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MICROWAVE HEATING APPLICATOR

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ABSTRACT OF THE DISCLOSURE

The applicator is a microwave heating apparatus having a circular multimode waveguide capable of propagating electromagnetic fields of different mode patterns coupled thereto from an excited rectangular multimode cavity resonator. The multimode waveguide includes two axially spaced apart, open ended sections on the order of 3λ long. The waveguide sections extend perpendicularly from coupling holes at the center of opposite sides of the rectangular cavity resonator. A vaned mode stirrer having a plurality of vanes circumferentially spaced about the coupling holes to radially extend into the cavity resonator is rotatably mounted between the long sides of the cavity resonator. The vaned mode stirrer is rotated to periodically change the mode pattern within the cavity resonator and preferentially couple and rotate TE modes in the multimode waveguide sections whereby a work piece is uniformly heated as it is advanced through the open ended waveguide sections.

BACKGROUND OF INVENTION

The present invention relates to apparatus for heating materials by high frequency electromagnetic fields. More particularly, it relates to such an apparatus which is able to uniformly heat a continuously moving work piece.

Microwave heating of materials with high frequency electromagnetic fields is a common and, in certain instances, the best suited method of heating materials. However, for several reasons, the practical utility of microwave heating techniques has been severely limited, particularly with respect to industrial applications. For example, often it is desired to uniformly heat a work piece of relatively large dimensions, i.e., a work piece having a dimension on the order of λ , the free space wavelength of the applied energy. Generally, it has been the practice to place such work pieces in excited cavity resonators or waveguides. Normally, the standing wave pattern produced in such devices includes localized regions of maximum and minimum electric field intensity separated by distances equal to $\lambda/4$. Unfortunately, in heating such relatively large work pieces, portions thereof located in the vicinity of maximum electric field intensity will be heated to a substantially greater extent than those portions located in the vicinity of minimum electric field intensity. This results in hot-spots being created in the work piece at locations separated by distances of $\lambda/2$, hence, non-uniform heating of the work piece.

To eliminate the effect of field distribution on heating, it has become the practice to provide multimode cavity resonator applicators. The total heat energy available to all portions of the cavity resonator is made more uniform by periodically changing the field distribution, hence, the mode pattern established therein. Various techniques have been proposed for accomplishing such shifting of the electromagnetic field distribution. Some of the more common techniques proposed have been modulating the frequency of the signal generated to excite the cavity resonator, mechanically changing the volume of the cavity resonator by moving a deformable wall of the resonator or

a diaphragm located therein, and revolving a fan-type structure to change the electrical space seen by the electromagnetic field. Although such applicators have been satisfactory for certain heating applications, they have been inadequate in many instances, particularly, in those cases where it is desired to heat a continuously moving work piece, in those cases where heating is done in large volume applicators, and in those cases where heating is conducted at high power levels, e.g., at 20 kw.

In order to heat a continuously moving work piece, it is necessary to provide the applicator with openings to allow the work piece to be passed through the applicator. By providing openings in a cavity resonator applicator, electromagnetic energy can escape from the applicator to be lost to the surroundings. Because of this energy loss, such applicators are characterized by poor efficiency. Furthermore, at high power levels, such escaping electromagnetic fields can be hazardous to personnel and can cause radio-frequency interference.

In addition to the foregoing disadvantages characteristic of most prior art applicators, those applicators including a rotating fan or moveable diaphragm mode stirrer are characterized by other disadvantages which severely limit their field of use, particularly, at high power levels. In such applicators, the mode stirrer is set into motion by a motor located external of the cavity resonator. The motor drive is coupled to the fan mode stirrer through the walls of the cavity resonator by suitable coupling means. The coupling means allows electromagnetic energy to escape from the cavity resonator to be lost to the surroundings. Furthermore, at high power levels, arcing occurs between the moving and stationary parts of the coupling means. If the heating is to be conducted in a contamination free environment, such arcing can not be tolerated. This is because arcing will cause the parts between which it occurs to sputter material and also can injure the material being treated. Of course, this sputtered material contaminates the environment of the cavity resonator, hence, the environment in which the heating is conducted.

SUMMARY OF THE INVENTION

The present invention is microwave heating applicator which overcomes the limitations and disadvantages of the prior art applicators. More particularly, the microwave heating applicator of the present invention includes a multimode cavity resonator arranged to excite a waveguide to propagate electromagnetic waves. Enhanced efficiency of operation is obtained by employing a multimode waveguide, i.e., a waveguide of a size capable of propagating electromagnetic waves of different mode patterns. The work piece to be heated is introduced into the waveguide. For heating a continuously moving work piece, an open ended waveguide having two axially spaced sections is used. The multimode cavity resonator is coupled to excite the multimode waveguide as the work piece is advanced through the waveguide.

Efficiency is optimized by employing a vaned mode stirrer to periodically change the field distribution, hence mode pattern, in the multimode cavity resonator and waveguide. The vaned mode stirrer comprises a plurality of circumferentially spaced outwardly extending vanes rotatably mounted within the cavity resonator. In one embodiment, the vaned mode stirrer is mounted between axially spaced sections with its vanes radially extending into the cavity resonator. When rotated, as for example, by a flow of hot air directed against the vanes, a periodic changing of the mode pattern is effected within the cavity resonator and waveguide, and TE modes are preferentially coupled and caused to rotate in the waveguide. By periodically changing the mode pattern, the uniformity

of the total heat energy available to all portions of the waveguide is enhanced. However, by simultaneously rotating the mode patterns established in the waveguide, particularly, when the waveguide is excited to propagate electromagnetic waves in the TE modes, the total heat energy available to all portions of the waveguide is made uniform.

Accordingly, it is an object of this invention to provide an applicator for uniformly heating a work piece by high frequency electromagnetic fields.

More particularly, it is an object of this invention to provide a microwave heating applicator capable of uniformly heating a continuously moving work piece.

It is a further object of this invention to provide a microwave heating applicator capable of uniformly heating a continuously moving work piece which minimizes the amount of electromagnetic energy escaping to its surroundings.

Another object of this invention is to provide a microwave heating applicator which supplies uniform total heat energy to all regions of the applicator which are intended for receiving work pieces.

Yet another object of this invention is to provide a microwave heating applicator suitable for uniformly heating work pieces having dimensions which are on the order of the free space wavelength of the applied energy.

Still a further object of this invention is to provide a microwave heating applicator for high power heating applications.

BRIEF DESCRIPTION OF DRAWING

The foregoing and other objects and advantages of the present invention will become more apparent from the following detailed description and appended claims considered together with the accompanying drawing in which:

FIGURE 1 is a perspective view of one embodiment of the applicator of the present invention.

FIGURE 2 is a front elevation cross-section view of the applicator of FIGURE 1.

FIGURE 3 is a cross-section of the vaned mode stirrer taken along lines 3—3 of FIGURE 2.

FIGURE 4 is a block diagram of a system for heat treating materials employing the applicator of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGURES 1 and 2, the microwave heating applicator of the present invention includes first and second axially spaced open-ended waveguides 11 and 12 of aluminum or other conductive material. Each waveguide has a cross-section in the plane normal to the direction of propagation of electromagnetic waves of a size sufficient to support a plurality of modes of propagation. Although various types of multimode waveguides can be used in the practice of the present invention, propagating electromagnetic waves in various mode patterns and uniform heating of a work piece passed through the multimode waveguides 11 and 12 is facilitated by using circular waveguides. The diameter of the circular multimode waveguide is selected to be greater than the dominant mode cutoff diameter, and preferably larger than λ . The length of each of the waveguides 11 and 12 is selected to insure efficient heating of the work piece passed therethrough, and to minimize the escape of electromagnetic energy to the surroundings. A length greater than $\frac{3}{4}\lambda$ and, preferably, of about 3λ , is satisfactory for common materials.

The multimode waveguides 11 and 12 are excited to propagate electromagnetic waves by a multimode cavity resonator 13 of aluminum or other conductive material. The size and configuration of the resonator 13 are selected so that a large number of different mode

patterns can be excited therein. In preferred practice, a rectangular cavity resonator is employed having side walls 14 and 16, end walls 17 and 18, top wall 19, and bottom wall 21 secured together, as by heliarc welding, to define enclosure 22. The height, width and depth dimensions of the enclosure 22 are made large compared to λ , for example, approximately $10\lambda \times 3\lambda \times 7\lambda$, and non-integral multiples of each other so as to maximize the number of different modes which can be excited therein.

The multimode waveguides 12 and 13 are secured to extend outward from the center of opposite resonator side walls 14 and 16. The rectangular configuration of the cavity resonator 13 insures the presence of an electromagnetic field at the coextending axes of the cavity resonator 13 and waveguides 11 and 12. Each of the resonator side walls 14 and 16 is provided with a circular aperture 23 at its center for communicating the cavity resonator 13 to the waveguides 11 and 12. In the preferred embodiment, the cavity resonator 13 and waveguides 11 and 12 are constructed of thin aluminum sheets $\frac{1}{8}$ inch thick. To ruggedly mount the waveguides 11 and 12 to cavity resonator 13, an aluminum disc 26, $\frac{3}{16}$ inch thick and 24 inches in diameter, is secured at each of the resonator side walls 14 and 16 by screws 27 which threadingly engage tapped holes in the side walls 14 and 16. Each aluminum disc 26 defines an aperture 28 in registry with the aperture 23 of the side wall to which the disc 26 is secured. Each pair of registered apertures 23 and 28 snugly receives one of the ends 31 and 32 of the open ended waveguides 11 and 12. The waveguide ends 31 and 32 serve as coupling holes communicating the waveguides 11 and 12 to enclosure 22. Each of the waveguides 11 and 12 are secured in place by four aluminum gussets 33, $\frac{1}{4}$ inch thick, 12 inches long and 8 inches high. The gussets are secured to the discs 26 and waveguides 11 and 12 by heliarc welding.

To provide ease of access to enclosure 22 in order to, for example, facilitate cleaning thereof, the end wall 17 is demountably fastened to the cavity resonator 13. As illustrated in FIGURE 1, end wall 17 is secured to the top, bottom and side walls of the cavity resonator 13 by screws 34 which threadingly engage the resonator walls to fasten the folded edge portion 36 of end wall 17 thereto.

The multimode cavity resonator 13 and waveguides 11 and 12 are excited by introducing electromagnetic energy into cavity resonator 13 at waveguide feed 37. To maximize the number of modes that can be excited in the cavity resonator 13, the waveguide feed 37 is positioned at least $\lambda/2$ from the adjoining walls and at an angle of, for example, 45° with the adjoining walls.

In order to accomplish uniform heating of a work piece passed through the multimode waveguides 11 and 12, mode stirring means 41 is provided to periodically change the electromagnetic field distribution in the multimode cavity resonator 13 and waveguides 11 and 12. Any of the various prior art techniques may be employed to accomplish the mode pattern changing. However, with reference to FIGURES 2 and 3, one embodiment of the microwave heating applicator of the present invention, preferably, employs a novel vaned mode stirrer 41 which serves both to change the field distribution and couple electromagnetic energy from the cavity resonator 13 to the multimode waveguides 11 and 12. More particularly, the vaned mode stirrer 41 comprises a plurality of circumferentially-spaced radially-extending generally-rectangular vanes 42-49 of 0.05 inch thick aluminum.

The vanes 42-49 are fastened at opposite ends thereof, for example, by heliarc welding, to axially spaced $\frac{1}{4}$ inch aluminum split rings 51 and 52 at regular circumferentially-spaced locations. The split ring halves are demountably fastened together by nuts 53 and bolts 54. The vaned mode stirrer 41 is rotatably mounted within

the cavity resonator 13 to extend between the resonator side walls 14 and 16 in axial alignment with the multimode waveguides 11 and 12. The inside diameter of the vaned mode stirrer 41 is adjusted to be equal to the diameter of the multimode circular waveguides 11 and 12.

To rotatably mount the vaned mode stirrer 41, opposite corners of each of the vanes 42-49 are provided with recesses 56 and 57 respectively along the inwardly facing edge 58 thereof. The outer surfaces of the ends 31 and 32 of waveguides 11 and 12 facing recesses 56 and 57 define circumferential recesses 61 and 62 opposite recesses 56 and 57. The vaned mode stirrer 41 is rotatably supported at the waveguide ends 31 and 32 by annular Teflon bushings 63 and 64 and are snugly seated in the recesses 56 and 57 to turn loosely in circumferential recesses 61 and 62. Teflon is a trademark designating tetrafluoroethylene fluorocarbon resins. To minimize arcing between the vaned mode stirrer 41 and waveguide ends 31 and 32 or cavity resonator 13, the vaned mode stirrer 41 is spaced from the waveguide ends and cavity resonator by at least $\lambda/4$.

To rotate the vaned mode stirrer 41, an inlet port 66 and air duct 60 are provided in the top wall 19 of the cavity resonator for coupling an air blower 65 (see FIGURE 4) to direct an air flow against the vaned mode stirrer 41. Other mechanical and electrical means can be employed to drive the vaned mode stirrer 41. However, such means require either mechanically coupling through the cavity resonator walls or through the waveguides. As noted hereinbefore, coupling through the cavity resonator walls creates arcing and energy loss problems, particularly at high power levels. On the other hand, coupling through the waveguides requires surrounding the work piece with a hollow drive shaft. The presence of such a drive shaft prevents any excess fluid that might be present from escaping the vicinity of the work piece whereas the open structure illustrated in the figures allows such fluid to escape. The air flow drive means has the additional advantages of ventilating the cavity resonator 13 and, if hot air is used, aiding in the heating process as the work piece is being treated.

In operation, as the vaned mode stirrer 41 is rotated by the hot air flow, the electromagnetic field distribution within the cavity resonator 13 and waveguides 11 and 12 is periodically changed. The periodic variation in the electromagnetic field distribution is controlled by the rate at which the vaned mode stirrer 41 is rotated and the extent of the changes in the electrical shape of the enclosure 22 created by the revolving vaned mode stirrer 41. The mode patterns coupled to the waveguides 11 and 12 are determined by the radial and longitudinal extent of the vanes and the chord distance between adjacent vanes of the vaned mode stirrer 41. By making the lengths of the vanes 42-49 greater than $\lambda/2$, the radial extent of the vanes becomes a less critical factor on coupling of electromagnetic energy from the resonator 13 to the waveguides 11 and 12. Furthermore, by employing vanes which have different radial extents, the electrical shape of the enclosure 22 as seen by the electromagnetic field established therein is made to assume a variety of forms. Hence, the number of mode patterns which can be created in the enclosure 22 is increased significantly above the number that would be possible with a vaned mode stirrer having vanes of uniform radial extent. In one embodiment, vanes 42 and 46 were $3/4\lambda$ long, vanes 43, 45, 47 and 49 were $7/8\lambda$ long, and vanes 44 and 48 λ long. Such a vaned mode stirrer produces a periodic variation in the mode pattern of two cycles per revolution of the vaned mode stirrer 41.

Besides causing a periodic variation in the mode pattern of the electromagnetic field established in enclosure 22, the vaned mode stirrer 41 further serves to couple electromagnetic energy to excite the waveguides 11 and 12 to propagate electromagnetic waves. Additionally, as

the vaned mode stirrer 41 is rotated, the electromagnetic wave pattern established within and between the waveguides 11 and 12 is caused to rotate. The period of revolution of the wave pattern is equal to the period of revolution of the mode stirrer 41 divided by number of cycles of variation in the lengths of the vanes comprising the vaned mode stirrer 41. To preferentially couple electromagnetic fields in the TE modes having non-circular electric field vectors transverse to the axes of the waveguides, the chord length between adjacent vanes of the vaned mode stirrer is made less than λ_c , the cutoff wavelength of the electromagnetic energy propagated between adjacent vanes. For the stirrer shown, the length is $\lambda/2$. By so constructing the vaned mode stirrer 41, those TE modes having circular electric field vectors and TM modes will not be excited through the space between the vanes.

To minimize the amount of electromagnetic energy escaping the waveguides 11 and 12, traps 69 and 71, for example, lossy wall waveguides, are mounted at each of the outer ends of the waveguides to absorb escaping radiation. Each of the lossy wall waveguides 69 and 71 includes an aluminum waveguide 72 enclosing a coiled hose 73 for carrying water. The coiled hose is retained within the waveguide 72 by end tabs 74. The hoses 73 of each of the lossy wall waveguides 69 and 71 are serially connected by connecting hose 76. A pump and reservoir (not shown) are connected between couplers 77 and 78 to circulate water through the serially connected hoses 73. The lossy wall waveguides 69 and 71 are fastened in place by supporting bars 79 secured to gussets 33 and supporting strap 81 secured to the cavity resonator 13. To further minimize the escape of electromagnetic energy from the applicator, the outer end 68 of the waveguide 12 and the outer end (not shown) of waveguide 11 respectively, extend into the adjacent lossy wall waveguides 71 and 69 a distance of $\lambda/4$. It has been found that under normal operating conditions with an input of 20 kw. of applied power to the cavity resonator 13, fifty feet of common garden hose coiled into a length of two feet reduced the energy escaping from the waveguides 11 and 12 to substantially below the level of 10 mw/cm², which level has come to be accepted as the standard for a non-hazardous condition.

Referring now to FIGURE 4, a microwave heating applicator constructed in accordance with FIGURES 1-3 was operated to cure a continuously moving epoxy impregnated fiber glass tube 82 having an outside diameter of 5 inches and a wall thickness of $3/8$ inch. The dimensions of the multimode cavity resonator 13 were 18 inches wide, 48 inches high and 48 inches long. Each of the multimode circular waveguides 11 and 12 were 16 inches long and had an inside diameter of 6 inches. A klystron source 83 energized by a power supply 84 and operated at 2450 mc. to deliver 20 kw. of power to the cavity resonator 13 was coupled by waveguide 86 to waveguide feed 37. To protect the klystron source 83 from damaging reflections, the klystron source 83 could be coupled to the cavity resonator 13 through a directional coupler 87. The directional coupler 87 would be coupled to a detector 88, e.g., a power meter, which responds to signals received therefrom to provide a signal to activate a relay 89 to de-energize the klystron source 83. Of the applied 20 kw. of input power, 17 kw. of power was coupled to heat the continuously moving work piece 82. Because the work piece 82 continuously absorbs energy as it advances through the waveguides 11 and 12 only 1 kw. of power was lost through each of their outer ends of waveguides 11 and 12 to be absorbed by the lossy wall waveguides 69 and 71. The vaned mode stirrer 41 was rotated at 16 revolutions per minute. In operation, it was found that the epoxy impregnated fiber glass tube 82 could be advanced at $1\frac{1}{2}$ feet per minute through the microwave heating applicator, and emerge therefrom completely cured. Hence, ninety feet of epoxy impregnated fiber tubing can be cured in one hour. If such materials are cured

by conventional conduction heating techniques, a curing time of one hour is required. Hence, to cure at the same rate as the particular apparatus of the present invention detailed above, a unit ten times the length of the apparatus of the present invention is required.

Besides microwave heating, the microwave heating applicator can be used to accomplish other types of microwave heating. For example, the applicator can be used to simultaneously dielectrically and inductively heat carbon, or if desired inductively heat conductors. However, the microwave heating applicator has been found to be particularly adept at dielectric heating of materials.

Although the present invention has been described in detail with reference to one particular embodiment for heating a continuously moving work piece, many modifications and variations are possible without departing from the scope of the invention. Most importantly, the microwave heating applicator could be employed to heat stationary work pieces positioned within the waveguides 11 and 12 and cavity resonator 13. In those instances, the outer ends 67 and 68 could be closed, for example, by a shorting piece or water load. Furthermore, a plurality multimode cavity resonator could be coupled to the waveguide in a staged fashion if it is necessary to extend the heating time. Such staged cavity resonators would be connected by waveguides sufficiently long, e.g., 3λ , to prevent coupling between the staged cavity resonators. Hence, the present invention is not intended to be limited except by the terms of the following claims.

What is claimed is:

1. A microwave heating applicator comprising at least one multimode cavity resonator adapted to receive electromagnetic energy from a source and excite non-propagating electromagnetic field patterns in said cavity, a multimode waveguide coupled to receive electromagnetic energy from said multimode cavity resonator and establish propagating electromagnetic field patterns therein, and mode stirrer means within said cavity resonator for changing the electromagnetic field distribution within said cavity resonator and preferentially coupling selected ones of said modes within said cavity to said multimode waveguide said mode stirrer means being a vaned mode stirrer including a plurality of circumferentially spaced conductive vanes extending radially outward from and along the axis of said stirrer with the distance between the most proximate parts of adjacent vanes being no greater than $\lambda c'$ the cutoff wavelength of the applied electromagnetic energy propagated between said adjacent vanes.

2. The applicator according to claim 1 wherein said multimode waveguide includes first and second axially-aligned waveguide sections, said waveguide sections coupled to said cavity resonator at opposite sides thereof.

3. A microwave heating applicator comprising at least one multimode cavity resonator adapted to receive electromagnetic energy from a source for exciting electromagnetic field patterns therein, a multimode waveguide coupled to receive electromagnetic energy from said multimode cavity resonator for establishing electromagnetic field patterns therein, and means for changing the electromagnetic field distribution within said cavity resonator, said multimode waveguide including first and second axially aligned waveguide sections, said waveguide sections coupled to said cavity resonator at opposite sides thereof, said means for changing the electromagnetic field distribution within said cavity resonator being a vaned mode stirrer including a plurality of circumferentially spaced conductive vanes extending outward from and along the axis of the vaned mode stirrer to define a space bounded by said vanes, said vaned mode stirrer being rotatably mounted within said cavity resonator to have said space bounded by said vanes in alignment with said axially-aligned waveguides to allow a work piece to pass through said space.

4. The applicator according to claim 3 wherein the

dimension of said vanes in the direction of the axis of said vaned mode stirrer is greater than $\lambda/2$.

5. The applicator according to claim 4 wherein said vaned mode stirrer includes vanes of different dimensions in the outwardly extending direction.

6. The applicator according to claim 5 wherein the distance between the most proximate parts of adjacently-spaced vanes is not greater than $\lambda c'$ the cutoff wavelength of the applied electromagnetic energy propagated between said adjacently-spaced vanes.

7. The applicator according to claim 6 wherein said multimode cavity resonator is rectangular, and said multimode waveguide is circular.

8. The applicator according to claim 7 wherein said vanes are generally rectangular slats circumferentially spaced about a circular locus to radially extend from the axis of the vaned mode stirrer into said cavity resonator, said axis of said vaned mode stirrer aligned with the axes of said waveguide sections, and said vanes are circumferentially disposed to provide a periodic variation in the radial extent of the circularly disposed vanes.

9. The applicator according to claim 8 wherein the chord distance between adjacent vanes is not greater than $\lambda/2$.

10. The applicator according to claim 9 wherein said waveguide sections are open-ended to allow a work piece to be continuously moved therethrough.

11. The applicator according to claim 10 further comprising means to direct an air flow against said vaned mode stirrer to rotate same.

12. The applicator according to claim 2 wherein said waveguide sections are open-ended to allow a work piece to be continuously moved therethrough.

13. The applicator according to claim 12 wherein the length of each waveguide sections is greater than $3/4\lambda$, the free space wavelength of the applied electromagnetic energy.

14. The applicator according to claim 13 further comprising a lossy wall waveguide mounted at the end of said open ended waveguide sections distal said cavity resonator to absorb electromagnetic energy escaping from said waveguide sections.

15. The applicator according to claim 1 wherein said waveguide is open-ended to have at least one of its ends extending outside of said cavity resonator.

16. The applicator according to claim 15 further comprising a lossy wall waveguide mounted at the end of said waveguide extending outside of said cavity resonator to absorb electromagnetic energy escaping from said waveguide end.

17. The applicator according to claim 16 wherein said lossy wall waveguide includes a tubular conductive member defining an inside surface, and a dielectric fluid conduit disposed along inside surface for conveying fluid for absorbing the electromagnetic energy escaping from said waveguide end.

18. The applicator according to claim 17 wherein said dielectric fluid conduit is a helically-coiled hose disposed in axial alignment within said tubular conductive member.

19. A microwave applicator comprising a multimode cavity resonator adapted to receive electromagnetic energy from a source for exciting electromagnetic field patterns therein; and a vaned mode stirrer for rotation about an axis within said cavity resonator, said vaned mode stirrer comprising a slat radially displaced from said axis and extending outwardly from and in the direction of said axis, means for rotatably mounting said vaned mode stirrer about said axis within said cavity resonator, whereby said slat is moved through an annular path about said axis, and means for supporting a work piece in the space bounded by said annular path.

20. The applicator according to claim 19 wherein said vaned mode stirrer includes slats of different dimensions

in the outwardly-extending direction and each of which have a dimension in the direction of the axis of said vaned mode stirrer greater than $\lambda/2$.

21. The applicator according to claim 20 wherein said slats are generally rectangular and circumferentially-spaced about a circular locus to radially extend from the axis thereof, and said slats are circumferentially disposed to provide a periodic variation in the radial extent of the circularly disposed slats.

22. The applicator according to claim 21 further comprising means to direct an air flow against said vaned mode stirrer to rotate same.

23. The applicator according to claim 19 further comprising at least one waveguide mounted to receive and propagate electromagnetic energy from said multimode cavity resonator.

24. The applicator according to claim 23 wherein said

vaned mode stirrer is rotatably mounted to have its axis in alignment with the axis of said waveguide.

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