processing conditions from 400C (752F) to 700C (1292F) is sufficient to process most waste sand (resin-coated and green sand).

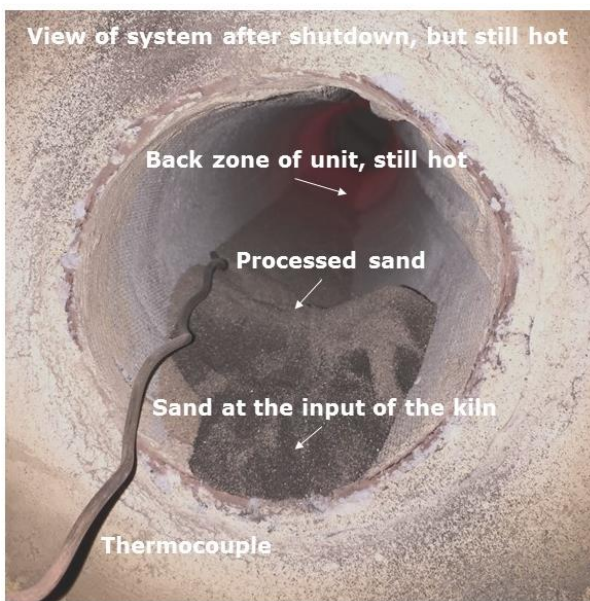


Figure 4



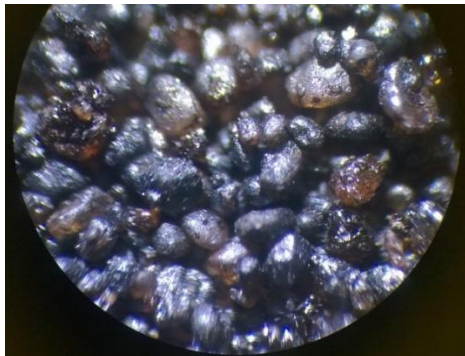
Figure4A

**Figure 4:** View of the unit stopped and opened during reclaiming process showing waste sand at the entrance and reclaimed sand exiting the unit.

**Figure 4A:** Close-up and microwave safe view of resin combustion under microwave exposure.



**Figure 4B:** View of the unit stopped and opened during reclaiming process showing waste sand at the entrance and reclaimed sand exiting the unit.



Waste sand before any reclamation



Reclaimed sand after microwave processing

**Figure 5:** Comparison of waste sand before and after microwave reclamation. Sand contains both red and black iron oxide. The resulting LOI was 0.01.

#### Microwave safety

All microwave reclaimer systems are designed with operator safety in mind first and foremost. These designed to have less than the leakage detected from a home microwave oven used in the kitchen, as required by OSHA.

#### Microwave Sand Reclaimer Sizes:

Conventional rotary kiln systems are designed for various sizes (length vs. diameter) depending largely on the throughput rate required as well as other factors. They can be small laboratory tube furnaces

that are no larger than 1-2 feet in length and 1-2 inches in diameter to cement clinkering kilns that can be as long as 300 yards or more, and having diameters of 10-20 feet or more. These lengths and diameters are the same for microwave-based systems. But, as described earlier, due to the unique properties of microwave energy systems employing microwave can be smaller than a convention rotary systems designed for a similar throughput rate.

Microwave sand reclamation systems designed for 1-2tph have processing sections of 10-12ft, while 2-4tph can have processing sections up to 20ft and with standard diameters or 2-4 feet. Increasing the diameter will allows the length to be reduced.

But these systems are also scalable to fit the needs of your foundry and designed to allow a range of scale-up options without adding significant capital cost from a base system.

#### Modular system design and flexibility:

The microwave sand reclamation system can have a modular design, with sections added to for higher processing at any time. These modules can be outfit with additional microwave power for significantly greater throughput or simply be used to enhance the process volume for increased throughput with the increased length. This allows you to purchase a smaller lower cost processor initially and add capability to it at a later point, as needed, thus keeping the initial investment lower.

\*Specific questions concerning modular techniques and additions should directed to M-Wave Consulting, as this contains proprietary information.

#### **Unique Abilities of Microwave Sand Reclaimers Over Other Sand Reclaimers:**

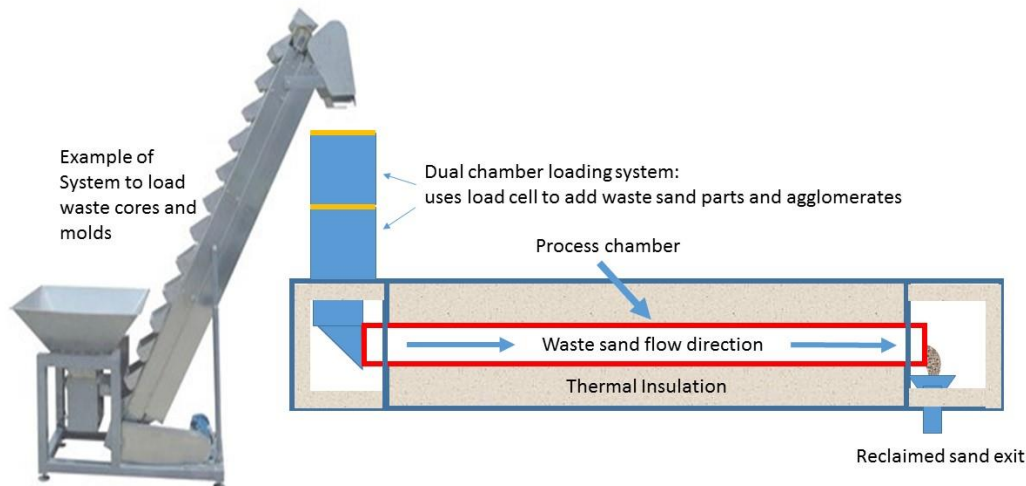
##### Reclaiming waste cores and mold lumps and agglomerates

Gas-fired sand reclaimers REQUIRE that waste core and mold lumps be broken down before the sand can be passed through and reclaimed. As Figure 1 showed earlier, gas-fired reclaimers operate by heating the surface and relying on thermal conductivity to reach the center of the mass it's trying to heat. Foundry sand is a very poor thermal conductor, so heating waste core lumps and agglomerates is very difficult and would require a lot of energy when using gas-fired systems.

Since microwave energy penetrates the bulk of the core or mold lumps or agglomerates and cause temperatures to build WITHIN the lumps or agglomerates, there is no need to significantly break down the core or mold agglomerates, additionally the rotating kiln provides agitation that aids in breaking down sand from lumps and agglomerates to primary grain size.

Therefore, a microwave reclaimer removes the need to crush waste core lumps and agglomerates prior to reclamation, saving both time and money on additional equipment.

Figure 6 shows the adaption that allows the reclaimer system to handle lumps and agglomerates. The system uses 2 loading areas the 1<sup>st</sup> chamber is loaded via conveying system and loads cores onto the ceiling of the 2<sup>nd</sup> chamber, the 2<sup>nd</sup> chamber (once the ceiling of the 1<sup>st</sup> chamber is closed) loads the lumps and agglomerates into the processing chamber for exposure to microwave reclaiming.



**Figure 6:** Dual loading chamber for microwave reclaiming of sand from lumps and agglomerates

Metals contained within lumps and agglomerates of core and mold sand are not a problem:

Usually a big concern for any microwave process technology is the effect of metals inside of the microwave unit. While metals reflect microwave energy and could potentially do damage to the typical microwave system, these microwave sand reclaimers have been designed in such a way that metals will not adversely affect the system. So metals within the microwave reclaimers will not pose an issue to the operation of the reclaimer, nor cause damage to these sand reclaiming systems.

However, large amounts of metals traveling through the system may cause damage to the internal ceramic components, so some sort of separation should be done to remove larger and denser metal objects from entering the system, but small stray metal pieces and parts will not be problematic.

Reclaiming waste cores for core patterning shops:

Core patterning shops have typically don't have large amounts of waste cores, however the costs to dispose of waste cores over the course of a year could be a significant cost to the core shop, in not only landfilling costs of accumulated resin coated sand, but also the cost of new sand to replace the waste sand. Unlike gas-fired systems, microwave based reclaimers can be designed small enough (100 pounds per hour or less) to process waste core sand to return the sand back to the core room and pay for itself within a very short period of time. Additionally these units are very portable, needing only a power outlet for operation.

Reclaiming of Green Sand

Green sand, having the constituents of bentonite clay, Sea coal, starch and potentially other additives can be returned for use without killing or deactivating the clay. Microwave systems, as used in many drying applications, can be designed to only target the water added to the green sand mixture which



only dries the clay instead of destroying it. Other systems, such as mechanical scrubbers, are needed to separate the dried components from the sand.

**Other Microwave System Offerings for the foundry:**

**Microwave LOI testing and lab units:**

Critical to any foundry is quality control of the incoming virgin and/or reclaimed sand and the most common method is obtaining an LOI on the sand. Microwave units to obtain LOI are fast, affordable and safe techniques for obtaining LOIs for any sand system using any kind of resin, bentonite, sea coal or other additives. Unlike resistance kilns with heating elements, microwave systems heat up the test materials quickly, finishing a test within 30 minutes from a cold start (from 70F to 1840F) and eliminating the need to put LOI sample crucibles in hot kilns, which can be a definitely safety hazard or take hours to complete an LOI test if the resistance kiln is started at 70F.

The below figure (Figure 7) shows a microwave LOI unit with insulation package rated for 1100C (2012F), controller reads temperature and controls the input power from an on-board thermocouple that is inserted into the “hot zone”. Figure 7A shows the unit prior to operation and Figure 7B shows the unit opened with the “hot zone” at processing temperatures.



Figure 7A



Figure 7B

**Figure 7: Microwave unit for laboratory and LOI characterization.**

**Options for Microwave Power (for foundry sand reclaimers):**

Microwave power can be supplied as (1) individual sources (each source can supply up to 3kW and is air cooled) and is built into the reclaiming unit or (2) as one generator (supplies 100kW of power and is cooled with 70F circulating water) which is a self-contained stand-alone power supply. Figures 8 and 9 show examples of individual microwave sources and microwave generators.



**Figure 8:** Image of source with waveguide (example only)



*Waveguides*

**Figure 9:** Generator with waveguides

Individual power sources are roughly 10-12 inches in length, whereas a microwave generator is roughly the size of a consumer home refrigerator. Typically the throughput rate requirements for the sand reclaimer determine whether or not individual sources are used or a generator is required. For throughput rates greater than 2tph a generator is usually preferred.

### **Warranties, Maintenance and Safety:**

Though all microwave sources, mechanical and supporting parts of the reclaimer come with 1-year warranties, each system is matched and power-balanced for optimum microwave performance. Because of power balancing and the design for safety, the foundry operators must not make unauthorized changes to the microwave reclaimer system that would cause it to become unbalanced or compromise the safety design for the system. Each system comes with training and instruction manuals that details all aspects of the system.

Beyond occasional use of an air hose to clear the processing chamber and insulation areas of dust and debris, the only items that should be replaced or require any maintenance is the thermal insulation near where the microwave power is located, roughly every 10-12 months or as recommended depending upon the amount of sand being reclaimed or the type of resins being removed. Carbonaceous buildup from resins or dust over a significant period of operating time can reduce the efficiency of the system. General housekeeping procedures remedy these issues.

Microwave safety is of the utmost importance and these systems are designed with a variety of safety features. There is EMI (electromagnetic interference) shielding that prevents any leakage, and microwave leak detectors that can be stand-alone or installed on-board, which monitor and alert the operator (or can also shut down the equipment) if a leak is detected above OSHA mandated levels.

Additionally all on-board microwave systems are safety interlocked, so if an operator or any unauthorized personnel attempts to open the system while operating, the power will immediately shutoff.

Machine guarding is strongly recommended, as it would be with any industrial equipment, but the type and level of guarding depends upon federal OSHA guidelines and the layout of the foundry.

## Summary

There are many advantages to installing a microwave system over gas-fired or mechanical reclaimers. Operating costs will be lower, the sand temperature can be controlled more effectively and units can be made in various sizes and throughputs, including being built on a modular basis. Any changes in the resin system by the foundry will not affect the reclaimer, all organic resins will process in the microwave system.

These patented and patent pending microwave sand reclaimers are simple, affordable and considerably more flexible than other sand reclaiming technique. Additionally, no specialized training is needed for operation or maintenance. As simple as operating a home microwave oven, the operators only need to know how to use the controllers to set a throughput speed and set a processing temperature.

These microwave systems aren't even affected by metals within the processing chamber and allow for lumps and agglomerates to be processed, something gas-fired reclaimers cannot accomplish.

Microwave is a clean technology. The fact a microwave units operation does not require the use of fossil fuels, means there will be significantly less combustion products and gases that will need to be handled to stay within emission regulations. This includes lower dust generation as well, as microwave systems do not require high velocity air or gas.

As the foundry mitigates changing economic and business climates, this technology has the capability of changing with the foundry as well, not only by providing simple and affordable methods to reduce or expand throughputs without adding significant capital cost; but also by providing flexibility in its application as well as simple operation and maintenance for foundry personnel.

\*If you would like further information or to inquire about a specific case, please contact Dr. Milt Mathis of M-Wave Consulting and M-Wave Foundry Technologies at [mathis@m2wav.com](mailto:mathis@m2wav.com) or 612-759-5558.

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