Feb. 24, 1953 R. H. HAGOPIAN 2,629,812

ADJUSTABLE DIELECTRIC HEATING EQUIPMENT

Filed Sept. 20, 1947

Fig. 1.

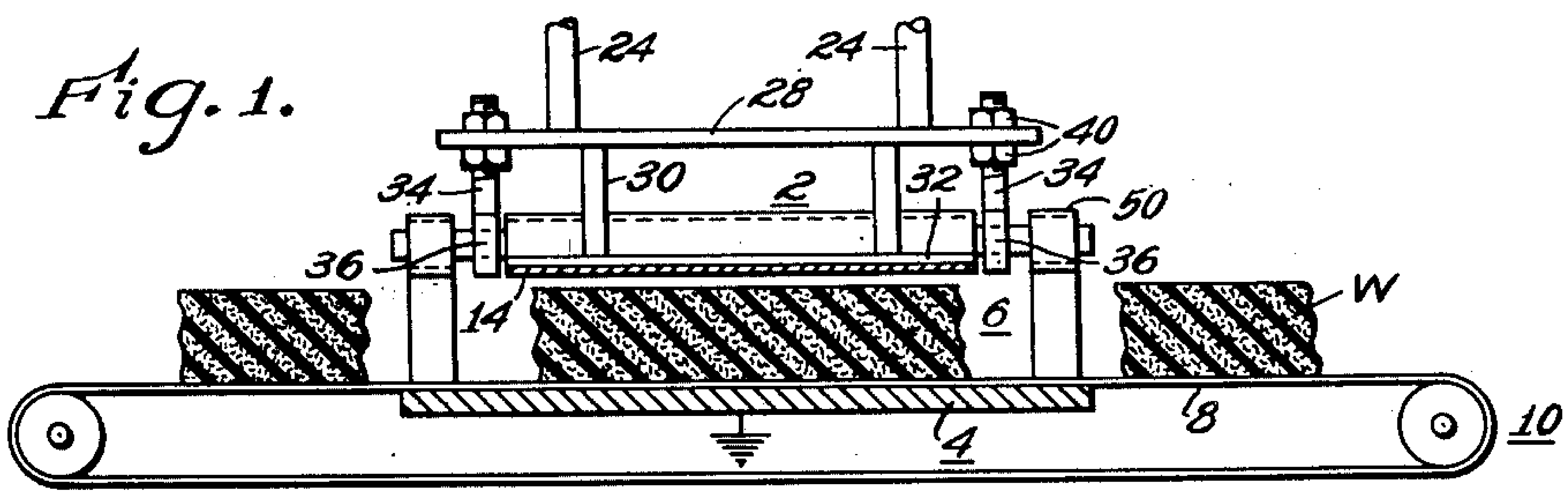


Fig. 2.

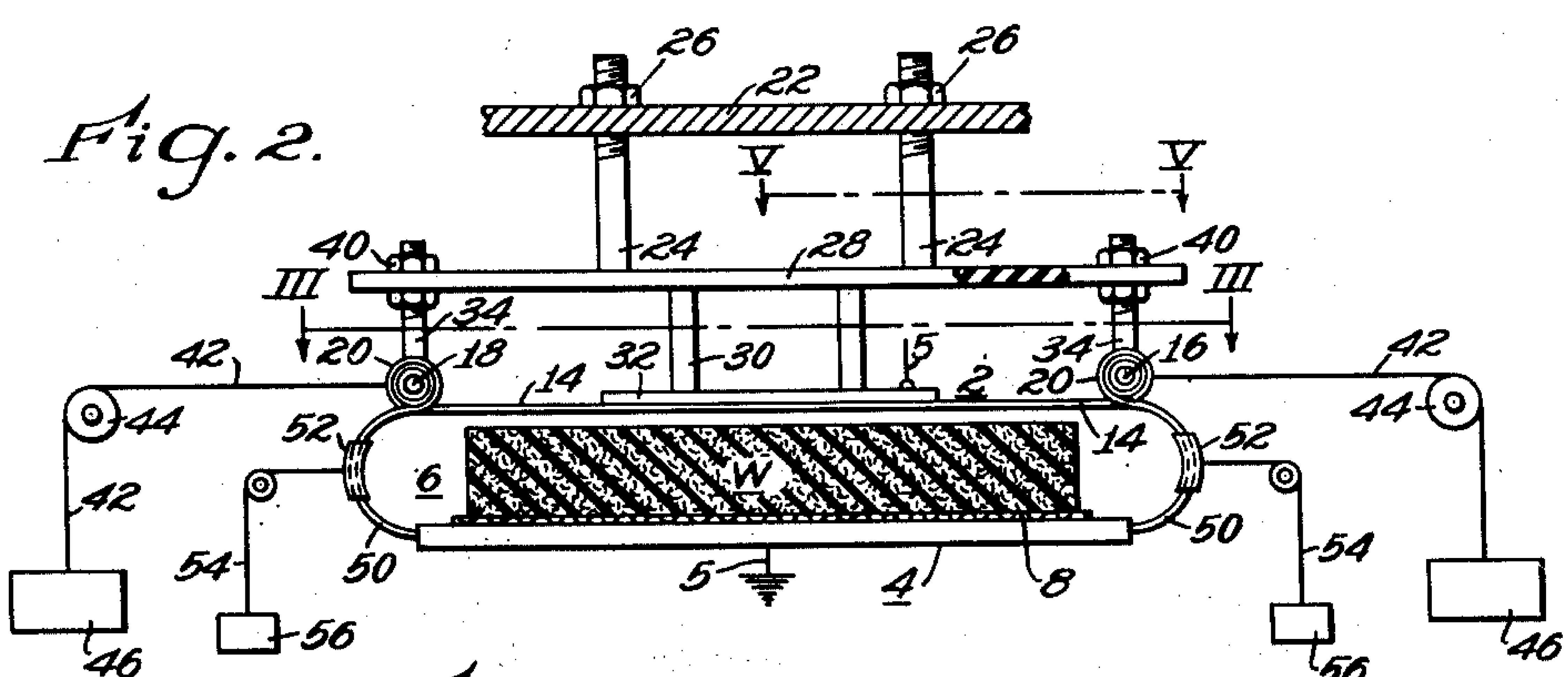


Fig. 3.

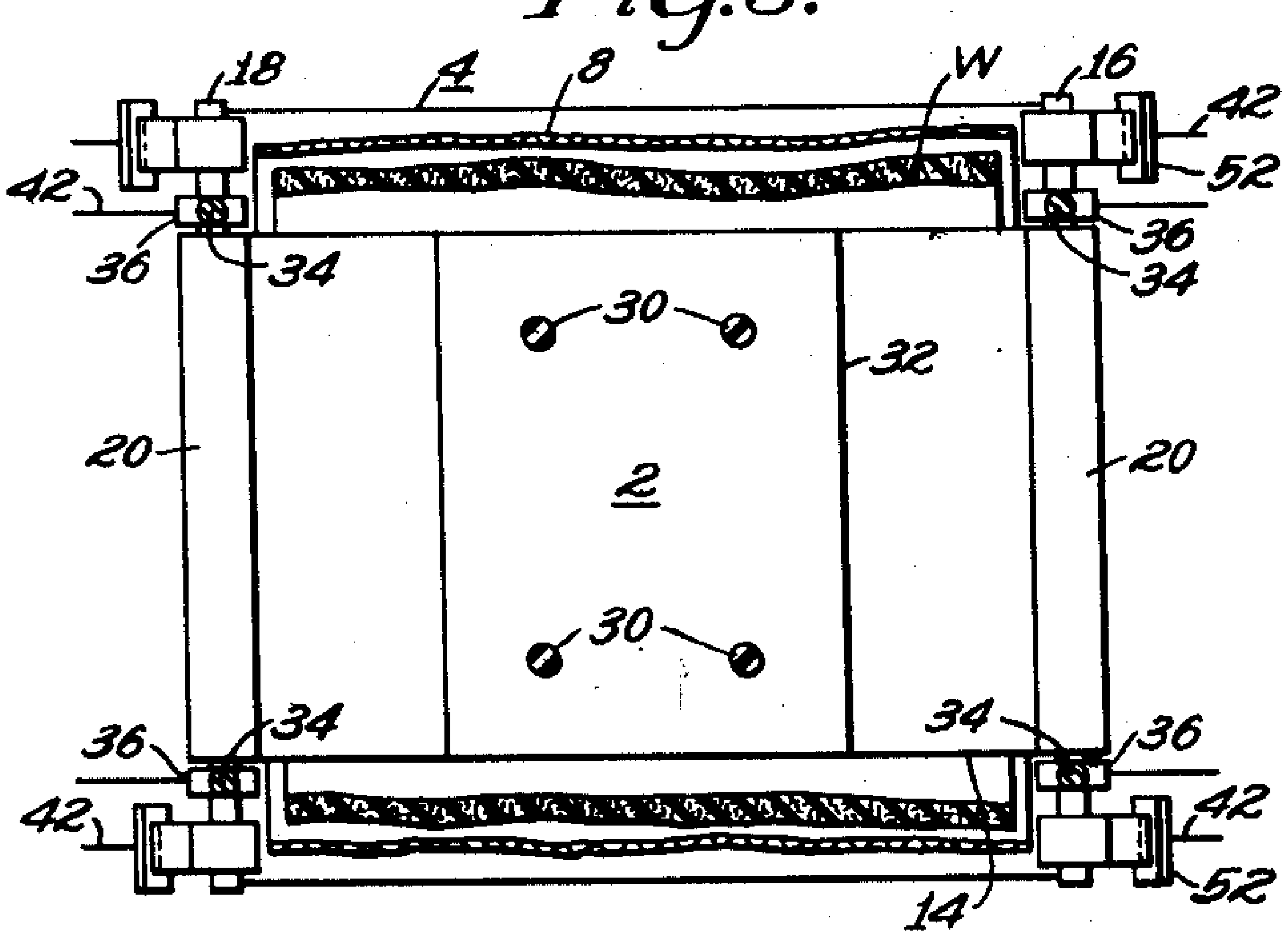


Fig. 6.

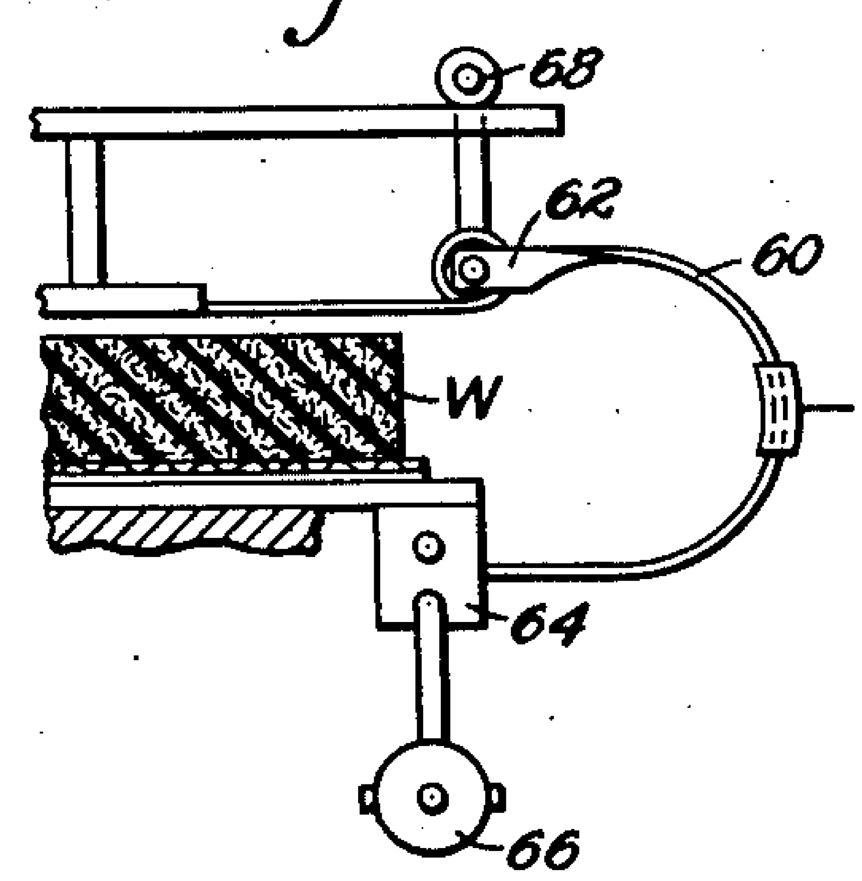


Fig. 4.

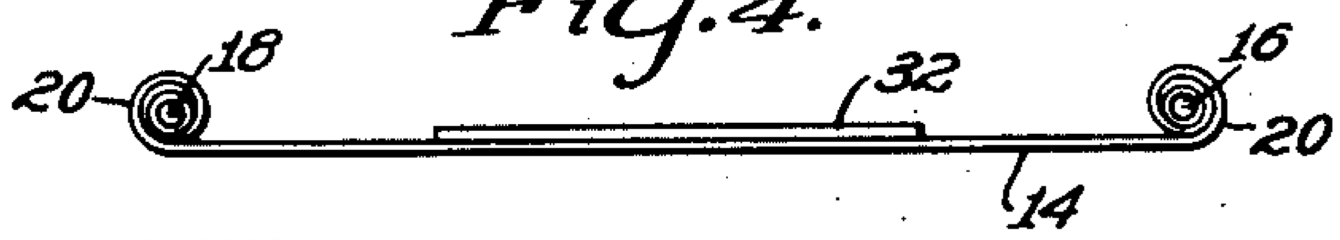
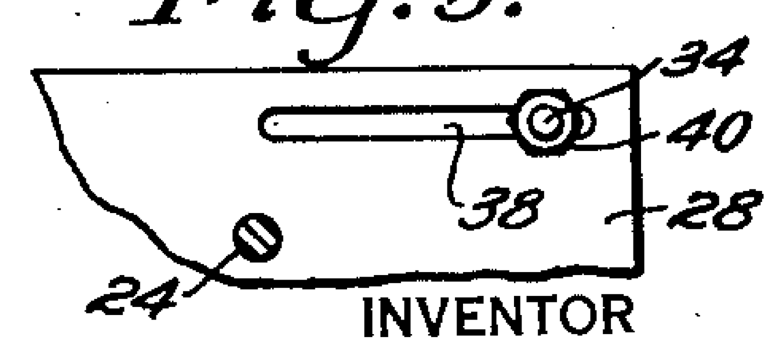


Fig. 5.



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UNITED STATES PATENT OFFICE

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ADJUSTABLE DIELECTRIC HEATING EQUIPMENT

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20 Claims. (Cl. 219—47)

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My invention is broadly directed to providing high-frequency dielectric heating means comprising a single set of spaced relatively insulated heating-electrodes of considerable area or expanse which can be readily adjusted to effectively heat materials of different physical characteristics or properties, and especially materials of different widths, which are separately passed between the heating-electrodes for dielectric heating.

The heating-electrodes of a dielectric heating means of a type with which my invention is concerned provide a capacitor which has a capacitance, at the supply frequency, that is determined by the physical construction and set up of the heating-electrodes and the physical constants of the material therebetween. Such a capacitor has a "Q" factor which is dependent upon the capacitance and the effective resistance of the material. Wide heating-electrodes can heat an elongated material of corresponding width; but if an elongated material of much narrower width is to be heated by the same heating-electrodes, the "Q" factor may rise to the point where power transfer from a high-frequency transmission line, or other power supply, to the heating-electrodes may be seriously impaired. The power transfer may become so low as to be insufficient to heat the material properly, or the power transfer may become so inefficient that corrective measures are justified.

In systems in which a high-frequency transmission line feeds the high-frequency energy into the heating load comprising spaced heating-electrodes, it is desirable to have the transmission line feed its energy into a load impedance, looking from the transmission line, which approaches the surge or characteristic impedance of the transmission line. Changing the width of progressively moving material to be heated may have a large and detrimental effect on this impedance matching. This detrimental effect on the impedance matching can be partially or wholly counterbalanced in accordance with my invention, by a corresponding change in the width of the heating-electrode. Such a change also keeps the "Q" factor more nearly constant.

For further providing a better impedance matching when the heating-electrode is changed in width, an embodiment of my invention incorporates a variable inductance across the spaced relatively insulated heating-electrodes. A network, consisting of the inductance in parallel with the capacitance between the heating-

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electrodes is thus formed. In one embodiment of my invention, to which I am not limited, the inductance is automatically increased or decreased by the same means which alters the width of the heating-electrode. This increase and decrease of inductance can be such that the network will remain substantially of the same effective impedance at the frequency of the power supply.

It is an object of my invention to provide a single dielectric heating means energized from a single source of high-frequency power, but capable of satisfactorily and efficiently dielectrically heating materials, or work, of various sizes and girths.

It is a further object of my invention to provide a dielectric heating means comprising a heating-electrode of comparatively large area but adjustable in one direction, for example, in width; the heating-electrode, however, presenting a continuous and smooth surface toward the material or work being dielectrically heated.

A further object of my invention is to provide a dielectric heating means for heating traveling material, the heating means having an adjustable heating-electrode of the type described, which can be quickly and easily changed to accommodate the width of the material being heated.

A further object of my invention is to provide a dielectric heating system of a type described, having an adjustable heating-electrode, with a variable inductance coil which is automatically varied whenever the heating-electrode is changed, for maintaining the electric relations of the network which includes the heating-electrodes.

Other objects, features and innovations of my invention will be discernible from the following description and generally schematic drawing of preferred embodiments, which are addressed to one skilled in the art who will readily understand how various parts of the embodiments, teaching the principles of my invention, can be altered without departing from the spirit and limits of the invention. In the drawing:

Fig. 1 is a view, partly in side elevation and partly in section, of an embodiment of my invention in which material or work is carried through a dielectric heating means on a conveyor;

Fig. 2 is a vertical view, at a right angle to Fig. 1, partly in elevation and partly in section, of apparatus in accordance with Fig. 1;

Fig. 3 is a vertical sectional view substantially on the line III—III of Fig. 2;

Fig. 4 is an edgewise view of the adjustable heating-electrode of Figs. 1, 2 and 3;

Fig. 5 is a sectional view substantially on the line V—V of Fig. 2; and

Fig. 6 is a fragmentary view corresponding to a portion of Fig. 1 but modified therefrom in several respects.

In Figs. 1–5 a dielectric heating means is shown which embodies my invention. The dielectric heating means comprises an upper heating-electrode **2** spaced from and insulated from a lower heating-electrode **4**. Preferably the heating-electrodes are of metal and have facing planar surfaces or faces of relatively large area or expanse to provide a work-space **6** therebetween. When the heating-electrodes are energized, as for example through high-frequency conductors **5**, a high-frequency field is established in the work-space **6**; and a dielectric material, such as, for example, rubber mats, therein will be heated. An upper run **8** of an endless conveyor **10** passes longitudinally along the top of the lower heating-electrode **4**, and carries the work W through the work-space **6** for dielectric heating. The conveyor may be slowly and continuously moved through the work-space **6** or may be moved intermittently in steps.

In the embodiment being described, the lower heating-electrode **4** is fixed in size and position, and is, preferably, grounded. The upper heating-electrode **2** comprises a continuous flexible metal strip **14** which has a fixed dimension, in this case length, in the direction in which the upper run **8** travels. In a transverse direction, shown in Figs. 2 and 4, the strip **14** has a variable dimension, in this case width, so that it can be adjusted to correspond to the width of whatever material is to be heat-treated or to the capacitance desired in the dielectric load consisting of the heating-electrodes and the material therebetween. To this end I provide separate spaced bar members or shafts **16** and **18** at opposite sides of the heating-electrode **2** and about which end portions of the metal strip **14** are spirally wrapped. The shafts **16** and **18** are arranged at opposite lateral sides of the work-space **6** so that the effective area of the upper heating-electrode **2**, which bounds or terminates the high-frequency electric field across the work-space **6**, constitutes substantially the flat portion of the strip **14**, or that portion which extends from the two roll or wound-up portions on the shafts. For identification the wound-up portions have been given the reference numeral **20**; but it is to be understood that in accordance with by invention, the diameters of wound-up portions **20** and the length of the flat portion of the strip **14** therebetween can be changed.

The upper heating-electrode **2** is supported in any suitable manner so that one or both of its ends can be independently wound or unwound, either manually by turning the shaft **16** or **18**, or automatically in any suitable manner. As more particularly shown in Fig. 2, a fixed main support **22** receives a plurality of screws **24** which are vertically adjustable in the support **22** by means of nuts **26**. The lower ends of the screws **24** carry an intermediate rectangular insulating supporting frame **28** which directly carries the heating-electrode **2**. Frame **28** centrally carries a plurality of insulators **30** to the far ends of which is secured a rigid member **32** in the form of a metal plate. A central portion of the strip **14** is

secured, as by welding, to the underside of the plate **32**, so that this portion of the strip will also be fixed in a position determined by the adjustment of the screws **24**.

Screw-rods **34** are carried at the four corners of the intermediate insulating frame **28**. Each of these screw-rods **34** terminates in a ring or bearing **36** which rotatably receives an end of a shaft **16** or **18** that extends longitudinally beyond the wound-up portion of the strip **14**. The position of each screw-rod **34** is transversely adjustable with respect to the intermediate frame **28**, as for example, by having each rod ride in a slot **38** which is elongated transversely to the direction of movement of the conveyor **10**, as shown in Fig. 5. Nuts **40** on the screw-rods **34** clamp the rods to the frame **28** in any desired adjusted position. When the nuts are loose, the screw-rods **34** slide in the slots **38** to allow the width of the strip **14** to be adjusted.

The distance between the heating-electrodes **2** and **4** can be adjusted through the nuts **26** on the screw-rods **24**. The width of the upper heating-electrode **2**, from shaft **16** to shaft **18**, can obviously be changed by winding or unwinding more or less of the strip **14** on the shaft **16**, or the shaft **18**, or both.

Changing the width of the heating-electrode **2** is accompanied by a change in the position of one or both of the wound-up portions **20** of the strip **14** with respect to its fixed central portion at the plate **32**. This changes the overlap of the surface of one heating-electrode with respect to the surface of the other. The position of each wound-up portion **20** with respect to this plate can also be changed by raising or lowering a shaft **16** or **18** in instances where it is desired to provide a non-uniform electric field along the path of travel of the material. However, it may be desirable to keep the flat portion of the strip **14** in a single level plane, in which case variations in the diameter of the wound portions of the strip on the shafts **16** and **18** may be compensated for by adjusting the nuts **40**. In order to help in aligning the flat portion of the strip so that it will be level whenever the strip-width is adjusted, each of the bearings **36** has an insulating cord **42** secured thereto. Each cord passes around a freely rotatable pulley **44** and extends to a suspended weight **46** to which it is tied. The weights **46** tend to keep the flat strip portion taut, while the apparatus is being adjusted. A particular advantage of using a single piece of metal for the strip **14** for the full width of the heating-electrode **2**, resides in the fact that a smooth and continuous surface for bounding the high-frequency heating-electric field in the work-space **6** is easily and economically provided.

From the foregoing structure it is apparent that I have provided dielectric heating means consisting of two relatively insulating heating-electrodes, one of which is wide enough to support a conveyor and the other of which can be adjusted to the width of the material that happens to be carried on the conveyor. In adjusting either the height or width of the upper heating-electrode **2**, the capacitance load branch circuit, which is fed by the high-frequency power supply, is altered; and, as explained in the copending application of W. H. Anderson and A. C. Frey, Serial No. 755,756, filed June 19, 1947, now Patent Number 2,583,133 it is sometimes desirable to have the heating-electrodes **2** and **4** in part of a parallel circuit which is tuned or resonant to the supply frequency, or in part of a network which is impedance matched to a transmission line. In the embodiment herein described, this may be done automatically by means of an adjustable tuning strap **50** at one or more corners of the heating-electrodes. An adjustable rolled tuning strap and a combination therewith are shown and claimed in the aforesaid application.

Each strap **50** has an end secured to the lower heating-electrode **4**. Its opposite end is wound on a protruding portion of the shaft **16** or **18**, as the case may be, but in a rotary direction which is opposite to that in which the strip **14** is wound on the particular shaft. In other words, looking at Fig. 2, the wound portion of the strip **14** at the left, is wound clockwise on the shaft **18**, whereas the strap **50** is wound counterclockwise on the same shaft. Accordingly, when this shaft **18** is turned for making the heating-electrode **2** narrower or decreasing the capacitance between the heating-electrodes **2** and **4**, a strap **50** unwinds and increases the inductance across the heating-electrodes **2** and **4** across which it is electrically and mechanically connected. The inductance strap or straps **50** need not be of uniform width but can be shaped so as to change the inductance in accordance with the variation in the capacitance between the heating-electrodes. In order to keep each strap-loop open and taut, an open slide member **52** may be provided through which the strap can slide. An insulating cord **54** is secured to the slide member **52**, and is held in tension by a weight **56**, so that the slide member presses on the strap-loop and tends to keep it open.

Instead of varying the inductance strap and the width of the upper heating-electrode **2** by a common mechanism, each inductance strap can be varied by looping one end of it around a shaft **16** or **18**, and carrying the other end on a shaft carried on the lower part of the lower heating-electrode **4**. Such an embodiment is shown in Fig. 6, in which a strap **60** has a turned end **62** having a hole through which a shaft, corresponding to **16** or **18**, freely passes. The other end of the strap **60** is wrapped around a shaft in a gearing **64** driven by a reversible electric motor **66**, as explained in the aforesaid patent application. A further feature of Fig. 6 lies in the supporting of the adjustable rods, which correspond to the rods **34**, on rollers **68**.

While I have described my invention in several preferred forms, it is obvious to one skilled in the art that the embodiments described are subject to wide variations and modifications within the principles of my invention.

I claim as my invention:

1. A dielectric heating means for heating different materials, comprising, in combination, a pair of spaced relatively insulated heating-electrodes, said heating-electrodes having substantially parallel and facing planar surfaces adapted to terminate an electric field, the said surface of a first of said heating-electrodes being smooth and unbroken throughout with an exposed area that faces the other of said heating-electrodes, said exposed area being adjustable respecting its physical dimensions, a conveyor device for carrying material in a predetermined direction between said heating-electrodes, the first said heating-electrode comprising a single and undivided member having a movable portion which is adjustable relative to the rest of the first heating-electrode for increasing and decreasing the size of its said surface.

2. A dielectric heating means for heating different materials, comprising, in combination, a pair of spaced relatively insulated heating-electrodes, said heating-electrodes having substantially parallel and facing planar surfaces adapted to terminate an electric field, the said surface of a first of said heating-electrodes being smooth and continuous throughout, a conveyor device for carrying material in a predetermined direction between said heating-electrodes, the first said heating-electrode having a movable portion which is adjustable for increasing and decreasing the size of its said surface, with said movable portion comprising a flexible strip forming a part of said surface.

3. A dielectric heating means for heating different materials, comprising, in combination, a pair of spaced relatively insulated heating-electrodes, said heating-electrodes having substantially parallel and facing planar surfaces adapted to terminate an electric field, the said surface of a first of said heating-electrodes being smooth and continuous throughout, a conveyor device for carrying material in a predetermined direction between said heating-electrodes, the first said heating-electrode having a movable portion which is adjustable for increasing and decreasing the size of its said surface, with said movable portion comprising a flexible strip forming a part of said surface, and characterized in addition by a winding means disposed so that a portion of said flexible strip can be wound on and unwound from said winding means.

4. A dielectric heating means for heating, comprising, in combination, a pair of spaced relatively insulated heating-electrodes, a first of said heating-electrodes comprising a predetermined fixed portion and a flexible portion having an end secured to the fixed portion, both portions defining a part of said work-space, and means for changing the expanse of said flexible portion along said part of said work-space, whereby to change the size of said work-space.

5. An invention in accordance with claim 4 but further characterized by said means for changing the expanse of said flexible portion being a winding device at the other end of said flexible portion.

6. A dielectric heating means of variable capacitance for heating different materials, comprising, in combination, a pair of relatively insulated heating-electrodes, means for supporting said heating-electrodes in predetermined spaced relation to form a work-space therebetween, a first of said heating-electrodes comprising a first fixed portion and a second flexible portion movable with respect to said first portion, said portions being on the same side of and forming part of said work-space, and being joined together so as to extend successively in a direction along said work-space.

7. An invention including that of claim 6 but further characterized by adjusting means attached to said flexible portion for changing the position of an end of said flexible portion of said strip with respect to said fixed portion, said adjusting means comprising a winding member having an axis associated with an end of said flexible portion, which is away from said fixed portion, upon which said flexible portion can be wound and unwound to variable extents for altering the extent of said first heating-electrode with respect to the other of said heating-electrodes said winding member also being linearly

movable in a line substantially perpendicular to its axis.

8. An invention including that of claim 6 but further characterized by said supporting means comprising a winding member associated with an end of said flexible portion, which end is away from said first portion, for winding and unwinding said flexible portion to variable extents, and means for keeping the unwound portion of said flexible strip taut.

9. An invention including that of claim 6 but characterized further by said portions comprising a strip having a continuous smooth surface extending across both of said portions.

10. An invention including that of claim 6 but characterized further by positioning means for changing the position of an end of said flexible portion with respect to said fixed portion and the other of said heating-electrodes, said positioning means comprising mechanism keeping said flexible portion taut.

11. An invention including that of claim 10 but characterized by said positioning means comprising a winding means for winding and unwinding said flexible portion to variable extents, said winding means comprising a rotatable bar with an end of said flexible portion being wrapped around said bar, and further characterized by a variable inductance strap, said strap having its ends electrically and mechanically fastened to said heating-electrodes, the mechanical fastening including a member for increasing and decreasing the length of said strap.

12. A dielectric heating means of a type described comprising, a supporting frame, a heating-electrode, an adjustable rod-mechanism secured to the frame for adjustably carrying the heating-electrode, said heating-electrode comprising a flexible strip having a spirally wrapped portion and an unwrapped portion, means for changing the size of the surface of said heating-electrode, said means comprising a winding and unwinding mechanism for said spirally wrapped portion, and means for keeping said unwrapped portion taut.

13. A dielectric heating-electrode of a type described comprising a plate member having a flexible strip secured to a face thereof, said strip having an end portion extending beyond said plate member, and a bar member on which said end portion is spirally wound.

14. An invention including that of claim 13 but characterized further by said strip member substantially covering the face of the plate member.

15. Dielectric heating means comprising, a pair of spaced relatively insulated heating-electrodes providing a work-space therebetween, an adjustable inductance strap across said heating-electrodes, a surface area of a first of said heating-electrodes being adjustable to vary the capacitance of said work-space, and common gearing for simultaneously varying the length of said strap and the area-extent of the surface of said first heating-electrode.

16. In combination, a parallel resonant circuit comprising a pair of spaced electrodes forming a capacitance, an inductance device connected across said electrodes to form an inductance, a first of said electrodes comprising a rollable portion, means to wind and unwind said portion to vary said capacitance, and means operable simultaneously with said winding means to adjust said device to increase said inductance when said portion is wound and to decrease said inductance when said portion in unwound.

17. Dielectric heating means comprising a pair of spaced heating-electrodes having facing overlapping surfaces, means supporting said heating-electrodes in an arrangement in which said surfaces are spaced and have a predetermined overlap and form a capacitance therebetween, a variable inductance device connected across said heating-electrodes to form an inductance, means operable for changing said arrangement to change said overlap, thereby varying said capacitance, and means simultaneously operable with said arrangement-varying means for varying said device to decrease its inductance when said overlap is increased and to increase its inductance when said overlap is decreased.

18. A dielectric heating means of variable capacitance for heating different materials, comprising, in combination, a pair of relatively insulated heating-electrodes, means for supporting said heating-electrodes in predetermined spaced relation to form a work-space therebetween, and a conveyor device to carry work into and out of said work-space in a predetermined direction, a first of said heating-electrodes comprising an integral and undivided member, said member being adjustable such that it provides an exposed surface of adjustable width transversely of said direction.

19. A dielectric heating means as defined in claim 18 but further characterized by said surface being smooth and unbroken over its entire exposed surface in all of its adjustments.

20. A dielectric heating means as defined in claim 18 but further characterized by an adjustable inductance device connected across said heating-electrodes, and means for simultaneously adjusting the width of said surface and said device but in opposite magnitude-directions.

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