May 25, 1948. G. H. BROWN 2,442,114

METHOD OF AND APPARATUS FOR SUBJECTING MATERIALS TO A RADIO-FREQUENCY FIELD

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Fig. 1.

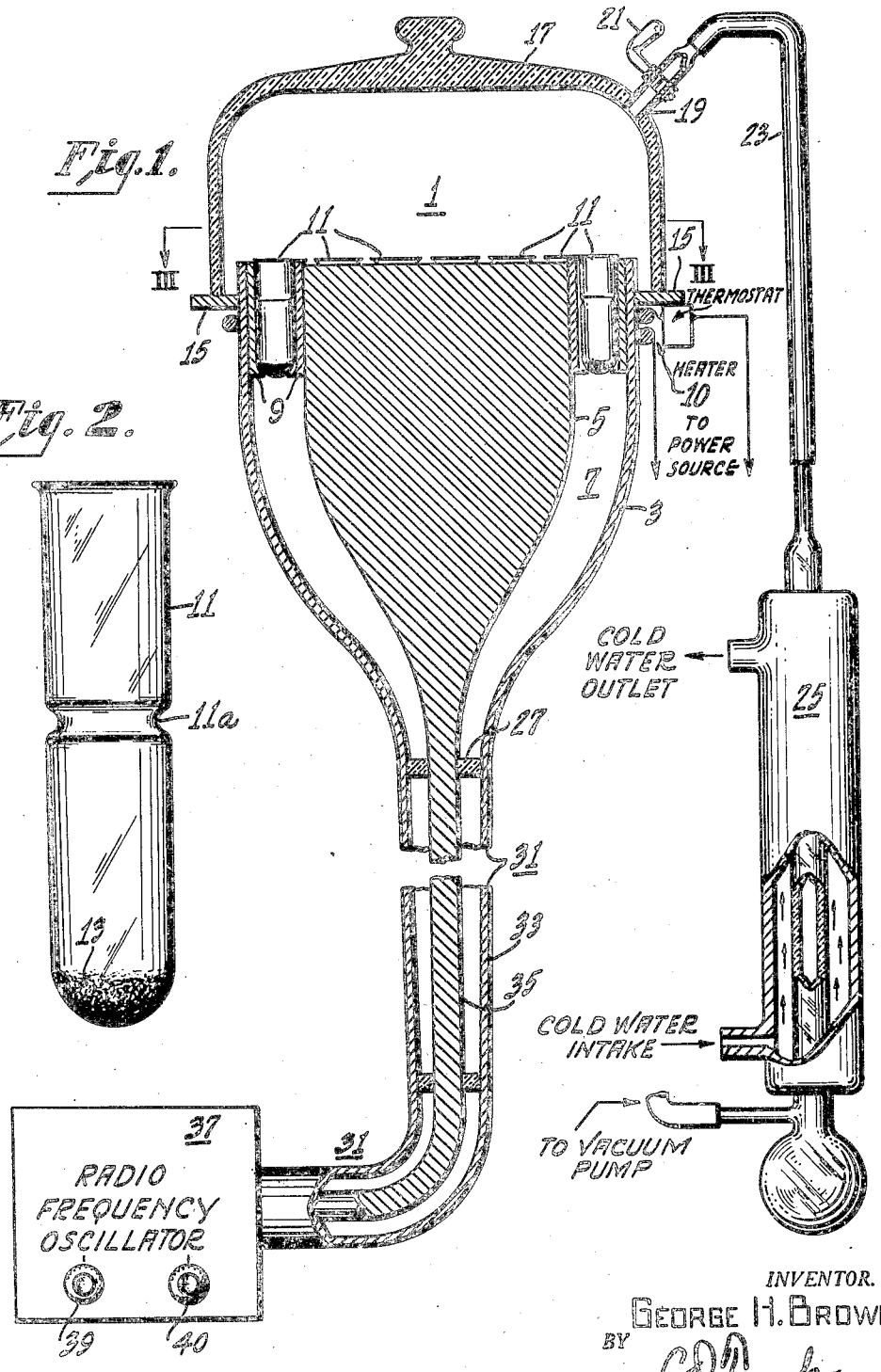

Fig. 2.

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Fig. 3.

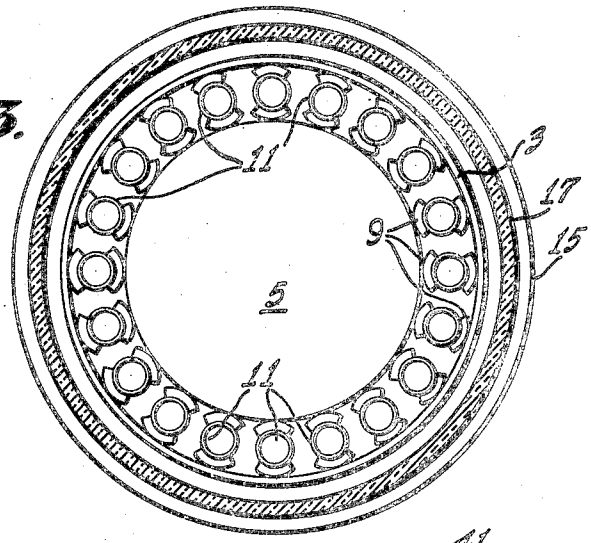
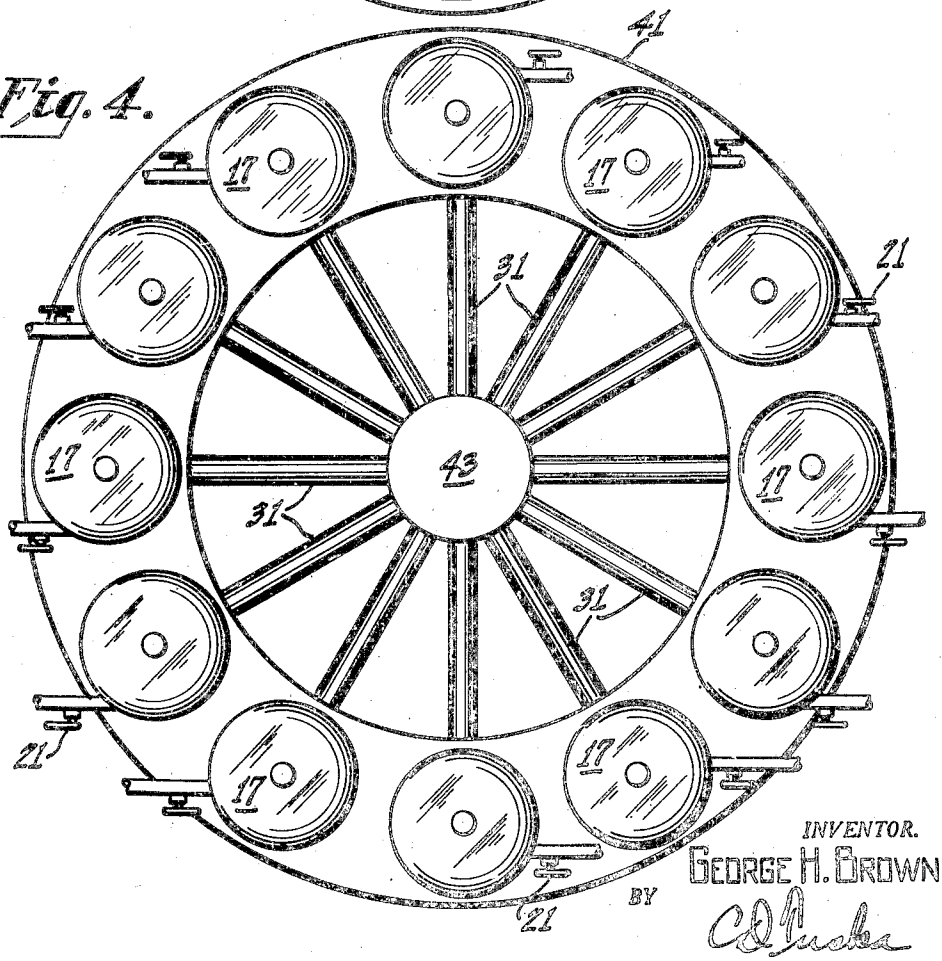


Fig. 4.



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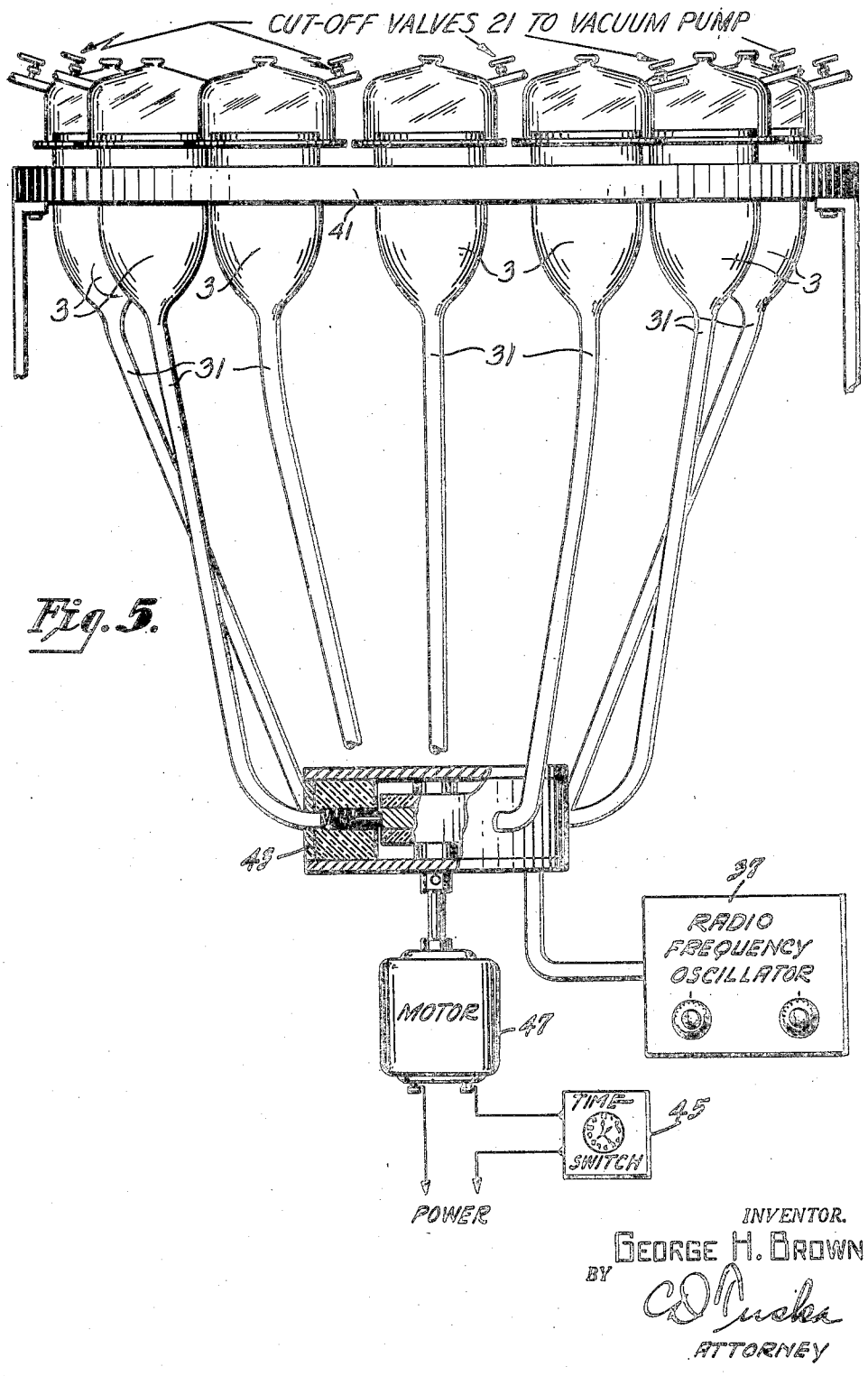

Fig. 5.

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UNITED STATES PATENT OFFICE

2,442,114

METHOD OF AND APPARATUS FOR SUBJECTING MATERIALS TO A RADIO-FREQUENCY FIELD

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Application April 27, 1944, Serial No. 533,077

7 Claims. (Cl. 34—1)

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This invention relates to improvements in the art of subjecting insulating or dielectric materials and objects to an electric field.

The prior art discloses numerous methods and means for treating various non-metallic objects and materials with a high frequency electric field, and many valuable advantages have resulted from the application of such inventions to industry. By way of example, as disclosed in copending application Serial No. 520,428 to George H. Brown and Rudolph A. Bierwirth, production of the rare drug penicillin can be speeded-up, on a commercial scale, by subjecting the ampoules or other receptacles in which the mother liquor is contained to an electric field of radio frequency. The R. F. field is applied in a relatively low vacuum (e. g. 0.2 to 2 centimeters) and subjects the fluid (which may be frozen) to such rapid dehydration that the labile equilibrium and the potency of the "X-factor" of the drug are not adversely affected.

In the Brown et al. process, as in numerous other cases, it is important that each article be subject to a field of substantially exactly the same intensity as the others. It might at first glance appear that this desired result could be achieved simply by mounting the ampoules or other containers on an endless conveyor and subjecting them, sequentially, to an electric field by means of a suitable applicator mounted in the path of the conveyor. Conveyor systems, however, are unsuited for use in processes wherein the radio frequency energy must be applied in vacuo, and further, the prior art fails to disclose an applicator or bank of applicators capable of providing a perfectly uniform distribution of an electric field of radio frequency about a large number of discrete articles.

Accordingly, the principal object of the present invention is to obviate the foregoing and other less apparent objections to prior art methods of and means for treating non-metallic objects and materials with an electric field, and to provide an improved and reliable system which is applicable to industrial processes of the type requiring the utilization, in vacuo, of a high frequency electric field.

Another and important object of the present invention is to provide a novel and efficient bank of electric field applicators for the treatment, by mass production methods, of large numbers of separate articles or containers such, for example, as drug ampoules.

The present invention is predicated upon an appreciation of the fact that the electric field present within a coaxial transmission line or cable is

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uniform at all points about its inner circumference, and the invention may be said to reside, at least in parts, in the application of this fact to the treatment of non-metallic objects and materials. Thus, it has been found that when provision is made for mounting a number of ampoules (or other containers or articles) in circular array in the space between the inner and outer conductors of a concentric line, each article (or its contents) is exposed to substantially the same number and intensity of lines of force. Accordingly, the present invention contemplates, and its practice provides, a radio frequency applicator possessing the electrical characteristics of a concentric line, and which comprises an inner conductor presented across an intervening space to the interior of a hollow outer conductor, and means for mounting the material or articles to be treated within said intervening space.

Since the concentric lines commonly employed in the transfer of radio frequency energy from a source to a load are usually unsuited to the practice of the invention, the invention dictates the construction of a transmission line comprising (*a*) an enlarged hollow section comprising the "applicator" and (*b*) a preferably "standard" section for coupling the applicator to a source of radio frequency energy. The applicator or terminal section of the transmission line may be integral with the standard section if desired and the standard section may be coupled to the oscillator by any suitable fixed or adjustable coupling circuit (e. g. lumped inductance or capacitance) or mechanism (e. g. a "trombone" type connector). The applicator preferably possesses substantially the same characteristic impedance per unit length as the "standard" section and means are provided, whenever necessary or desirable, for evacuating the applicator.

The invention further contemplates a "bank" of such applicators and the provision of means for sequentially energizing each applicator in the bank.

Certain preferred details of construction together with other objects and advantages will be apparent and the invention itself will be best understood by reference to the accompanying drawings wherein:

Fig. 1 is a partly diagrammatic sectional view of an "ampoule dryer" including an evacuable concentric line applicator constructed in accordance with the principle of the invention.

Fig. 2 is an enlarged side elevational view of a glass (or other dielectric) ampoule, suitable for use in the applicator of Fig. 1.

Fig. 3 is a sectional view looking in the direction of the arrows III—III of Fig. 1,

Fig. 4 is a plan view of a bank of applicators arranged in accordance with the principle of the invention, and

Fig. 5 is a side elevational view, partly in section, of the apparatus of Fig. 4, and includes a switch for sequentially connecting each applicator in the bank to a source of radio frequency energy.

Referring now to Fig. 1 wherein 1 designates generally, an electric-field applicator constructed in accordance with the invention and comprising a circular cup-shape metal vessel 3 having a second conductor 5 of similar contour presented to the interior of the cup across an intervening space 7. The outer and inner conductors 3 and 5 preferably terminate in the same plane and the annular space 7 adjacent to this plane is adapted, as by the provision of a number of suitable mounting elements 9, to receive a multiplicity of objects 11. When, as in the Brown et al. disclosure, the material to be treated comprises a frozen or chilled fluid concentrate of penicillin liquor the objects 11 may comprise a multiplicity of unsealed glass ampoules 11 which are provided with a stricture 11*a* (see Fig. 2) so that when the liquor 13 is agitated by the electric field applied thereto by the conductors 3 and 5 it will not spill over but will merely wet the inner surface of the tube. The supports 9 for the containers 11 are preferably constitued of metal so that they will conduct heat to the containers 11 form an auxiliary source of heat 10 (later described) but should not comprise a conductive bridge between the inner and outer conductors 3 and 5.

In the instant case, the cup-shape outer conductor 3 is provided with a circumferential rim or flange 15 which serves as a support for a bell jar 17 or other air-tight cover for the applicator. This cover 17 has a port 19 therein through which connections are made to a vacuum system comprising a cut-off valve 21, a flexible hose 23, a condenser 25, and a pump, not shown, but which will be understood to be capable of maintaining a vacuum of the order of from 0.2 to 2 centimeters of mercury in the event that the material to be processed comprises penicillin liquor. The interior of the applicator, adjacent to its base, is provided with a gasket 27 which serves not only as an air-tight seal but also as an insulating support and spacer for the inner conductor 5.

It will be observed upon inspection of Fig. 1 that the applicator tapers gradually inward adjacent to its base and terminates in a concentric line 31 of "standard" dimensions. That is to say, the diameters of the outer and inner conductors 33 and 35 of the concentric line 31 will ordinarily be chosen with a careful regard to the frequency of the current to be applied to the applicator 1 and the ratio of these dimensions is preserved, substantially, in the applicator by the tapered construction of the outer and inner conductors 3 and 5 thereof. Thus, the characteristic impedance of the line including the section 31 and the applicator 1, is maintained substantially constant throughout its length.

The oscillator 37 for supplying the applicator 1 with radio frequency current through the transmission line 31 may be of any standard type and may be provided with suitable controls 39 and 40 for adjusting its frequency and power output. Thus, in one practical embodiment of the invention, the source 37 comprised an oscillator which was adjusted to deliver 500 watts at a frequency of the order of 150 megacycles per second. Since the nearly dried material does not absorb substantial amounts of radio frequency power, it is advantageous to apply heat by any conventional means such as an electric heater which may include a coil 10 disposed around the outer conductor and a thermostat for regulating the applied power from any suitable source.

As previously set forth, the present invention lends itself readily to the production by mass production methods of the rare drug penicillin. That this is so will be apparent when it is appreciated that a bank of twelve applicators (see Figs. 4 and 5) each accommodating twenty ampoules (see Fig. 3) is capable of handling 240 ampoules per hour. Thus, should each ampoule contain 100,000 Oxford units of penicillin, this single bank of applicators can handle the entire output of the largest present-day producer of that drug in the United States.

Referring now in detail to Figs. 4 and 5: In these drawings, twelve applicators, each with its bell jar or cover 17 in position, are shown mounted in spaced array on a fixed circular shelf or table 41. Thus, each of the applicators is accessible to the technician in charge of loading and unloading the apparatus. The lower ends of the applicators protrude from the underside of the support 41 and the standard transmission line sections 31 are arranged to be connected, selectively, to the R. F. oscillator 37 through a suitable switch 43. A time control mechanism 45 periodically applies power to a motor 47 which actuates the switch and thus connects each of the applicators to the oscillator in sequence. While one applicator is in use the previously used applicators may be unloaded and the succeeding ones loaded and placed on the pump preparatory to being energized. To illustrate these successive stages of the above described method and to show all of the concentric line, switch and vacuum hose connections would needlessly complicate the drawings.

While the foregoing disclosure describes a method and apparatus for treating a multiplicity of discrete objects, it is apparent that the invention is likewise applicable to the treatment of single objects or containers. Thus, the applicators here illustrated may be used to advantage in the processing of fluids, pulverulent materials and comminuted solids simply by substituting a single, preferably annular, container (not shown), for the multiplicity of test tubes or ampoules shown in the drawings. Similarly, other types of containers or supports adapted to the particular insulating object or material to be treated will suggest themselves to those skilled in the art of handling such objects and materials.

What is claimed is:

1. Apparatus for subjecting an object to an electric field, said apparatus comprising, in combination, a concentric transmission line including spaced inner and outer conductors of standard form and dimensions and an expanded open-ended terminal section, an oscillator connected to said concentric line for establishing an electric field between said spaced conductors in and about the space adjacent to the open end of said expanded terminal section, and a support for supporting the said object in the space between said inner and outer conductors.

2. Apparatus for the uniform treatment of a

multiplicity of substantially identical objects with an electric field, said apparatus comprising an outer conductor, an inner conductor mounted within and in spaced relation with respect to said outer conductor, the relative dimensions of said outer and inner conductors and hence of the space therebetween being so proportioned as to exhibit the electrical characteristics of a concentric transmission line, means including said conductors for establishing a uniform electric field within and about said space, and means for mounting said multiplicity of objects in circumferentially spaced array within the space between said inner and outer conductors.

3. Apparatus for simultaneously dehydrating the contents of a multiplicity of ampoules containing substantially equal quantities of a pharmaceutical or biological material, said apparatus comprising an evacuable vessel, heat conductive supports for supporting said multiplicity of ampoules in spaced circular array within said vessel, means for establishing a partial vacuum within said vessel and ampoules, means for establishing a radially extending radio frequency field at all points between the inner and outer boundaries of the circle within which said ampoules are supported, whereby the contents of said ampoules are subjected simultaneously and equally to the dehydrating action of said partial vacuum and said radio frequency field, and an auxiliary source of heat adjacent to said heat conductive supports for maintaining the contents of said ampoules at a desired temperature.

4. In apparatus of the character described, a concentric line comprising a transmission section including inner and outer conductors of standard form and dimensions and an integral terminal section possessing substantially the same electrical characteristics as said transmission section, the inner and outer conductors of said terminal section being spaced apart and comprising an expanded continuation of the inner and outer conductors of said transmission section, means for establishing an electric field within the space between the inner and outer conductors of said terminal section, and means for mounting a multiplicity of objects in a circle concentric with said conductors in the space between said conductors.

5. Apparatus for the treatment of materials comprising a support, a bank of electric field applicators mounted in circular array on said support, said applicators each comprising an evacuable receptacle containing a section of a concentric transmission line having spaced inner and outer conductors and adapted to contain in the space between said conductors a multiplicity of

containers for the material to be treated, a source of radio frequency energy, means for selectively connecting said concentric transmission line sections to said source in a desired sequence, and means for evacuating said evacuable receptacles.

6. The method of heating the contents of a multiplicity of dielectric fluid receptacles simultaneously and equally by subjecting said receptacles to the action of a radio frequency field, said method comprising disposing said dielectric fluid receptacles in circular array, and establishing a radially extending radio frequency field between all points on the inner and outer boundaries of the circle in which said dielectric fluid receptacles are disposed.

7. The method of dehydrating a pharmaceutical or biological material to provide a product of uniform potency and dryness, said method comprising, inserting equal quantities of said material in a multiplicity of dielectric ampoules, disposing said ampoules in circular array within an evacuable space, establishing a partial vacuum within and about said ampoules, and establishing a radially extending radio frequency field of substantially uniform intensity between all points about the inner and outer boundaries of the circle within which said ampoules are disposed, whereby the contents of said ampoules are subjected simultaneously and equally to the dehydrating action of said partial vacuum and said radio frequency field.

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