

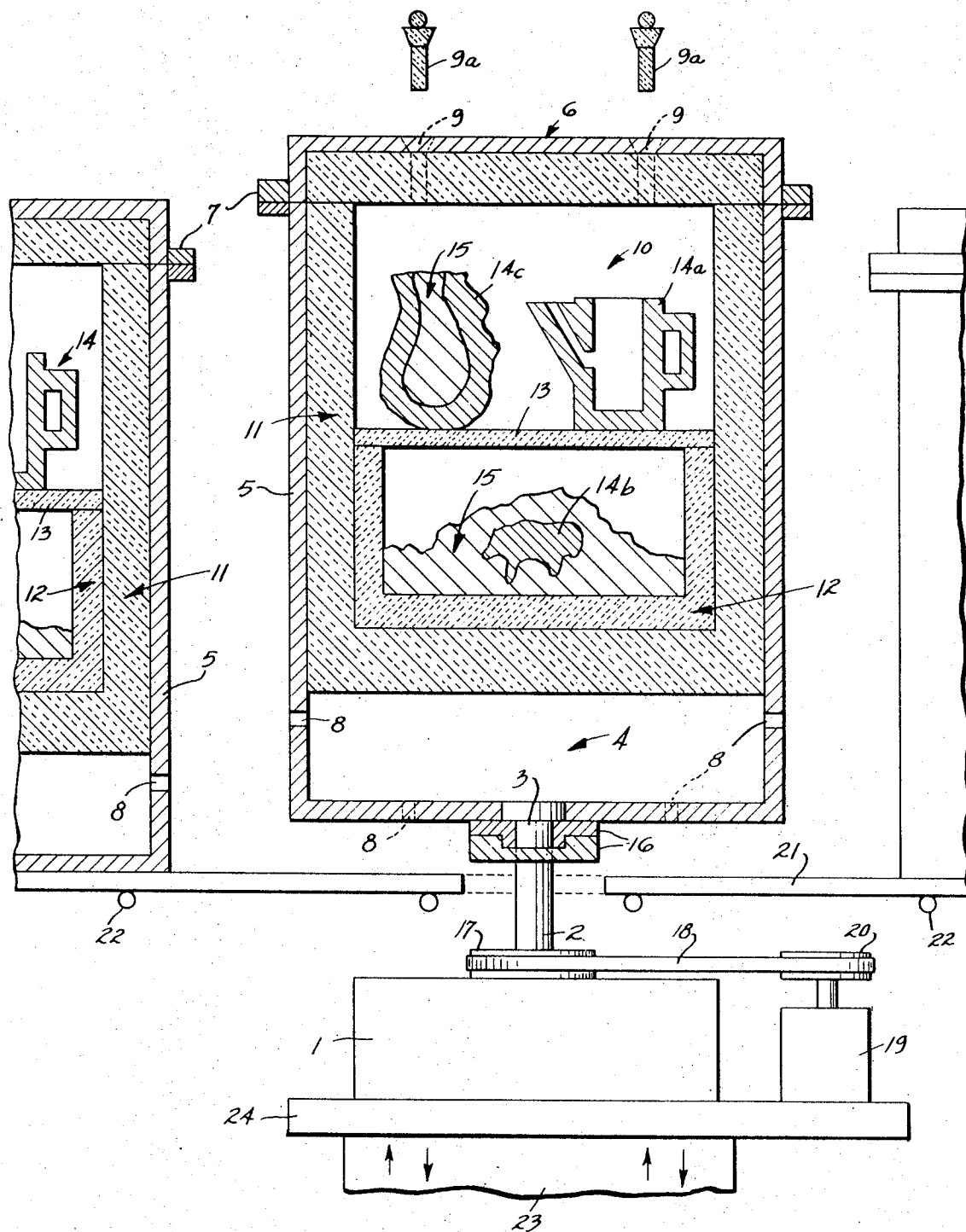
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M. L. LEVINSON

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METHOD OF FIRING CERAMIC ARTICLES UTILIZING MICROWAVE ENERGY

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INVENTOR
MELVIN L. LEVINSON

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ATTORNEY

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METHOD OF FIRING CERAMIC ARTICLES UTILIZING MICROWAVE ENERGY

Melvin L. Levinson, 1 Meinzer St., Avenel, N.J. 07001
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8 Claims

ABSTRACT OF THE DISCLOSURE

A process for firing ceramic articles in which the articles are fed into a microwave cavity wherein a plurality of particles of resistive materials are located in a predetermined fixed relationship with respect to the articles. Microwave energy is emitted to the particles so as to generate a multitude of arcs therethrough to thereby convert said microwave energy into a high refractory heat energy for firing the articles.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a division of application Ser. No. 497,851, filed Oct. 19, 1965.

BRIEF DESCRIPTION

In my previous invention copending application No. 470,809, "A Heating and Loading Implement for Devices Employing Microwave Energy Radiated into a Closed Cavity," filed July 9, 1965, now abandoned and replaced by my continuation-in-part application, U.S. Ser. No. 704,389, filed Feb. 9, 1968. I described how intense heat in excess of 2000 degrees F. is possible in a microwave powered oven. One object of this invention is to further describe methods to generate and control this heat. Another object of this invention is to create an electronic kiln, a new versatile tool. One example of the use of this kiln is to couple microwave generated intense heat capable of firing ceramic with the known extremely useful, penetrating and speed drying power that microwave energy has on wet clay.

My previous invention described how a useful implement could be made of an electrical insulating material and a material which converts microwave energy into heat energy. I indicated how by selecting the material, varying the power of the microwave energy, and/or the time, I could vary my results. This means that in my implement there is heat available for a self warming dish on one hand, and an electronic furnace on the other. I achieve the intense heat readily thru controlled arcing brought about by dividing suitable material. I divide solid electrical conducting material and pile it as one might coal or charcoal and suitably insulate it and subject it to microwave energy. I find no established microwave theory to explain this easily achieved, readily available, intense heat.

My personal understanding is as follows:

(1) The "coals" of a good conductor, as copper, apparently short to one another so presenting a seemingly solid electrical surface and causing erratic unsatisfactory results.

(2) With "coals" of electrical carbon, there seems little heat generated by the electrical carbon itself, but the "coals" support profuse arcing and an immediate release of heat energy. Large pieces of electrical carbon support large arcs difficult to control. Small pieces of divided electrical carbon support a multitude of small arcs which release heat readily and are simpler to control. This crushed carbon is quite satisfactory.

(3) "Coals" of iron arc and turn red hot hot swiftly.

(4) "Coals" of simple electrical iron compounds, such as magnetite or iron ores, inherently are resistive and are easy to use. My experience with using unrefined iron ore has revealed some anticipated erratic results. These result from the impurities in the ore, e.g., magnesium burns explosively bright, etc. Still, such erratic results may be minimized by exposure of the divided ore in special pre-conditioning microwave ovens, or by other accepted ways of removing the impurities. These "impurities" can be used to an advantage. The ceramic artisan can add selected chemicals which ignite during the high firing temperatures to add their heat or to chemically affect the object being fired.

(5) I have expressed a preference for the type ferrite found in common radio antennas. I find this ferrite material easily available, of a uniform refined nature, and easily broken into "coals." The DC resistance is high, the high resistance adds I²R losses; the magnetic properties higher hysteresis losses. Ferrite is capable in itself of converting microwave energy into stored and dissipated heat energy, my controlled arcing adds to this. With the cessation of the applied microwave energy the ferrite gives up its stored heat to the object to be heated. The slow decay of this stored heat is important in many processes of this invention and my previous invention. The ferrite also provides for a slow build up of heat and, accordingly, does not set up as destructive heat strains in the containers as would similar size carbon "coals."

The slow build up and decay of the heat is directly proportion to the amount of material used.

Crushed material presents a random confusion of molecular directions. I feel this contributes to the noticeable lack of the Curie effect found in a comparable mass of an undivided piece. Also, it is possible that the hundreds of tiny arcs generated in my invention are hundreds of old fashioned arc transmitters giving up heat as they re-radiate microwave energy. The DC resistance goes up as the same amount of material is more finely divided. By selecting the size and type of divided material the designer has a measure of control of the size and number of the arcs.

In my previous invention I confined the microwave energy to heat energy converting material in a good electrical insulator, preferably Pyrocera, manufactured by Corning Glass Works, Corning, N.Y., and placed the load or object to be heated in juxtaposition therewith.

This invention differs from this previously invented implement as follows:

The implement is expanded radically to form a cavity surrounded by a high heat insulating material to conserve the amount of microwave energy needed. Means are provided for the ingress and egress of the object to be heated.

Inside and/or around the object to be heated is placed the divided material which converts microwave energy to heat energy.

The undivided ferrite, special glass, ceramic of certain composition, and similar microwave to heat converting materials, and/or my "Heat Equalizing and Directing Means for Heating Implements Used in Microwave Devices," copending application No. 483,144, filed August 23, 1965 now abandoned and replaced by my aforementioned continuation-in-part application, Ser. No. 704,389, filed Feb. 9, 1968, could well be used to make this invented kiln more versatile. For the divided carbon a high resistance shield, e.g., one made of undivided ferrite, might be indicated, or low resistance shield, as copper, may be completely buried in carbon and heated at relatively low temperature levels.

The amount of useful, available heat generated is a result of the output power of the microwave generator, the time it is applied and the amount of heat insulation. The more microwave energy to heat energy converting material that is used the less chance there is of large unwanted arcs occurring. A paltry amount of heat converting material is contraindicated. The more material used the more even the heat distribution and the less energy available for individual arcs. The microwave kiln should have more energy converting material for a given amount of microwave output power then would be useful in my previous discussed implements. For in a kiln the object to be heated generally absorbs little microwave energy, and the heat converting material must properly load the microwave generator.

The accompanying diagram is a composite of my invented microwave kiln showing the salient features of three, soon to be described methods.

In said diagrams:

A microwave generator 1 couples its energy through a matched waveguide 2, through a microwave access 3, into a microwave oven cavity 4. The outer confining microwave impervious walls 5 of the microwave kiln surround the oven cavity 4. An access opening door 6 is provided in the outer oven wall 5 to the kiln cavity 10. Seals 7 are provided for the access opening door 6 in the oven wall 5 to prevent the escape of microwave energy and to minimize arcing. Optionally vents 8 provide a buffer of circulating air, between the intense heat of the kiln cavity 10, and the microwave generator 1. Optional openings 9 may be placed anywhere on the circumference of the active microwave kiln if the heat insulation is porous or partially porous to water vapor, and said openings may serve as kiln peekholes. Optionally a plug or plugs 9a are provided, which when removed temporarily, would permit the escape of water vapor. 9 could also represent a commonly found kiln peekhole. Both openings 8 and 9 are made such to negate the escape of microwave energy. The working kiln cavity 10 is the active part of the oven cavity 4. Heat insulating material 11 confines and allows a build-up of heat in the kiln cavity 10. On option, a protective material 12 may be used which is capable of withstanding higher localized heat than the material 11 although it doesn't necessarily provide the high heat insulation of material 11. Means 13 are provided to keep the outside of the object to be heated physically away from the intense heat of the microwave energy to heat energy converting material 15, as hereinbefore discussed. Three different objects 14a, 14b and 14c, may be heated in three different ways to accomplish this heating as follows:

(a) The microwave energy to heat energy converting material 15 is shown resting in its protective holder 12 and may be used to heat 14a.

(b) Converting material 15 is used for burying object 14b to be heated.

(c) Converting material 15 is used for filling a selected part of the inside of another one of the objects, 14c.

I envision three methods of using my microwave kiln configuration as follows:

(1) The first method is to take the insulating wall 11, which surrounds the kiln cavity 10 and its contents and use them directly within an existing microwave oven.

(2) Place a microwave impervious outer confining wall 5 and access opening door 6 is placed around the insulating wall 11, which surrounds the kiln cavity 10 and its contents. Into this outer wall 5, through a microwave access opening 3, is matched the output of a microwave generator 1.

(3) A dependent kiln is made of a microwave impervious outer wall 5, with an access opening door 6 which surrounds an insulating wall 11, that surrounds the kiln cavity 10 and its contents. Into the outer wall 5, is placed a standardized microwave coupling access opening 3. A number of such dependent microwave kilns, on pro-

gram can mate in turn with the matching standardized output coupling 16 of the master microwave generator 1. A great number of inexpensive microwave kilns can be conveyed to an expensive microwave generator, fired, then conveyed away and allowed to slowly cool. Conversely, the master microwave generator can move from one stationary dependent kiln to another.

I will now describe the parts illustrated to make a microwave kiln conveyor type operation as just described. A movable wave guide coupling 16 is provided to mate with the microwave access 3 on the end of waveguide 2. Between the microwave generator 1, and attached to waveguide 2, is placed a powered rotating coupling 17, which when it rotates moves waveguide 2, coupling 16 and the total microwave kiln in relation to the stationary microwave generator. This in effect stirs the microwave energy and evenly distributes it through the microwave kiln. Means 18, such as an endless belt, are provided to couple the moving output of a motor 19, through the motor's output gears 20. A conveyor belt 21, movable along support 22, is provided for the movement of the kilns to waveguide 2. Conventional means 23 are used to raise and lower a platform 24, which holds the master microwave generator and motor 19 assembly, to engage and rotate the described, dependent microwave kilns on program. If desired the kilns could be made stationary and the master microwave generator rotated. Of course, a conventional field stirrer could be used.

A knowledge of microwave ovens with their common accessories as field stirrers, exhaust fans, chokes, handles, et al., coupled to a working knowledge of a ceramic kiln and its construction, is presumed. Microwave energy is very efficient for drying wet clay, still caution is advised as the ceramic artisan must chart new firing schedules to prevent unwanted damage since temperatures in excess of 3000° C. are possible. A magnetron whose output is adjustable is favored. A knowledge of microwave's effect on different types of clay also must be taken into consideration when utilizing this apparatus. For instance, if the clay has a certain iron content, it will be self heating as compared to clay which has no iron content.

My microwave kiln is different in some ways than existing kilns. New skills must be acquired to capitalize on its advantages. This is evident from my diagram, where I illustrated how it is possible to fill the inside of the object 14c to be heated with microwave energy to heat energy material 15, as inexpensive divided iron ore, divided carbon etc. Here one truly heats the object from the inside out, with the optional advantage of permanently leaving this inexpensive heating material 15 in the object to be fired. This energy converting material can be formed and moved around anywhere in working cavity 10, and so can provide spot heating or even heating since the object to be heated can be buried in this energy converting material. In fact, I see no reason why for certain brick work and special effects the kiln cavity could not be filled completely with this divided heat converting material 15. The material is porous and does not hinder the escape of water vapor. Different divided heat converting material can usefully be used simultaneously in the same kiln. One novel use might be to build the microwave energy to heat energy converting material 15 inside the object to be heated, then cover, paint, spray, or dip the whole thing with an inexpensive porous heat insulating material. Dry and fire the object in one continuous operation, cool and ship. The ultimate consumer can remove the inexpensive, heat insulating material 15 now doubling as packing material to use the protected fired object. I expect that some may desire to supplement the microwave heat with conventional common electrical or combustion type heats with no great difficulty.

I use the word kiln in its broadest meaning encompassing lehr refractory.

With the foregoing and other objects in view, the invention resides in the novel arrangement and combination of

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parts and in the details of construction here described and claimed, it being understood that changes in the precise embodiment of the invention here described and claimed, it being understood that changes in the precise embodiment of the invention here disclosed may be made within the scope of what is claimed without departing from the spirit of the invention.

I claim:

1. A process for heating an article which comprises: feeding said article into a microwave cavity, locating a plurality of loose or divided particles of resistive material selected from the group consisting essentially of ferrites, iron, iron ore, and carbon in a predetermined fixed relationship with respect to said article, and emitting microwave energy to the plurality of particles so as to generate a multitude of arcs therethrough and thereby convert said microwave energy into heat energy for heating the article.
2. A process, according to claim 1, wherein the plurality of particles are located within the internal walls of the articles.
3. A process, according to claim 1, wherein the article is submerged in the plurality of particles during passage through the cavity.
4. A process, according to claim 1, wherein the article is adjacently disposed with respect to the plurality of particles during passage through the cavity.
5. The process according to claim 1 wherein the resistive material consists essentially of magnetite iron ore.
6. A method of firing a ceramic article by microwave energy at a firing temperature higher than available from the exposure of said articles to said microwave energy which comprises:
 - locating said article in such a position as to subject it to said microwave energy,
 - locating a plurality of loose or divided particles of a

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lossy material selected from the group consisting essentially of ferrites, iron, iron ore, and carbon in a predetermined fixed relationship with said article, which will on exposure to microwave energy, provide the required firing temperature to fire said article, emitting microwave energy to said material to generate a multitude of arcs therethrough thereby generating high refractory heat energy for firing said article.

7. A method of firing a ceramic article, according to claim 6, which includes the step of: containing both the lossy material and the article in a heat insulating material before firing.
8. The process according to claim 6 wherein the resistive material consists essentially of magnetite iron ore.

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JULIUS FROME, Primary Examiner

J. H. MILLER, Assistant Examiner

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