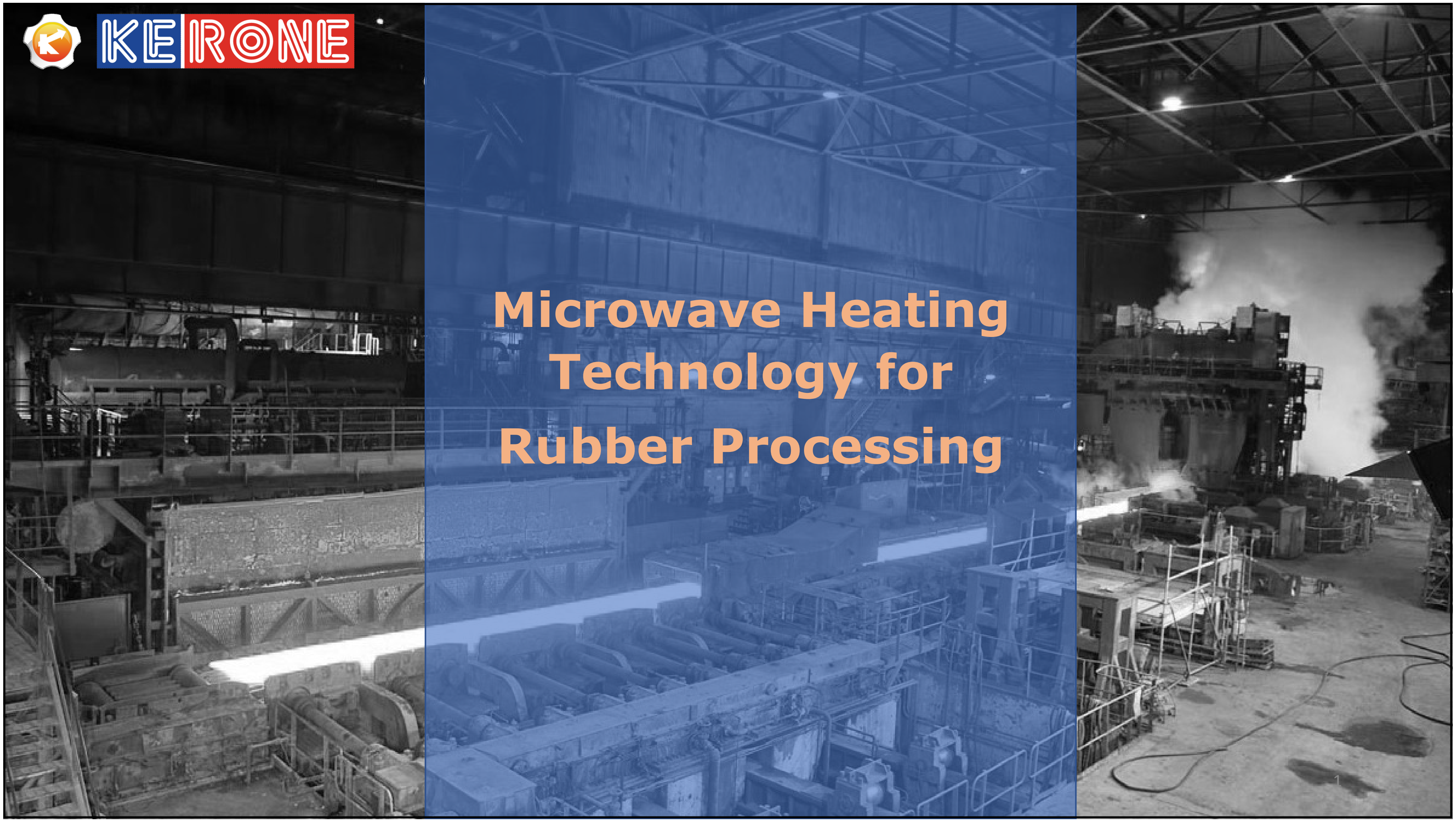


Microwave Heating Technology for Rubber Processing

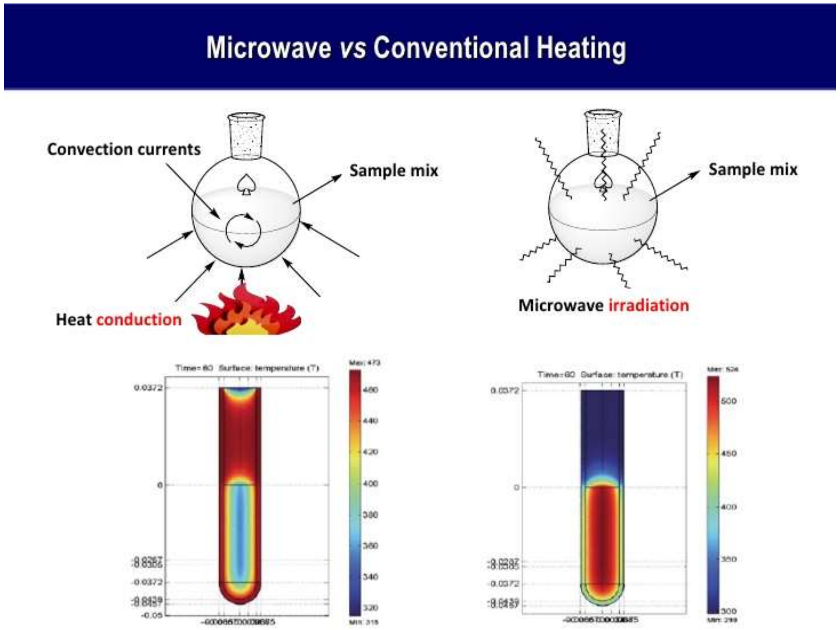
KERONE

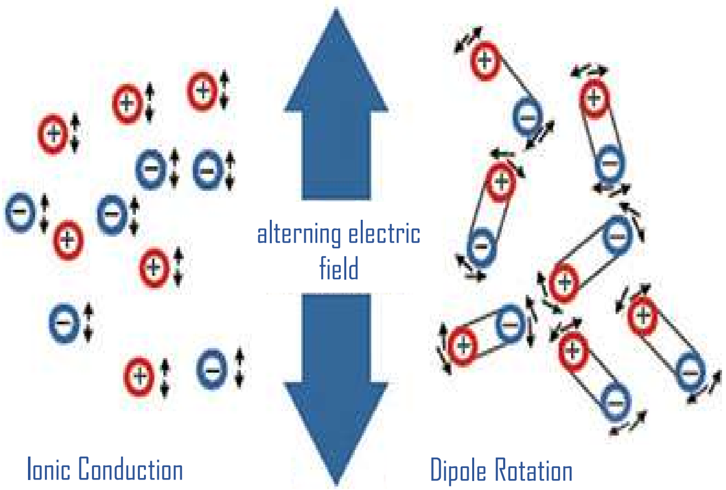
Introduction

With 85% of the homes containing microwave ovens, most people have experienced the speed and the penetrating effect of the microwave heating. The rubber industry is used as an example since microwave continuous vulcanization of automotive weather stripping used worldwide, wherever automobiles are manufactured.

Conventional and traditional technology for applying heat to rubber during the vulcanization process has relied on labor intensive steam autoclaves (a batch system), long and inefficient hot air tunnel ovens, and environmentally unfriendly high temperature liquid salt systems. These are now being replaced by highly efficient, high speed microwave curing ovens automated with electronic controls and sensors.

Microwaves are electromagnetic waves whose frequency varies within 300 MHz to 300 GHz. Domestic microwave appliances operate generally at a frequency of 2.45 GHz, while industrial microwave systems operate at frequencies of 915 MHz and 2.45 GHz.

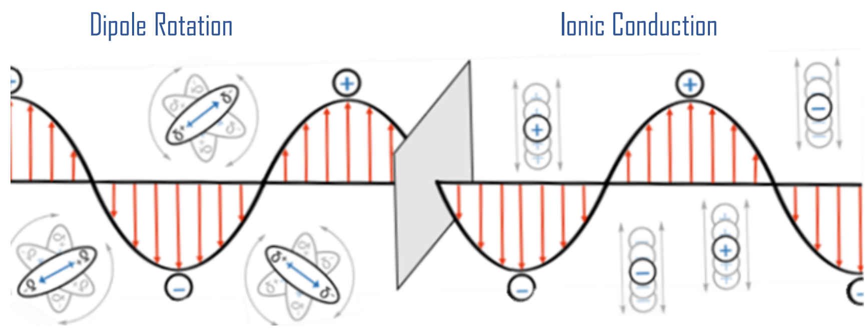




Microwave Heating Mechanism

There are essentially two mechanisms for the absorption of microwave power by materials. One is that of dipole rotation which would apply to polar materials such as nitrile and neoprene polymers. The molecules of these polar compounds are electrically neutral, but have a spatially separated positive and a negative electric charge. They appear as molecular electric “compass needles” or dipoles which react to the polarity of field changes and orient and reorient themselves as the amplitude of the field increases from zero in one direction , reaches a maximum, decreases back to zero and then increases to a maximum in the opposite direction. The field has both amplitude and direction. At 2450 MHz, the field is alternating or reversing its direction (polarity) at a rate of 2450 million times per second. The polar rubber molecule in this alternating microwave field will attempt to rotate its negative pole in the direction of the field. It will then return to its normal state of disorder as the amplitude moves to zero, and then will attempt to rotate its positive pole to the opposite direction of the field and do all this activity at a frequency of 2450 MHz.

The second mechanism of microwave heating is that of ionic conduction. It is commonly known that non-polar rubbers such as Natural Rubber, EPDM, SBR, etc., are not receptive to microwave energy but are made receptive by the addition of carbon black. The heating effect of non-polar rubber with carbon black is due to ionic conduction or ohmic heating. Free ions exist at the interface of semi-conductor materials, the interface between the carbon particle and the polymer. These ions are not electrically neutral, but rather are either positively or negatively charged. As such, they are attracted by electric fields and their movements in such fields constitute a flow of current. Their velocity represents kinetic energy given to them by the microwave field. The free ions do not travel very long in the microwave field before they collide with unionized molecules giving up their kinetic energy in a randomized billiard ball fashion almost as fast as they obtain it. You will note in Table III the dramatic effect on microwave receptivity when salt is added to the polar water to induce ionic conduction.



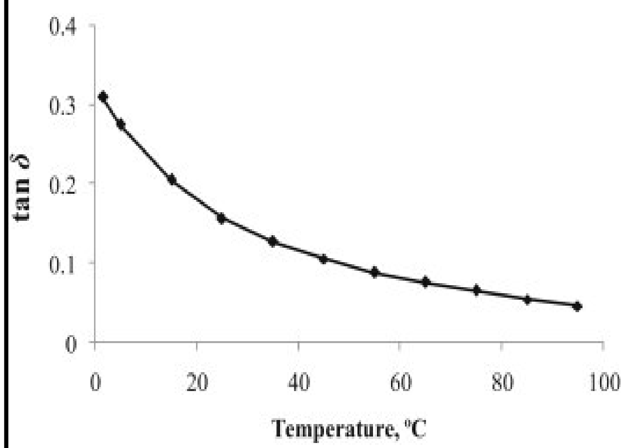
Dielectric Properties and Penetration Depth (cm) of Various Materials at 2450 MHz

Material	Temperature Degrees C	Dielectric Constant	Dielectric Loss	Factor Penetration Depth D ½ (CM)
Water (Distilled)	25	78.0	12.0	1.0
Water (Distilled)	45	70.7	7.5	-
Water (Distilled)	95	52.0	2.4	-
Ice	-12	3.2	0.003	800
Natural Rubber	25	2.2	0.01	200
Neoprene	26	2.8	0.14	16.1
Polyethylene	-	2.3	0.001	2045
Thermoset Polyester	20	4.0	0.02	135
Teflon	20	2.1	0.001	3256
Nylon	20	2.4	0.02	104
Soda Lime Glass	20	6.0	1.02	2.8
Borosilicate	20	4.3	0.02	140
Glass Ceramic	20	6.0	0.03	110
Alumina	20	9.0	0.005	809
Quartz	20	4.0	0.001	5393

KERONE

Dielectric properties

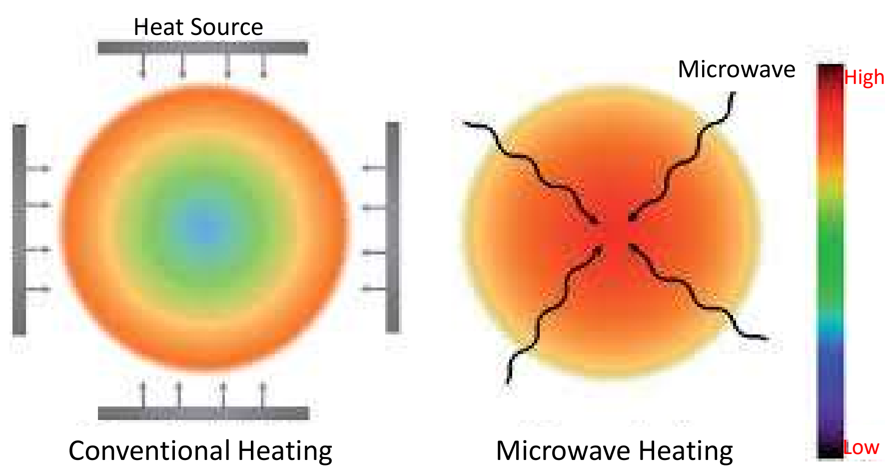
The ability of a material to convert microwave to heat can be understood by knowing its dielectric properties. The real part of dielectric property, termed as dielectric constant, signifies the ability to store electric energy and the imaginary part of dielectric property, termed as dielectric loss, signifies the ability and convert electric energy into heat, $\varepsilon_r = \varepsilon_r' - j\,\varepsilon_r''$
where ε ' and ε" are dielectric constant and dielectric loss respectively and j = −1. The ratio of dielectric loss to dielectric constant is given by loss tangent and is expressed as,
tan δ = $\frac{k''}{k'} = \frac{\varepsilon''}{\varepsilon'}$
where κ ' and κ " are relative dielectric constant and relative dielectric loss respectively, which are given as $k' = \frac{\varepsilon'}{\varepsilon_0}$ and $k'' = \frac{\varepsilon'}{\varepsilon_0}$. Here, ε_0 is the permittivity of free space (ε_0= 8.854 x 10-12 F/m). The dielectric properties are mainly affected by the operating temperature and the microwave frequency used. Based on the microwave absorption, materials are classified into (i) absorbers or high dielectric loss materials which are strong absorbers of microwave (ii) transparent or low dielectric loss materials where microwave passes through the material with little attenuation and (iii) opaque or conductors which reflect the microwaves.



shows the variation in the dielectric properties for water with the temperature, expressed as tan δ. Based on this variation, it is possible to consider that the effects of microwaves are temperature dependent once tan δ decreases with the increase of temperature.

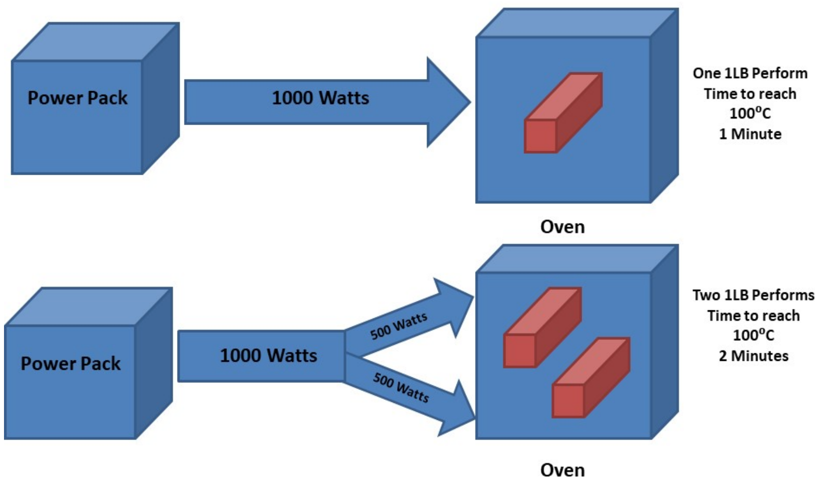
Penetration Depth

The greatest advantage of microwave processing comes from the penetrating effect of microwave energy due to the internal mechanisms of molecular friction which were explained earlier. It is this ability to penetrate which results in very high quality extrusions evenly heated throughout their mass, a very important factor for automotive weather stripping. Conventional methods of processing such as salt bath, hot air and steam put high temperature on the outside of the extrusion and depend upon the thermal conductivity of the rubber to absorb the internal heat. Microwaves penetrate as soon as they are turned on, but indeed, they do heat from the outside in. Their instantaneous effect, however can cause the misconception that they heat from the inside out. We should understand the nature of microwave penetration.
The rate at which the energy is absorbed or decreased is called the penetration depth and, in general, it is defined as the depth at which the power level of the microwave energy is decreased by 50%. This means that half of the power is absorbed between the surface of the rubber and the penetration depth or, that at distances greater than twice the penetration depth, the power of the wave is negligible.
Table III illustrates the penetration depth in centimeters of various materials at the microwave frequency of 2450MHz and at a starting temperature of about 25 degree Celsius. As microwave receptivity decreases, penetration depth increases. The more receptive the material, the more rapidly it will absorb the energy thereby attenuating the penetration



Energy Conversion Offers High Speeds

Microwave Heating Is *Energy* Conversion Not Oven Heating



An extremely important concept to appreciate in the microwave process is that microwave heating is energy conversion and not oven heating. This requires a reorientation of conventional processing thinking. People tend to consider ovens as having heat and that material is put into a hot oven. This is not the case in the microwave process. Here, the rubber is put into a microwave field and the rubber converts the energy from this field into heat within itself as stated earlier. This is illustrated in Figure 7 where the oven delivers a constant amount of power.

In this example, 1000 watts raises the one pound preform to 100 degree Celsius in one minute. Taking the same oven, remove the heated preform and insert two identical room temperature preforms of the same configuration and weight as the first example, and turn on the 1000 watt oven. Both preforms must now share the available energy, each receiving half of the thousand watts, namely, 500 watts each, and it will, therefore, take two minutes for them to reach 100 degree Celsius in the same oven. Theoretically, therefore, doubling the load, doubles the time if the power remains fixed. To remain at the original one minute time with double the load would require doubling the microwave power.

Applications Of Microwave In The Rubber Industry

Continuous Vulcanization Line

Microwave continuous vulcanization ovens the type shown in picture have the ability to continuously vulcanize extruded rubber weather stripping and similar mechanical goods at extremely high speeds and with high quality results. The microwave oven provides the temperature rise from the extruder up to cure temperature and a hot air oven or ovens set at the cure temperature downstream of the microwave oven provides the necessary residence time at that temperature to complete the cure.

In the case of sponge or multiple durometer extrusions with a sponge component, the microwave is usually preceded by an infrared or hot air tunnel whose purpose is to put an attractive skin on the sponge prior to its being blown in the microwave oven. Hot air or infrared technologies are used since shallow penetration only to the surface of the extrusion is necessary to achieve this skin. Picture shows an 19 meter long system includes microwave full round pre-heat tunnel followed by the infrared tunnel for curing which is then followed by the water cooling system.

KERONE

Bale Pre-Heating System

Bales of natural rubber especially, and many synthetic rubbers benefit from storage in a 'Hot Room' prior to being prepared for the mixing department. Natural rubber in particular arrives in factories in a 'Frozen (hard) state due to crystallization and will require few days storage in warm condition so that damage does not occur to the mixer from the hard rubber charge. Crystallization occurs very rapidly at temperature as low as -26°C but the rate between 0 to 10°C is still appreciable.

Microwave energy is used in the mixing room to rapidly pre-heat bales of natural rubber prior to mixing. Conventional heated tempering rooms are not necessary since frozen rubber blocks can be promptly tempered for processing as a result of microwave pre-heating. Picture shows a conveyorized microwave tunnel pre-heater which pass rubber bales through belt conveyor. This conveyorized bale pre-heater can tempers 1.5Ton of rubber per hour. The system can be synchronized with mixer to automatically dump the heated bales in mixer.

Microwave Solid Tyre Preheating System Prior to Moulding

Preheating is the process that is performed on rubbers before moulding and vulcanization, the preheated rubber has lower inner tension hence the process becomes more fluent, the time required for the processing is reduced. Pre-heated rubber reduces the curing time and allows the rubber to flow easily and fill the mold cavity efficiently. This system can process tires of weight around 10-350kgs. Pre-heating reduces the vulcanization time by approximately 40%. Ou microwave based heating solutions are designed to adhere to the client's requirement. Microwave pre-heating systems can be designed for a continuous line or a batch type oven according to product and process requirements.

Batch Microwave System for Preheating Sheets and Preforms

Preheating is the procedure that is performed on rubber products before trim and vulcanization, the preheated rubber preforms and sheets has brought down inward pressure subsequently the procedure turns out to be progressively familiar; the time required for the processing is decreased. Pre-heated rubber lessens the relieving time and enables the rubber to stream effectively and fill the mold cavity productively. Pre-warming lessens the vulcanization time by roughly 40%. Our microwave based warming arrangements are intended to adhere to the customer's prerequisite. Microwave pre-warming frameworks can be intended for a ceaseless line or a batch type oven, for which Kerone furnishes the most required assistance and solution with economy of scale.

Microwave Boost

An application that is increasing in popularity is the insertion of a short, continuous microwave tunnel in an existing conventional and hot air, salt bath or ballotini line. The microwave boosts the temperature of the rubber when it comes out of the extruder thereby permitting the line to run at speeds 25-40% higher with complete cure. Picture shows a microwave boosters which is only 5 meters long, yet powerful enough to provide a uniform and significant temperature rise. It can be easily synchronized with existing system also to increase the productivity.

KERONE

The Results: Gains in Quality, Productivity, and Safety

- A more desirable product.

Now, supplies rubber to customer-specified lengths and tight tolerances. For instance, items like high-pressure gaskets are less likely to fail if they have not been spliced.

- Increased flexibility.

Microwaves cure diverse shapes at uniform rate, so manufactures a greater variety of products.

- Elimination of steps.

Lubrication and manual handling of the product are virtually eliminated. Workers no longer cu rubber and load and unload pans and autoclaves.

- Safer work environment.

The hazards associated with steam curing have been eliminated. Injuries, mainly due to workers cutting their hands during slicing operations, have decreased.

- Less floor space.

The straight 115foot production line requires 20% to 35% of the space occupied by a conventional line.

- Energy savings.

The microwave units have a working efficiency of about 50% versus 10% for steam produced by an oil-fired boiler, more than offsetting the higher cost of electricity.

- Reduced labour costs.

Less labour is required to handle the product. Labour costs have decreased from 14% to 9,5% of total unit product cost.

- Material savings.

Raw materials for the new formulations are slightly more expensive. But the fast cure cycle eliminated scrap from slumped or distorted product, resulting in material savings of 5%.

Operating Cost

Energy costs for microwave heating are comparable to those of conventional heating methods but may be offset by savings in other areas of production, such as increased production speeds or reduction in inventory.
Maintenance and labour costs are also roughly equivalent to those of conventional methods.
Magnetrons have an average lifetime of 5000 to 6000 hours. Replacement costs for a 2450-MHz magnetron range from approximately $150 for a 1 - kW tube to $3000 for a 6-kW tube.
Applications of microwave heating prove successful when at least some of the following parameters contribute to favorable process economics:

- A batch process can be converted to a continuous one.
- The finished product has high value.
- The microwave equipment functions only for the process steps for which it is best suited.
- Current plant space is minimal

Summery

Microwave technology offered many advantages as compared to traditional processes: direct heating of the rubber mass and not of the moulds, faster, more even and selective heating, higher performance, less energy consumption, better quality and reproducibility of the finished product, less energy leakage to the environment, cleaner, less space for the installation, easier maintenance, electronic operation and control, automation capacity and a more comfortable working environment.

Application of microwave energy has been shown to accelerate the heating and vulcanization process as compared to hot air. In the microwave/hot air continuous vulcanization process, it is important to raise the temperature of a profile to almost the vulcanization Temperature in the microwave tunnel so as to increase the efficiency of me process.

KERONE

Our Clients...

KERONE

Serving Across Borders…

KERONE

Thank you

Locate-Us

UNIT I

B/10,Marudhar Industrial Estate,
Goddev Fatak road, Bhayander(E),
Mumbai-401105 India

Phone : +91-22-28150612/13/14

UNIT II

Plot No. B-47, Addl.
MIDC Anandnagar, Ambernath (East),
Dist. Thane- 421506 India

Phone : +91-251-2620542/43/44/45/46

EMAIL

info@kerone.com | sales@kerone.com |
unit2@kerone.com

WEBSITE

www.kerone.com | www.kerone.net |
www.keroneindia.com