Jan. 28, 1958 J. W. MANN ET AL 2,821,611

ARCUATE, CYLINDRICAL AND CUP-SHAPED COMPOSITE R. F. ELECTRODES

Filed March 18, 1954 3 Sheets-Sheet 1

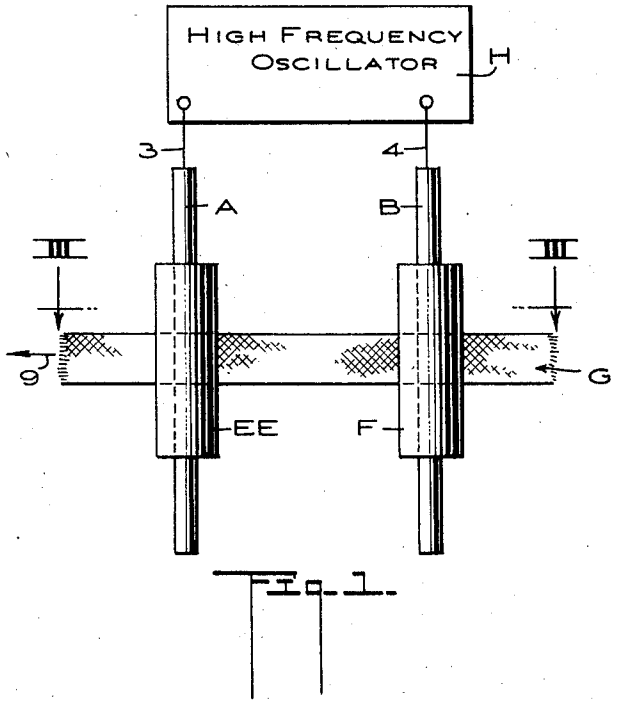


Fig. 1.

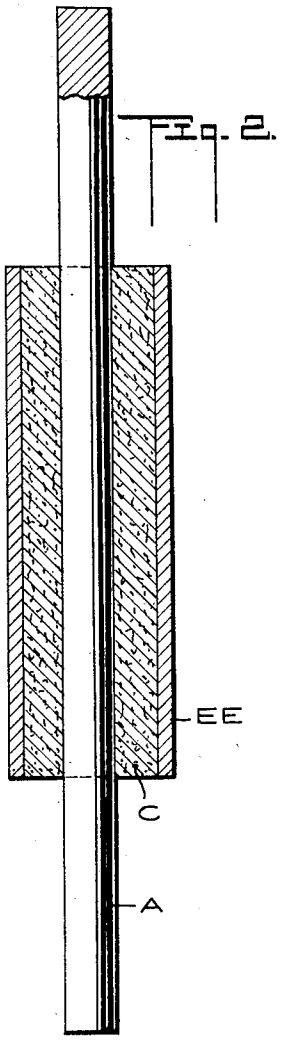


Fig. 2.

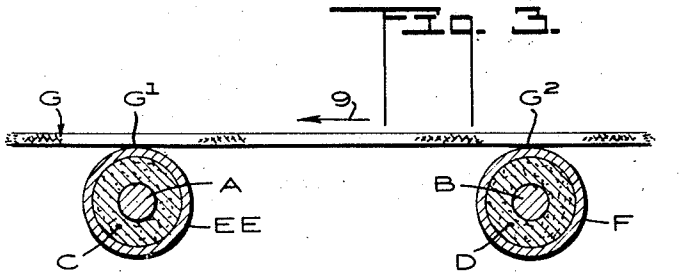


Fig. 3.

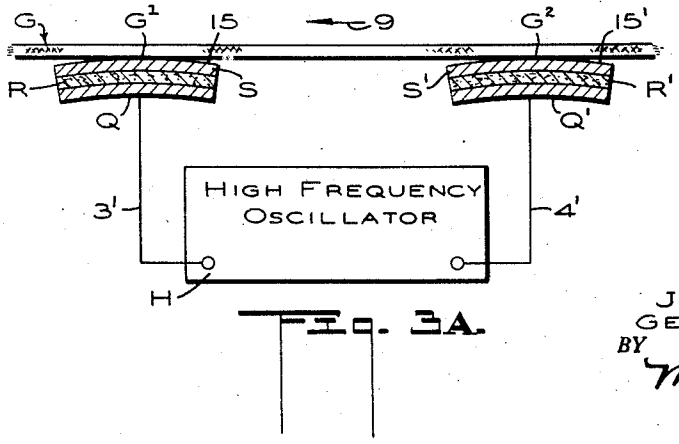


Fig. 3A.

INVENTORS
JULIUS W. MANN
GEORGE F. RUSSELL
BY Munn & Liddy
ATTORNEYS

Jan. 28, 1958 J. W. MANN ET AL 2,821,611

ARCUATE, CYLINDRICAL AND CUP-SHAPED COMPOSITE R. F. ELECTRODES

Filed March 18, 1954 3 Sheets-Sheet 2

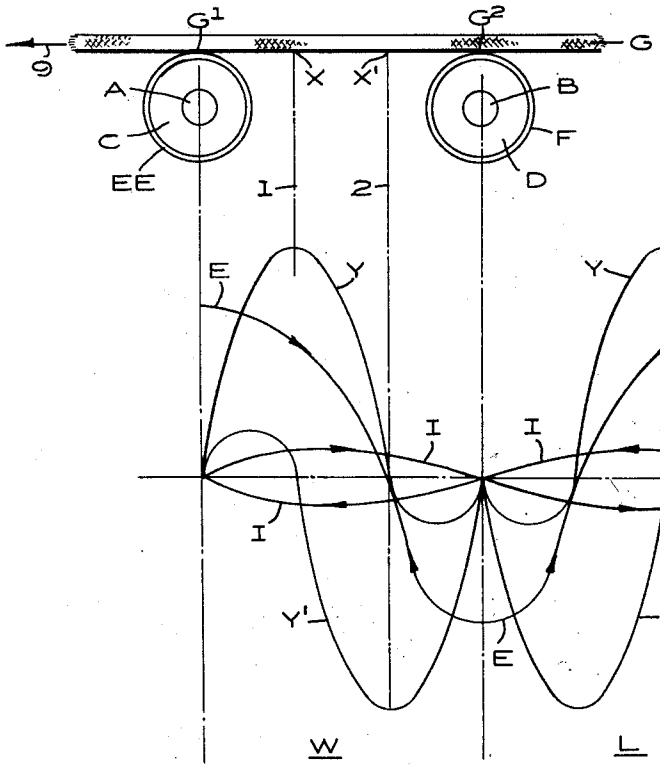


FIG. 4.

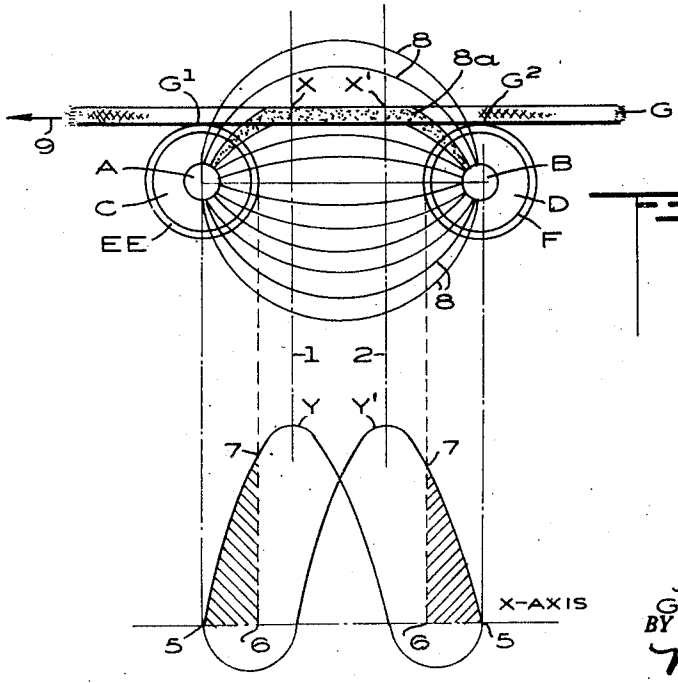


FIG. 5.

INVENTORS
JULIUS W. MANN
GEORGE F. RUSSELL
BY
Munn & Liddy
ATTORNEYS

Jan. 28, 1958 J. W. MANN ET AL 2,821,611

ARCUATE, CYLINDRICAL AND CUP-SHAPED COMPOSITE R. F. ELECTRODES

Filed March 18, 1954 3 Sheets-Sheet 3

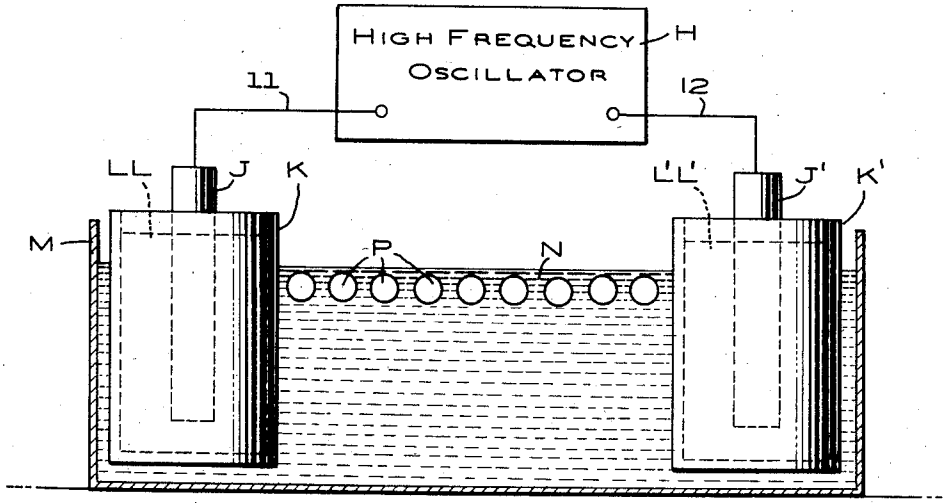


FIG. 6.

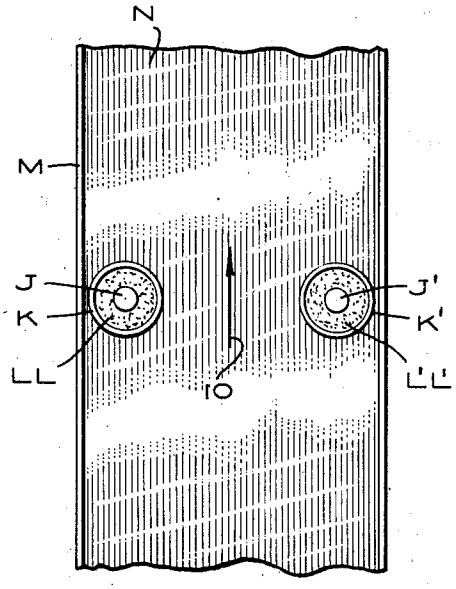


FIG. 7.

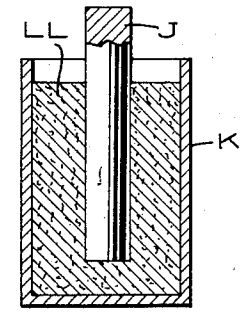


FIG. 8.

INVENTORS
JULIUS W. MANN
GEORGE F. RUSSELL
BY Munn & Liddy
ATTORNEYS

United States Patent Office 2,821,611
Patented Jan. 28, 1958

2,821,611

ARCUATE, CYLINDRICAL AND CUP-SHAPED COMPOSITE R. F. ELECTRODES

Julius W. Mann and George F. Russell, Tacoma, Wash.

Application March 18, 1954, Serial No. 417,069

7 Claims. (Cl. 219—10.61)

In our copending application on a Composite Electrode Heat Storage Applicator, Ser. No. 417,068, filed August 19, 1954, we described and claimed a particular type of composite R. F. electrode heat storage applicator that was flat in shape. This type of R. F. applicator has been used successfully in the bonding of scarfed joints by radio frequency heat where the problem arose of causing the feather edges or tips of the scarfed joints to adhere firmly to the stock. The flat type of R. F. applicator has also been used with marked success on the adhesion of thin veneer face stock to core stock. The flat type of applicator has many other uses also.

The composite R. F. electrode can be used for other purposes if it is changed in shape from a flat type to an arcuate shape, a cylindrical shape or a cup shape. For example, the R. F. drying of ribbon or threads after they have been dyed with a particular color or the heat treatment of any general dielectric material such as paper, felt, cardboard, cellulose products, or such dielectric material, can be accomplished with our composite electrodes without the danger of arcing even though the material is still moist or wet with the liquid dye, or other materials which might be prone to induce arcing. If two unprotected R. F. electrodes contact such materials, there will be a great tendency for the high frequency current to pass from one electrode to the other in the form of an arc, using such dielectric material as the path along which it will travel, thus ruining the material by burning it. Unprotected or unheated R. F. electrodes normally operates while in a cold state, thus inducing moisture condensation on themselves which again aids in starting R. F. arcs between the electrodes.

It is now known that in a standing wave system, the electric strain is greatest in the region of the potential state; namely, the voltage antinodes. The highest voltage strain is at the surface of the work or live electrodes in a single standing wave system of the kind shown in our Patent No. 2,506,158, issued May 2, 1950, on a Standing Wave in a Radio Frequency Circuit. It is also known that the voltage drops to zero somewhere between the two electrodes as will be shown hereinafter in more detail. Therefore, if each live electrode is enclosed in a cylindrical layer of a high loss dielectric of suitable thickness, and the cylindrical layer in turn has its outer surface protected by a metal sleeve, then the moist or wet dielectric strand contacting the metal sleeve (or idling electrode) will be spaced the proper distance from the live electrode to reduce the high voltage strain at the point of contact. There will be less tendency in such a structure as we have invented for an electric arc to pass from one composite electrode to the other and use the moist dielectric as a path.

We have further disclosed in our Patent No. 2,599,850, issued June 10, 1952, on the Process of Controlling and Placing of R. F. Heat in a Dielectric, that the heat placement between the live electrodes can be controlled so that certain areas can be made hotter than others. In the present case, we provide a cylindrical form of composite

R. F. electrode and a moisture-containing dielectric strand is passed by the two of these composite electrodes so as to contact with the outer metal tubing or idling electrode of each. The two composite electrodes are connected to a source of R. F. oscillations, such as the radio circuit shown in our Patent No. 2,506,159, and the inclusion of the high loss dielectric cylindrical layers locates the peak of energy conversion more nearly in these high loss dielectric layers with the result that their temperature will be raised and they in turn will heat the outer metal tubes or idling electrodes by conduction. The moist strand or ribbon-like dielectric material contacting the heated metal outer sleeves of the two composite electrodes as it continuously passes thereby, will be dried by conduction due to the actual contact with the metal tubes or idling electrodes, as well as by the R. F. field of force generated between the two composite electrodes and through which the moist strand-like dielectric passes. The heating of the outer metal sleeves prevents condensation forming thereon and reduces arcing tendencies.

The physically heated metal sheath or idling electrode, surrounding the high loss dielectric interposed between itself and the R. F. charged live electrode, and against which passes the moist dielectric materials to be heated or dried wholly or in part, has the added useful purpose of preventing condensation on its structure, of moisture vapors that are forced out of or evaporated from the drying dielectric by the high frequency field of force. Thus, the heated idler or encasement sheath prevents a primary cause of arcing in dielectric high frequency heating and drying; namely, the collection of condensing vapors on cold electrode surface areas, which are most conducive to the commencement of R. F. arcs.

In the present case, we also show a cup-shaped composite R. F. electrode. The live electrodes are centered in metal cups that constitute the idling electrodes, and a high loss dielectric material is placed in each cup and supports the live electrode so that no part of it contacts with the inner surface of the metal cup. The "cupper" composite electrode may be used for heating liquid dielectrics that flow thereby and the liquid may in turn carry the solid dielectrics which also may be heated.

Care must be taken that the liquid dielectric in which the cupper composite electrodes are immersed, does not flow over the top rims of the metal cups or idling electrodes. The cupper composite electrodes are normally used, in pairs and plus and minus instantaneous electrical charges are impressed on the live electrodes when they are connected to an R. F. source. Because of the isolation of the live or central electrodes, the liquid or electrolyte being heated could be of any characteristic so long as the exposed metal cup would not enter into composition with the liquid in which it is immersed.

In a continuous process, the liquid dielectric material would float around and past the cup-shaped composite electrodes, which themselves are immersed in the liquid. Again, the liquid dielectric would be heated not only by the R. F. field as it passed between R. F. composite electrodes, but in addition, it would be heated by coming into contact with the heated metal cups. The metal cups in turn are heated by contacting with the high loss dielectric material that is contained in the cups and this same material prevents any electrical connection between the live electrodes and the cups or idling electrodes.

Other objects and advantages will appear in the following specification, and the novel features of the device will be particularly pointed out in the appended claims.

Our invention is illustrated in the accompanying drawings forming a part of this application, in which:

Figure 1 is a front elevation of two cylindrical-shaped composite electrodes shown connected to a R. F. oscilla-

tor and having moist or wet strand-like dielectric continuously passing thereby and contacting with both composite electrodes;

Figure 2 is an enlarged longitudinal section through one of the composite electrodes shown in Figure 1;

Figure 3 is an enlarged horizontal section taken along the line III—III of Figure 1;

Figure 3A is a schematic sectional view of two modified composite R. F. electrodes, each having a slightly curved outer surface on its idling electrode against which the moist or wet strand-like dielectric contacts as it continuously passes thereby;

Figure 4 is a diagrammatic view illustrating the current, voltage and power curves in the radio circuit in relation to the two composite electrodes that are connected to the radio circuit;

Figure 5 is a diagrammatic view illustrating the heat curves generated by the radio circuit and their relation to the two composite electrodes;

Figure 6 is a modified form of composite electrode where the outer shell takes the form of a cup and two of these are used for heating a liquid dielectric that may have solid dielectrics therein;

Figure 7 is a top plan view of Figure 6; and

Figure 8 is a longitudinal section through one of the composite electrodes illustrated in Figure 7.

While we have shown only the preferred forms of our invention, it should be understood that various changes or modifications may be made within the scope of the appended claims without departing from the spirit and scope of the invention.

In carrying out our invention, we provide two identical composite R. F. electrodes and they include a pair of live electrodes indicated at A and B in Figure 1. The live electrodes are made of metal which will conduct radio frequency current and are preferably cylindrical in cross section although we do not wish to be confined to any particular cross-sectional shape. A surrounding layer of a high loss dielectric is mounted on each live electrode, and these are shown at C and D in Figures 2 and 3. A metal sleeve or idling electrode encloses each surrounding or cylindrical layer of the high loss dielectric, and these are illustrated at EE and F in Figures 1, 2 and 3.

The electrodes A and B are considered live electrodes while the metal sleeves EE and F may be termed idling electrodes. The cylindrical layer of the high loss dielectric C or D, may consist of asbestos, transite or other suitable material. These cylindrical layers C and D act as insulators between the live electrodes A and B, and the idling electrode metal sleeves EE and F. The cylindrical insulating layers C and D also act as heat storage areas and in turn will heat the idling electrodes EE and F by conduction in a manner hereinafter set forth.

Both Figures 1 and 2 illustrate a continuously moving moist or wet dielectric G, contacting the outer surfaces of both metal sleeves or idling electrodes EE and F. In our copending case on the composite electrode heat storage applicator, and in our Patent No. 2,599,850, we show a graph of a power curve when the current and voltage curves are partially in phase. A similar graph is shown in Figure 4 of the present drawings in relation to the two composite electrodes. The standing wave distribution curves Y and Y′ are shown when the current I and the voltage curve E are brought more into phase by the placing of the energy-consuming moist or wet dielectric G so that it will contact both of the idling electrodes EE and F as the strand-like moist or wet dielectric is continuously moved thereby.

The power peaks of the power curves Y and Y′, will deliver heat to the continuously moving moist or wet dielectric G at the points X and X′ in the capacitance portion W of the R. F. circuit. The inductance portion L is also shown in Figure 4. Dot-dash lines 1 and 2 extend from the power crests Y and Y′ to the points X and X′ on the moist or wet flexible continuously moving dielectric G. In Figure 4, the power crests Y and Y′ are shown on opposite sides of the *x*-axis, whereas in Figure 5, the power crest Y′ has been revolved 180° so as to extend on the same side of the *x*-axis. The small loops associated with the large loops in both Figures 4 and 5, are the negative power loops. The current loops I and the voltage loops E, are not shown in Figure 5.

Figure 1 shows the live electrodes A and B connected to a high frequency oscillator H by wires 3 and 4. The radio frequency circuit of the oscillator H is preferably of the type described and claimed in our Patent No. 2,506,158, issued May 2, 1950, on a Standing Wave in a Radio Frequency Circuit. It is possible to use a radio circuit that is a single or double ender and we therefore do not wish to be confined to either a single ender or a double ender type of radio circuit. In our Patent No. 2,599,850, we show that the electric field in a standing wave system is nonuniform and therefore the placement of maximum peak energy conversion will be located at the points X and X′ on the moist or wet strand-like continuously moving dielectric G.

It has been shown that little or no heat energy is released at the surface of the live electrodes A and B. On the other hand the voltage potential is high at points adjacent to the live electrodes, as indicated by the voltage curve E in Figure 4. Both Figures 4 and 5 illustrate the crests of the power curves Y and Y′, lying near the cylindrical layers C and D of the high loss dielectrics. These layers C and D will therefore be heated because they are composed of a heat-retaining dielectric, such as asbestos. The layers C and D when heated, will also heat the idling electrodes EE and F by conduction, and the latter will heat the portions of the moist or wet continuously moving strand-like material G that contacts therewith, and prevent vapor condensation on the surface of such members.

It should be kept in mind that the heated cylinders EE and F prevent vapor condensation from forming thereon even though the dielectric material G being heated is moist or wet. The elevated temperatures of the heated idling electrodes EE and F prevent any loose moisture vapor driven off from the dielectric G, from condensing on these outer electrodes.

The thickness of the cylindrical layer of the high loss material C and D, determines the proportion of energy used to heat the high loss dielectric forming the cylindrical members C and D. In Figure 5, the proportion of energy so used is represented by the shaded areas 5, 6, 7. The dielectric strain on the load G in the capacitance W, is reduced by the amount absorbed by the dielectric G in the high voltage E field area. The thinner the cylindrical layer C or D, the more nearly the electric strain approaches the maximum voltage strain which pertains when the load or fabric dielectric G rides directly on the live electrodes A and B without being spaced therefrom by the materials C and D.

The tendency for any arcing between the live electrodes A and B and moving through the moist or wet dielectric G as a conductor is practically eliminated for the reason that in a standing wave system, the electric strain is greatest in the region of the potential state; namely, the voltage antinodes. In Figure 4, the voltage curve E shows that the highest voltage strain is at the live electrodes A and B. The voltage drops to zero where the voltage curve E crosses the *x*-axis. The metal sleeves or idling electrodes EE and F are spaced from the live electrodes A and B by the thickness of the high loss dielectric cylindrical layers C and D. Therefore the voltage potential of the curve E will not be so great at the metal sleeve EE and F as it is at the live electrodes A and D, because the voltage curve is nearer the *x*-axis and therefore nearer to zero potential.

In Figure 5, we show the R. F. lines of force 8 that extend between the live electrodes A and B when they are connected to the R. F. oscillator H, shown in Figs.

1, 3A and 6. The lines that flow through a portion of the continuously moving moist or wet strand or fabric G are indicated by the stippled area *8a*. This portion of the dielectric G will therefore be heated by the R. F. lines of force and the two hot spots will be at X and X' as already explained. In addition, the continually moving moist or wet strand G will be subjected to a drying action by coming into direct contact with the heated metal sleeves EE and F at G1 and G2, see Figures 3, 4 and 5. Moisture in the continuously moving strand G will be effectively dried by: one, the application of external heat of conduction from the heated sleeves EE and F at the contact points G1 and G2, and; two, the application of internal heat of radio frequency by the radio frequency lines of force *8a*.

The heat stored in the high loss dielectric cylinders C and D, may reach several hundred degrees Fahrenheit, and these will heat the metal sleeves or idling electrodes EE and F. This heat will be transferred to the continuously moving moist or wet dielectric G and will travel into the dielectric to aid in the drying operation. The strand G continuously moves in the direction of the arrow **9**, shown in Figures 1, 3, 4 and 5. The high loss dielectric cylinders C and D act as cauls for spacing the strand G from the live electrodes A and B, and they also store heat. The metal sleeves EE and F prevent wear taking place on the cylinders C and D from the continuously moving moist or wet strand G contacting therewith and conduct the stored heat from the cylinders to the strand.

In Figure 3A, we show a slightly modified form of composite R. F. electrode that has an outer surface which is convex in shape, but does no necessarily have to be a complete cylinder as is shown by the cylindrical sheaths EE and F of the composite electrodes in Figures 1, 2 and 3. The live electrodes are indicated at Q and Q'. A layer R and R' of a high loss dielectric material is placed on the live electrodes Q and Q', and spaces them from idling electrodes S and S', that have their outer surfaces **15** and **15'** convex in shape.

Wires **3'** and **4'** connect the live electrodes Q and Q' to the high frequency oscillator H. The moist or wet strand G continually moves past the idling electrodes S and S' as indicated by the arrow **9** and the dielectric G tangently contacts the idling electrodes S and S' at the points G1 and G2.

This form of the invention operates in the same general manner as the form illustrated in Figures 1, 2 and 3. Heat is generated in the layers R and R' when the live electrodes Q and Q' are connected to the high frequency source of current H, and a radio frequency field of force is established between the R. F. composite electrodes. The heated layers R and R' will in turn heat the idling electrodes S and S' by conduction. Any moisture driven off from the dielectric strand G and contacting the idling electrodes S and S' will be quickly evaporated because the idling electrodes are heated. There will be no tendency for arcing between the idling electrodes due to the condensation of any moisture thereon.

The moist or wet dielectric strand G will be dried as it passes through the R. F. field established between the composite R. F. electrodes, and as it comes into direct contact with the heated convex surfaces **15** and **15'** of the idling electrodes S and S' at the points G1 and G2.

One of the major points of novelty that resides in the two forms thus far described is that the heated outer shells EE and F, and the heated convex plates S and S', will not collect condensing moisture vapor from the material being heat-treated in the R. F. field and that contacts these members. It should be understood that the dielectric strand G is to be construed broadly enough to include any general class of moist dielectrics that can be heat treated for elevating its temperature and thereby assist in elminating at least a portion of its moisture content.

It should also be kept in mind that the invention is not to be restricted to only drying a dielectric. We wish to include the heat treatment of a dielectric substance that passes the idling electrodes and contacts therewith. Our invention contemplates the heat treatment or the drying of a dielectric because one may be accomplished without the other and vice versa.

In Figures 6, 7 and 8, we show another modified form of composite R. F. electrode that is designed to be used in heating liquid dielectrics. One of these modified composite electrodes is illustrated in section in Figure 8, and it comprises a live electrode J, that is placed in a cup-shaped idling electrode K, and is insulated therefrom by a high loss dielectric LL. The high loss dielectric LL practically fills the cup and may be asbestos, transite, etc. Two composite electrodes of the modified type are shown in Figures 6 and 7, and the left-hand one in both figures will be given the same letters to similar parts as that illustrated in Figure 8, while the similar parts of the right-hand composite electrode in Figures 6 and 7 will receive the same letters except that they will be primed.

One use of the cup-shaped form of composite electrodes is illustrated in Figures 6 and 7, where we show a trough M and cause a liquid dielectric N to flow along the trough in the direction of the arrow **10**. The liquid may carry solid dielectrics P, see Figure 6, that are to be heated, or the liquid N itself may be heated by the R. F. field lines of force. The live electrodes J and J' are connected to the high frequency oscillator H by wires **11** and **12**, see Figure 6.

When the R. F. oscillator H is turned on, radio frequency lines of force will pass between the live electrodes J and J' and will heat the liquid dielectric N that flows between the composite electrodes. If the liquid dielectric carries the solid dielectrics P, they will be heated also by the radio frequency lines of force. The members P may be particles of food such as peas or corn kernels that are to be cooked.

The high loss dielectric LL and L'L' will store heat in the same manner as the insulating cylinders C and D, and the insulating layers R and R', and this heat will be conducted by the cup-shaped idling metal electrodes K and K' to the liquid N for heating it. The liquid N will therefore be heated by the radio frequency lines of force from the live electrodes J and J' and also by contacting with the cup-shaped metal idling electrodes K and K'.

If it is desired to cause the liquid dielectric N to move in the direction of the arrow **10** in Figure 7, and to carry the solid dielectrics P, past the composite electrodes without damming up in front of the electrodes, baffles, not shown, could be placed in advance of the electrodes. These baffles could have their leading edges contacting the side walls of the trough M, and the other ends of the baffles could be placed adjacent to the portions of the outer surfaces of the electrodes that are disposed nearest to each other. All of the solid dielectrics would then be guided between the composite electrodes by the angularly arranged baffles. The baffles would not be necessary if only the liquid dielectric is being heat treated by the composite electrodes.

The spacing between the two composite R. F. electrodes and their relation to the side walls of the trough M in Figures 6 and 7, should be carefully considered. If the trough M is metallic or non-dielectric, the spacing between the composite electrodes and the trough should be so arranged that a minimum proportion of the R. F. energy is dissipated through the trough structure from one composite electrode to the other. It is of course desirable that the greatest amount of R. F. energy pass through the dielectric fluid N and the solid dielectrics P from one composite electrode to the other. We therefore do not wish to be confined to the exact spacing between the various parts as is illustrated in Figures 6 and 7.

We claim:

1. A composite R. F. electrode comprising: a live electrode adapted to be connected to a source of high frequency current; a layer of a high loss dielectric material contacting a portion of the live electrode; and a metallic idling electrode contacting the layer of dielectric material and thereby being separated from the live electrode; said idling electrode having an outer surface that is convex in shape.

2. A composite R. F. electrode comprising: a live electrode adapted to be connected to a source of high frequency current; a layer of a high loss dielectric material enclosing a portion of the live electrode; and a metallic idling electrode consisting of a metal sleeve covering the periphery of a dielectric layer and being free of any electrical connection with the live electrode; said idling electrode being adapted to contact with the surface of the dielectric work that is to have a high frequency field applied thereto, and to space the work from the live electrode; said layer of high loss dielectric material being adapted to store heat generated by the high frequency field emanating from the live electrode and to deliver the heat to the idling electrode so that this heat can be applied at least in part directly to the work by conduction.

3. A pair of composite R. F. electrodes: each comprising an elongated live electrode adapted to be connected to a source of radio frequency current; a layer of a high loss dielectric material enclosing a portion of each live electrode; a metallic idling electrode consisting of a metal sleeve covering the periphery of each dielectric layer and being free of any electrical connection with the live electrode; the two idling electrodes being adapted to contact with the surface of a work dielectric so as to space the work from the live electrodes; the layers of high loss dielectric storing heat generated by the radio frequency field formed between the two electrodes and delivering this heat to the idling electrodes and to the work dielectric by conduction; the heated metallic idling electrodes preventing any condensation of water vapor thereon; and the two live electrodes establishing an R. F. field around the work for heating it internally.

4. A composite R. F. electrode comprising: a metallic idling electrode consisting of a cup-shaped member made of a conducting material; a high loss dielectric material carried by the cup-shaped member; an elongated live electrode having one end embedded in the high loss dielectric material so as to be insulated from the idling electrode; said live electrode being adapted to be connected to a source of high frequency current.

5. A pair of composite R. F. electrodes: each comprising a metallic idling electrode consisting of a cup-shaped member made of a conducting material; a high loss dielectric material carried by each idling electrode; an elongated live electrode for each idling electrode and having an end embedded in the high loss dielectric material so as to insulate the live electrode from the idling electrode; said live electrodes being adapted to be connected to a source of high frequency current so as to establish a radio frequency field therebetween; the R. F. field also penetrating the high loss dielectric materials for heating them; the two idling electrodes being adapted to be immersed in a liquid dielectric; whereby a portion of the radio frequency field will heat the liquid dielectric; the heat received by the high loss dielectric materials being delivered to the idling electrodes and to the liquid dielectric by conduction.

6. An apparatus for the R. F. heat treating of a moving dielectric work comprising: a pair of composite R. F. electrodes, each consisting of substantially concentric outer and inner metallic members separated by a high loss dielectric layer; the inner metallic members being connected to a source of R. F. energy for establishing an R. F. field of force between the composite electrodes; whereby the dielectric layers will be heated by the R. F. field and in turn will heat the outer metallic members by conduction so that the moving dielectric work when contacting the outer hot metallic members will be heated internally and will also be penetrated by the R. F. field of force for the internal heating of the dielectric work and the elevation of its temperature.

7. A composite electrode comprising a curved metallic heat-retaining electrode and adapted to contact with dielectric work; a similarly contoured live electrode evenly spaced from the first-mentioned electrode and being connectible to a source of high frequency current; and a high loss dielectric material fixed between the two electrodes; the heat-retaining electrode having no galvanic connection with the live electrode.

References Cited in the file of this patent

UNITED STATES PATENTS

2,423,902	Peterson	July 15, 1947
2,436,732	Rowe	Feb. 24, 1948
2,463,054	Quayle et al.	Mar. 1, 1949
2,526,697	Scott	Oct. 24, 1950