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The Economics and Adaptation of Microwave Heating & Cooling

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THE ECONOMICS AND ADAPTATION OF MICROWAVE HEATING & COOLING

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Abstract

From cooking potatoes to medical surgery, the microwave is causing an interesting and beneficial transition in our daily lives. High technology is producing an avalanche of microwave appliances and equipment which offer favorable results in energy conservation with impressive safety parameters at competitive costs. This paper examines the basis for the comparative economic benefit from microwave applications and sights several commercial and industrial avenues of conservation metit.

Introduction

Since mid 1972, exorbitant claims of microwave equipment producers suggesting that up to 600% cuts in energy use over conventional methods have warranted a number of investigations into the subject. (1) Beyond the microwave oven and the examples of energy conservation in the culinary arts, how many other applications can be found for other every day thermal needs? The most common frequency adapted by this young industry is 2450 MHz with a corresponding wave length of 12.4 cm. There is another frequency used by the industry for special special application at a considerably higher power level of 915 MHz. The low frequency equipment is also three times more expensive per Kw than the FCC approved higher frequency. The FCC has designated these two frequencies for microwave thermal applications. The new U.S. Military Microwave Bands palce the 2450 MHz within the newly designated microwave "E" Band considerably below most of those bands used for Radar and microwave communications. (2)

Energy Economics of Microwave Thermal Generation

Let us begin with the first figure and an explanation of the physical property comparison between electric resistance heating and microwave heating in the preparation of food stuffs appropriately entitled, "The Tale of Two Baked Potatoes". (See Figure 1: The Tale of Two Potatoes)

Figure 1 comments:

After numerous runs of side by side comparison of cooking potatoes in an electric resistant heat oven and a microwave oven (and many meals of baked potatoes) several facts emerge:

1) The raw starchy material of the potato is converted from a thermal insulator to a thermal conductor, and only the microwave can produce this physical property conversion within the chemical changes of cooking the potato.

2) The thermal conductivity of a three dimensional object is related to a thermal front which moves through the object based upon the thermal insolation properties of the target material. In the case of the baked potato in the resistance oven, this front moves inwardly toward the center of the potato at a rate found to be 3 cm/hr. In the case of the microwave cooked potato, this thermal front moves outwardly from the center of the potato to the outside surface at an average rate found to be 12 cm/hr. This represents a rate of change within the potato 4 times faster using the microwave than the RH oven.

3) It was determined by the use of a portable standard watt-hour meter that the amount of energy required to bake a potato (batch of 4) in a resistance heat oven set at 400°F is 3406 BTU/potato. The amount of energy required to cook a comparably sized potato in a microwave oven (batch of 4) is 277 BTU/potato. This means that you can cycle 12 potatoes through the microwave oven for nearly

FIGURE 1 THE TALE OF TWO BAKED POTATOES
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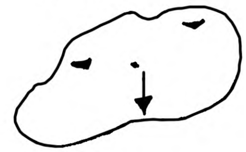
RESISTANCE HEAT OVEN		MICROWAVE OVEN
KW RATING	4.0 KW	1.12 KW
TIME & TEMP	1HR @ 400°F	15 MIN. @ ?
KWH:	4.0	0.280



THERM FRONT VEL:	3CM/HR	12CM/HR
THERM EFF:	10.5 BTU/°F	0.86 BTU/°F
	3406 BTU/POTATO	277 BTU/POTATO

CONV. 3413 BTU/KWH

FIGURE 2 CHARACTERISTICS OF MICROWAVES
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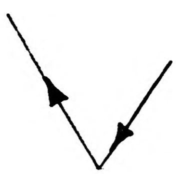
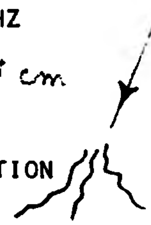
2450 MHZ
$\lambda = 12.4$ cm



REFLECTANCE

ALL SMOOTH METAL SURFACES



ABSORPTION

SOLIDS
- CARBON
- WOOD
- METAL CERAMICS

LIQUIDS
- PLANT LIPIDS
- WATER & SEAWATER
- DIESTER OILS

GASES
- METAL HALIDES
- SODIUM VAPOR
- MERCURY VAPOR

TRANSPARENCY

- PLASTICS
- EPOXY RESINS
  - FIBREGLASS
- NON LEADED GLASS
- AIR
- CERAMICS

the same energy that is required for each potato cycled through the RH oven. There is also a side benefit of less than one third of the Kw demand is needed for the MW oven over the RH oven to accomplish the same thermal task in this intance of baking potatoes. The energy conversion factor is 3413 BTU/kWh.

There are three fundamental properties of microwave which qualify a material for thermal applications; reflectance, absorption and transparency. The term "lossy material" is used commonly in the industry to describe the specific ability of the material or medium to disperse the microwave by conductivity in mhos/meter. (3) But the term or the function does not describe the thermal changes which occur in different materials exposed to microwave energy. A brief study was conducted by the Missouri Energy League this past summer to attempt classification of target materials based upon the thermal characteristics of microwave absorption in solids, liquids and gases. (See Figure 2: Characteristics of Microwaves)

Figure 2 comments:

1) Carbon materials such as arc rods can be arranged to absorb MW energy to the point that enough heat is generated from the target pile to heat steel to nearly its melt point. Extended experiments were discontinued because obvious safety and fire hazards evolve quickly with open waveguide sample runs.

2) Wood samples warm slowly. Oak wood for example is more dense than pine wood and reaches a higher temperature due to MW absorption. The temperature data is inconclusive because some wood samples of the same wood type, but different shapes, had unexplained variations in readings.

3) Crystalline minerals and metal ceramics seem to be in a class by themselves. Leaded glass temperatures are governed by the thickness fo the glass, the shape of the target and the sample's orientation to the direction of the oncoming microwave irradiation.

4) All smooth surfaced metals tested reflect MW energy at RT. Mercury, which is a liquid at room temperature, both reflects and absorbs MW energy very nearly on a 50/50 basis. The Mercury heats to a point until streaks of electrical flashes on the surface give off bursts of light indicating a phase change of this material to a vapor which is toxic.

5) Plant lipids or vegetable oils (soybean oil, safflower oil and sunflower oil) make interesting MW target materials. Temperatures not exceeding 400°F can be easily obtained and controlled. This is discussed further with Figure 3.

6) While water is a good absorber of MW energy, once boiling the steam is transparent. Actual seawater boils below 212°F due to the 35,000ppm of dissolved salts in an aqueous medium when exposed to MW energy. Foaming of hot brine is a problem in attempting to extract the steam for condensation to drinking water.

7) Diester oils, used as synthetic oil lubricants, begin to decompose over 370°F when exposed to MW energy.

8) Arc tube gases, such as sodium and mercury vapors, ioize to produce visible light with a by-product of RF pulses.

In a more detailed view of microwave liquid target materials, two fundamental properties are related; liquids classified as absorbers, which are electrically conductive at room temperature will continue to absorb MW energy until thermally destroyed or until phase change occurs. Liquids which are electrical insulators or high dielectrics, will absorb MW energy only up to a limit, then the material becomes nearly 100% transparent to MW energy. Increasing the power density of the MW input will not increase the target temperature any higher. Decreasing the power density by 20% does not lower the temperature, but maintains it at the same level. If the material is cooled by an outside source, then it begins to absorb and heat to the pass-through temperature. Vegetable oils have such a property.

(See Figure 3: Microwave Absorption Properties)

Figure 3 comments:

1) Its a though a molecular thermostat exists to control the material's ability to absorb and pass-through MW energy without affecting the chemical structure of these long chain glyceryl hydrocarbons. You cannot overheat Crisco with microwave, but with diester oil, the microwave will take the temperature to the fire point or a point of thermal decomposition.

2) Petroleum oils and lubricants are at least 90% transparent to MW energy at 2450 MHz. Gasoline and other combustible fuels were not tested for MW absorption.

From the same source of microwave energy, namely the Magnetron tube and its power control circuit on single phase 110VAC, temp-

FIGURE 3 MW ABSORPTION PROPERTIES

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TARGET MEDIUM

INT	HVO (CRISCO)	WATER	CARBON	HPS
	RT	RT	RT	RT
1'	126°F	98°F	380°F	IONIZES TO VISIBLE LIGHT
2'	168°F	124°F	460°F	
3'	214°F	164°F	500°F +	
4'	254°F	200°F	-	
5'	285°F	BOILING	-	
6'	306°F	-	-	
7'	328°F	-	-	
8'	346°F	-	-	
9'	352°F	-	-	
10'	362°F	-	-	
11'	368°F	-	-	
12'	372°F	-	-	
13'	375°F	-	-	
14'	374°F	-	-	
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$$\text{MW } AC_F = 1/TC_f$$

Whereby, in a target medium: AC_f = Microwave energy absorption coefficient

TC_f = Microwave energy transparency coeff.

eratures as high as 2500°F to as low as -125°F can be obtained by changing the wave guide, the reflectance chamber, the target material and the target loop. Most of the components are relatively easy to obtain at the latest cost of \$650/Kw_e. (See Safety Warning on this page)

Chilling equipment uses the Freon absorption method with a closed loop which is not exposed directly to MW energy. The Freon is heated in a special way by means of a hot oil heat exchange which is a part of the MW target cell. High side pressures to 350PSI can be obtained. A liquid injection pump replaces the customary electromechanical compressor, thus greatly reducing the noise required for refrigeration. Some petroleum gases can also work with such a system. Energy conservation data indicates that 30% savings can be realized in most cases using microwave over contemporary methods of chilling. The following table is the first attempt to estimate the cost of a wide spectrum of microwave user equipment possibilities. (See Figure 4: Estimate of Microwave Equipment Costs)

Conclusions

In looking at Figure 4, while capital costs for such equipment run considerably higher in some cases over conventional technology, MW equipment does not require natural gas or imported oil for its source of energy. Energy savings in trimed kilowatt-hours are expected to run 20 to 35% for cost reduction per mmBTU produced for either heating or cooling with microwave technology. Electric energy generated from renewable resources deems microwave technology as our best means of energy conservation over a wide replete of energy user applications. The best of both worlds, the soft path and the hard path, are brought together with the microwave to form reliable energy systems which optimize jobs, safety and dollar generation in our present world where change is synonymous with survival. Thank you.

Selected References

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3. Ibid, p. 37.

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Safety Warning

Microwave energy technology in the hands of untrained personnel is dangerous. Microwave leakage and exposure to high voltage discharges produced from open microwave components can cause permanent injuries and burns to amature experimenters. Microwave experiments of the kind given above should be conducted by trained technical people.

FIGURE 4 ESTIMATE OF MICROWAVE ADAPTATION COST

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