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ULTRA-HIGH FREQUENCY HEATING SYSTEM

Filed June 28, 1963

FIG. 1

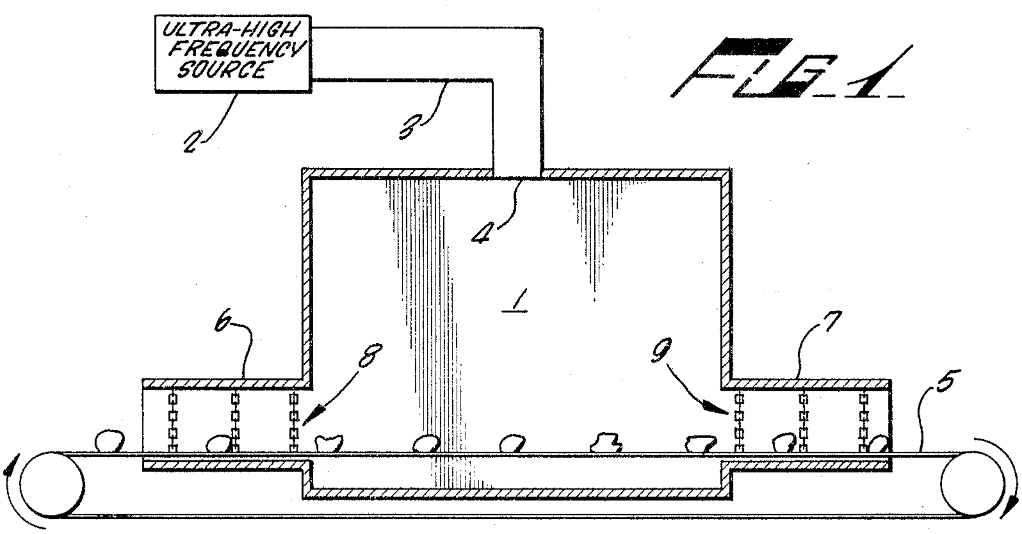
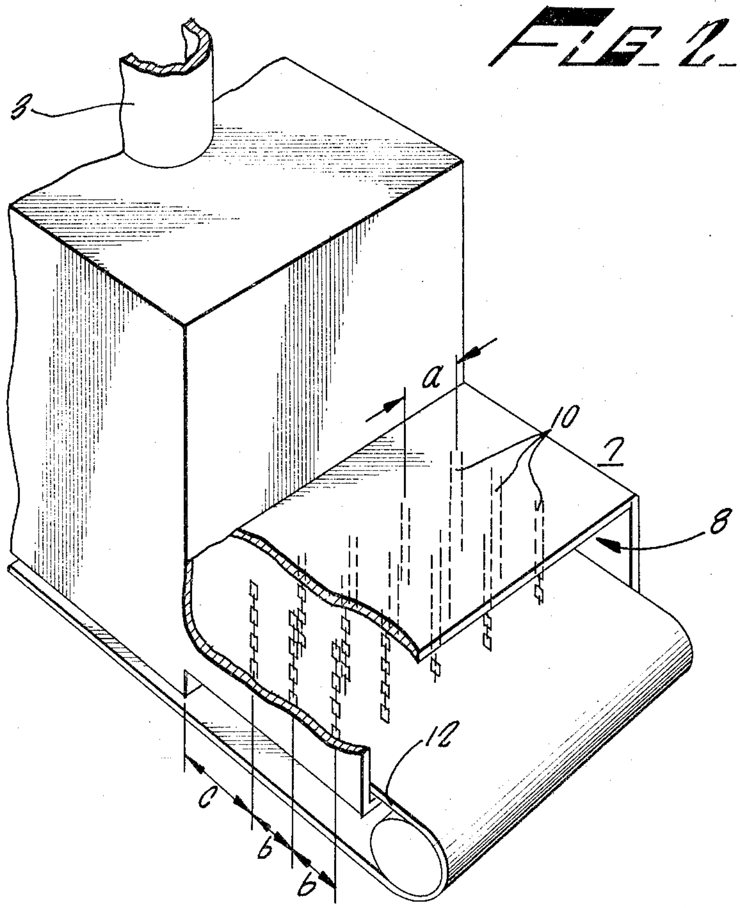


FIG. 2



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ULTRA-HIGH FREQUENCY HEATING SYSTEM

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1 Claim. (Cl. 219—10.55)

This invention relates to heating apparatus and, more particularly, to ultra-high frequency heating apparatus including inlet and outlet openings for the continuous flow through the heating chamber of the product to be heated and, more particularly, the prevention of radiation from the apparatus through these openings.

For large scale heating or drying of products by ultra-high frequency methods, it is necessary to provide means for continually transporting material through the chamber so that the process can be effected in a rapid and efficient manner. In order to do this, inlet and outlet openings must be provided through which the material may pass on a belt, moving tray or other means of conveyance. These openings must be provided with means of preventing the leakage and radiation of ultra-high frequency energy to the exterior of the chamber. It is known that the radiation of energy outside of the chamber is undesirable because it reduces the amount of energy available for heating the material within the chamber. Furthermore, this leakage may constitute a safety hazard to personnel in the vicinity. The maximum average power density that is considered safe for humans is 10 milliwatts per square centimeter. It can be readily appreciated that this level may be easily exceeded when a heating chamber is operated at an input level of one kilowatt or more, unless means are provided to block the escape of this energy.

It is known that the radiation and leakage of the ultra-high frequency energy to the exterior can be prevented by using inlet and outlet openings and ducts which are small enough so that they are below cutoff at the frequency of operation of the heating chamber. By selecting openings and ducts which have dimensions less than that required for the transmission of the ultra-high frequency energy, the radiation is prevented. However, the maximum dimension of the duct permissible is less than one-half the free space wavelength of the ultra-high frequency energy in the heating chamber. Since the frequencies commonly employed for ultra-high frequency heating corresponds to wavelengths of about 5 inches, it is obvious that the use of ducts having dimensions less than one-half the wavelength of the ultra-high frequency energy restricts the utility of the heating apparatus to products of small dimensions.

An alternative means of preventing the radiation of the ultra-high frequency energy is to employ one-quarter wavelength chokes or closures in the ducts. These generally consist of short circuit sections of transmission line or wave guide which interrupt the field within the duct and alter the impedance in such a manner as to restrict energy flow and consequent radiation. These devices are generally effective under no load conditions and at a single operating frequency. However, under the conditions usually employed in ultra-high frequency heating chambers the frequency of the energy may vary from that for which the quarter-wave sections are designed. This can seriously reduce the effectiveness of the quarter wave enclosures. Furthermore, since the dimension of the enclosures must be comparable to that of the duct, it is obvious that many modes may be allowed to propagate within the enclosure section. These modes may be excited in an unpredictable manner by the presence of the product to be dried or heated within the duct. Thereafter, the quarter wave chokes are no longer as effective for the prevention of radiation.

This invention provides a simple, effective, and inexpensive means for preventing the radiation of ultra-high frequency energy from a heating chamber. In an ultra-high frequency heating system comprising a heating chamber which has ultra-high frequency energy applied thereto for operating upon products conveyed therethrough, there is provided an inlet passage coupled to the chamber and an outlet passage coupled to the chamber. The product is conveyed through the inlet passage to the heating chamber and from the heating chamber through the outlet passage. There is provided in each passage a means for preventing the radiation of ultra-high frequency energy from the chamber through the passage. The preventing means comprises a flexible conducting curtain which acts as a microwave closure to prevent the radiation of energy. A preferred embodiment of the flexible curtain includes a plurality of chains mechanically and electrically connected to one wall in both the inlet and outlet passages. The chains are of sufficient length so that they would make contact with the opposite wall of the passage if it were not for the conveying means in the passage. However, the chains are electrically connected by the electrical capacity present between the wall and the chains.

The above and other features and advantages of the present invention will be understood more clearly and fully upon consideration of the following specification and drawing, in which:

FIG. 1 is a pictorial representation of an ultra-high frequency heating apparatus employing radiation prevention devices in accordance with the invention; and

FIG. 2 is a pictorial diagram partially cut away of an enlarged view of the outlet passage from the heating apparatus shown in FIG. 1.

A typical ultra-high frequency heating apparatus is shown in FIG. 1 and comprises a heating chamber **1** made of a metallic casing generally in the shape of a cube. The invention is not limited to use with just single heating chambers as shown in FIG. 1, but may be employed where there are a plurality of heating chambers which have means for the continuous passage of product to be heated into and out of the heating apparatus.

The heating chamber **1** of FIG. 1 is energized by an ultra-high frequency source **2** coupled to the chamber by a wave guide **3**. There is an aperture **4** provided in the top wall of the heating chamber **1**. The ultra-high frequency energy is coupled from the source **2** into the chamber **1** to heat the product as it passes through the chamber. The product is continuously supplied to the heating chamber by a conveyance means shown in FIG. 1 as a belt **5**. The belt passes into the chamber **1** by way of an inlet passage **6** and passes out of the chamber by way of an outlet passage **7**. In the chamber **1** of FIG. 1 for illustrative purposes, there is shown a rectangular opening **8** in one wall of the enclosure which defines the heating chamber. The rectangular opening provides a means for the passage of the product to be heated into the chamber. There is additionally provided a second rectangular opening **9** in the wall of the enclosure for the passage of the product out of the chamber. To each rectangular opening **8** and **9**, there is coupled the inlet and outlet passages **6** and **7** respectively. It is noted that the inlet and outlet openings and passages are not restricted to rectangular configurations, but may be of any configuration suitable for the product to be dried and the heating apparatus in use.

The openings and passages through which the product travels into and out of the heating chamber 1 will permit the radiation of ultra-high frequency energy into the surrounding area which is undesirable and detrimental. Therefore, there is provided means for preventing the radiation from energy through the openings 8 and 9 and the passages 6 and 7. This means is shown as a plurality of conducting elements positioned between the top wall of the passage and the bottom wall of the passage. The construction of the preventing means may be seen and understood more clearly by reference to FIG. 2 which is an enlarged view of the passage 7 and opening 9 of the heating apparatus of FIG. 1. Referring to FIG. 2, the passage 7 is shown in outline form to more clearly present the flexible conducting members which, acting together, form the conducting curtain blocking the transmission of ultra-high frequency energy through the passage. The flexible conductors 10 may take a variety of forms such as metal chains, flexible wire, thin pieces of flexible metal or hinged conductive rods. Flexibility is important so that the flow of the product to be heated through the passage is not impeded. The conducting members 10 must be good electrical conductors to effect maximum shielding. Number 12 brass chain known to the trade as safety or plumbers chain is a preferred embodiment for the conducting elements 10. When a chain is used, it is important that the contact resistance of the lengths be a minimum.

In order to provide the blocking of ultra-high frequency energy, the spacing *a* between the conductors should be less than one half the wavelength of the energy from the source 2 which is applied to heat the product in the heating chamber 1. For best results, the distance *a* should be considerably less than one half the wavelength because of the effect upon the wavelength by the product as it passes through the passage. In general, the blocking effect is improved as the spacing between the conductors is reduced. The minimum spacing below which negligible effect is realized is one tenth of the wavelength of the energy in the heating chamber 1. The conducting elements 10 are mechanically and electrically connected to the top wall 11 of the passage 7 in such a manner as to insure a good contact. The elements 10 extend across the height of the passage to effect the blocking of the ultra-high frequency energy. In the absence of a conveyor belt in a passage, a good contact is made with the bottom wall 12 of the passage. However, when a belt is used, the conductive elements 10 terminate on the belt and are in electrical contact with the bottom wall 12 through the capacitance present between the conductive elements and the bottom wall. Although a single row of conductive elements 10 aligned on the top wall 11 perpendicular to the direction of travel of the product through the passage forms an adequate barrier at low power levels of ultra-high frequency energy, the performance is greatly improved by the use of two or more rows. Thus, a second and third row of conductive elements 10 are attached to the top wall 11 in FIG. 2. The spacing *b* of the rows of conductive elements 10 is not critical and can be adjusted in a particular configuration to give optimum results.

However, to minimize disturbances within the heating chamber 1, the distance *c* of the first row of conductive elements 10 from the exterior of the heating chamber should be approximately one-half the wavelength of the energy within the chamber.

It will be recognized by those skilled in the ultra-high frequency heating art that variations and modifications may be made to the heating system within the scope of this invention. Some of these changes may include changes in the shape of the heating chamber and in the shape of the input and output passages and openings. Additional changes could be made by providing aluminum, silver, copper or other highly conductive materials for the chains. Additionally where contamination of the conductors may be a problem because of contact with the product being conveyed through the passage, the conductive elements may be plated with a corrosion resistant metal such as rhodium or gold or may be enclosed in a protective medium such as a spray coating of plastic or dielectric or they may be enclosed in a plastic sheath which will preserve the flexibility while maintaining a corrosion free surface.

What is claimed is:

An ultra-high frequency heating system comprising a heating chamber, means for propagating ultra-high frequency energy at a selected wavelength within the chamber to heat articles introduced within the chamber, an inlet passage extending outwardly of the heating chamber and coupled to the chamber, an outlet passage extending outwardly of the heating chamber and coupled to the chamber, means for transporting the product to be heated successively through the inlet passage, the chamber, and the outlet passage, the transporting means being transparent to ultra-high frequency energy, and means positioned in the inlet and outlet passages for preventing the radiation of the ultra-high frequency energy from the chamber through the passage, the preventing means including rows of flexible chains mechanically and electrically connected to the top wall of the passage and electrically connected to the bottom wall of the passage, the chains being connected to the bottom wall of the outlet and the inlet passages by the capacitance defined between the chains and the bottom wall through the transporting means, the first row of chains being arranged transversely to each passage and being positioned approximately one-half of the wavelength of the ultra-high frequency energy from the wall of the chamber to which the passage is coupled and transversely spaced between $1/10$ and $1/2$ of the wavelength of the ultra-high frequency energy and with the additional transverse rows of chains positioned in each inlet and outlet passage a preselected distance outwardly of said first row.

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