

July 4, 1967

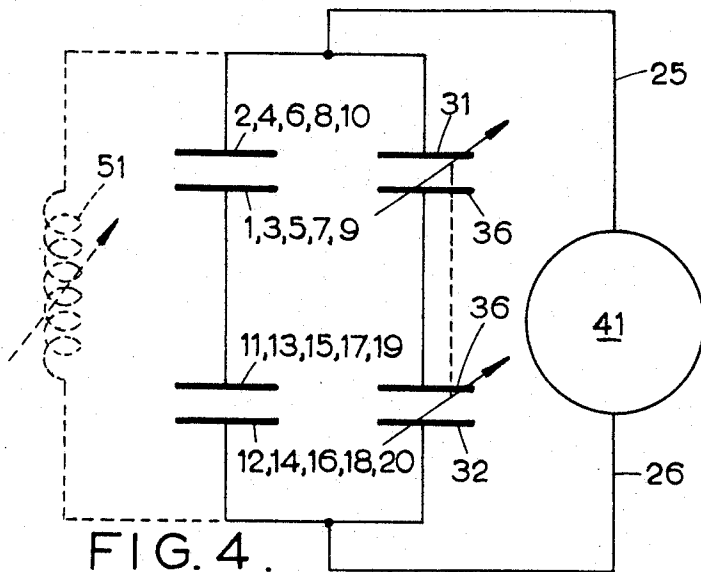
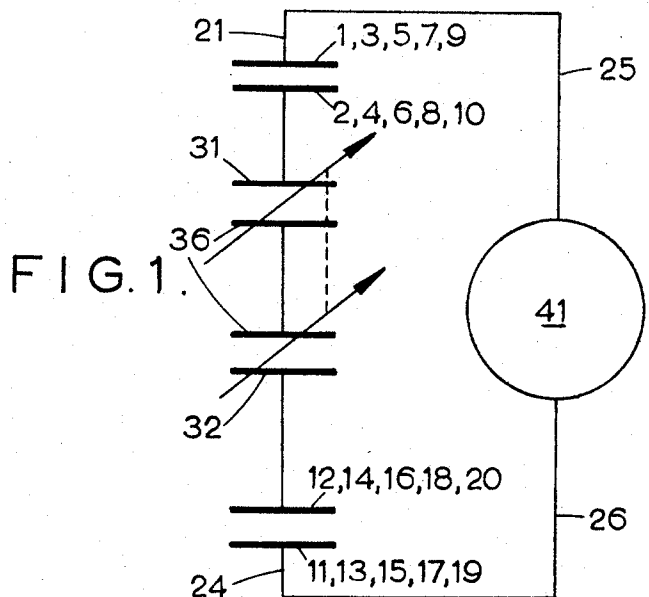
J. McDOUGALL CLARK

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HIGH-FREQUENCY HEATING APPARATUS

Filed Jan. 12, 1965

5 Sheets-Sheet 1



INVENTOR

JOHN McDOUGALL CLARK

BY

Holte and Holte

ATTORNEYS

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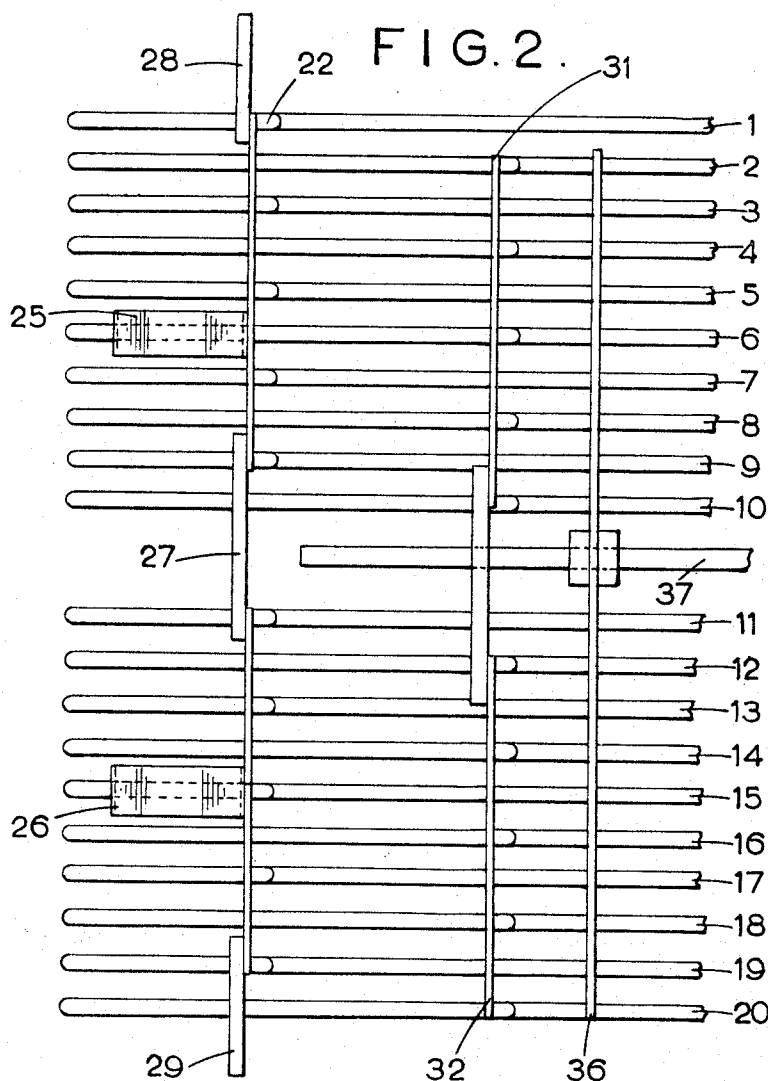
J. McDOUGALL CLARK

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HIGH-FREQUENCY HEATING APPARATUS

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INVENTOR

BY JOHN McDOUGALL CLARK

Holte and Holte

ATTORNEYS

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J. McDOUGALL CLARK

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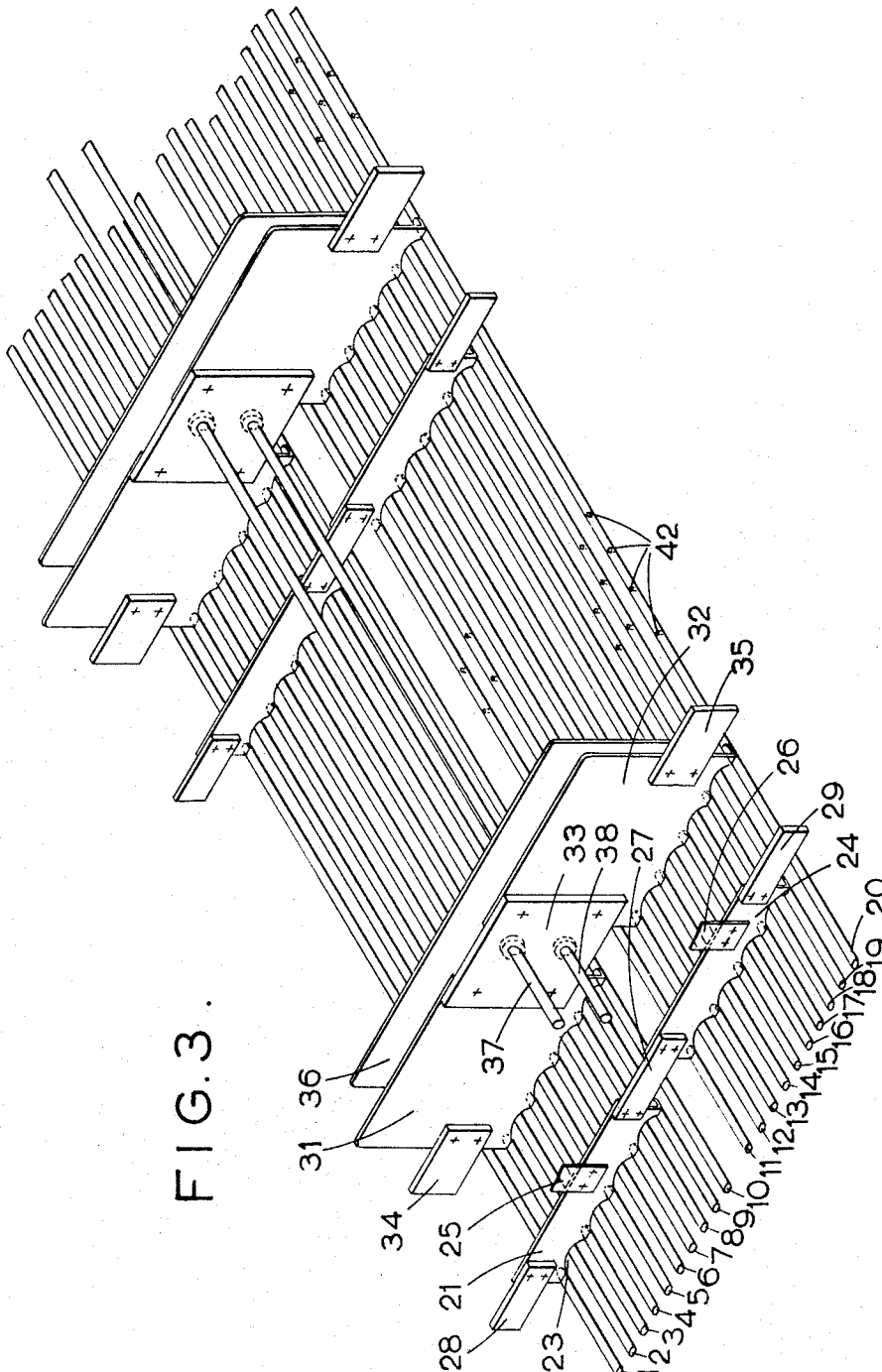


FIG. 3.

INVENTOR

BY JOHN McDOUGALL CLARK
Wolfe and Wolfe
ATTORNEYS

July 4, 1967

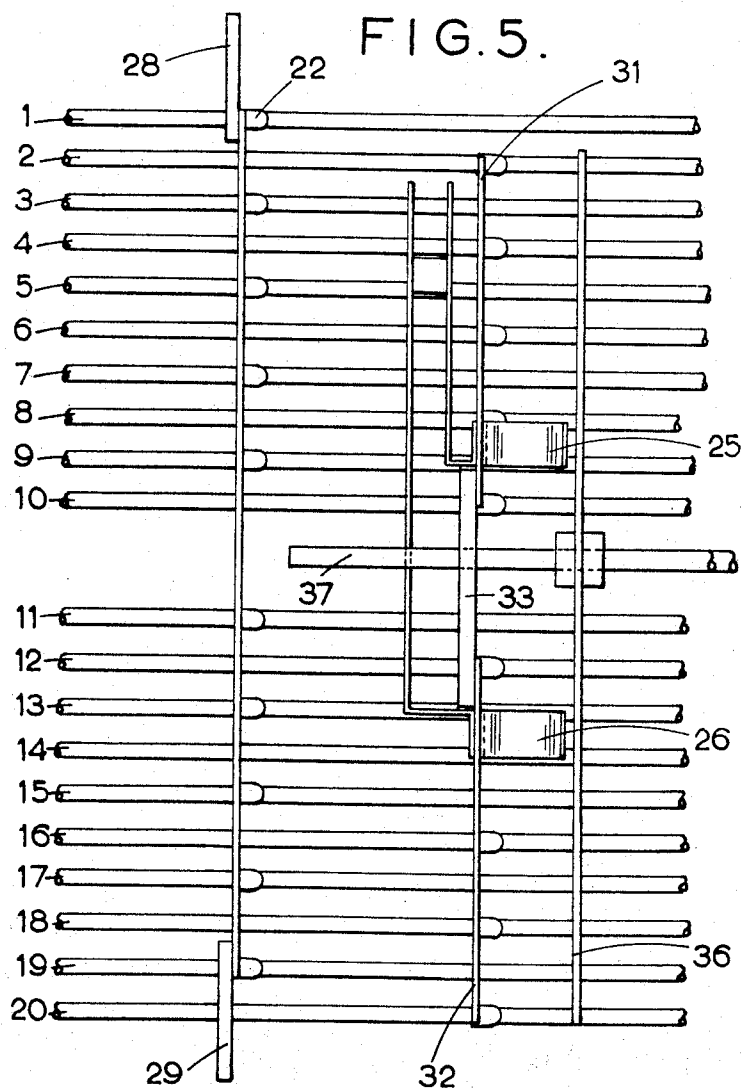
J. McDOUGALL CLARK

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HIGH-FREQUENCY HEATING APPARATUS

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5 Sheets-Sheet 4



INVENTOR

JOHN McDougall Clark

BY

holte and holte

ATTORNEYS

July 4, 1967

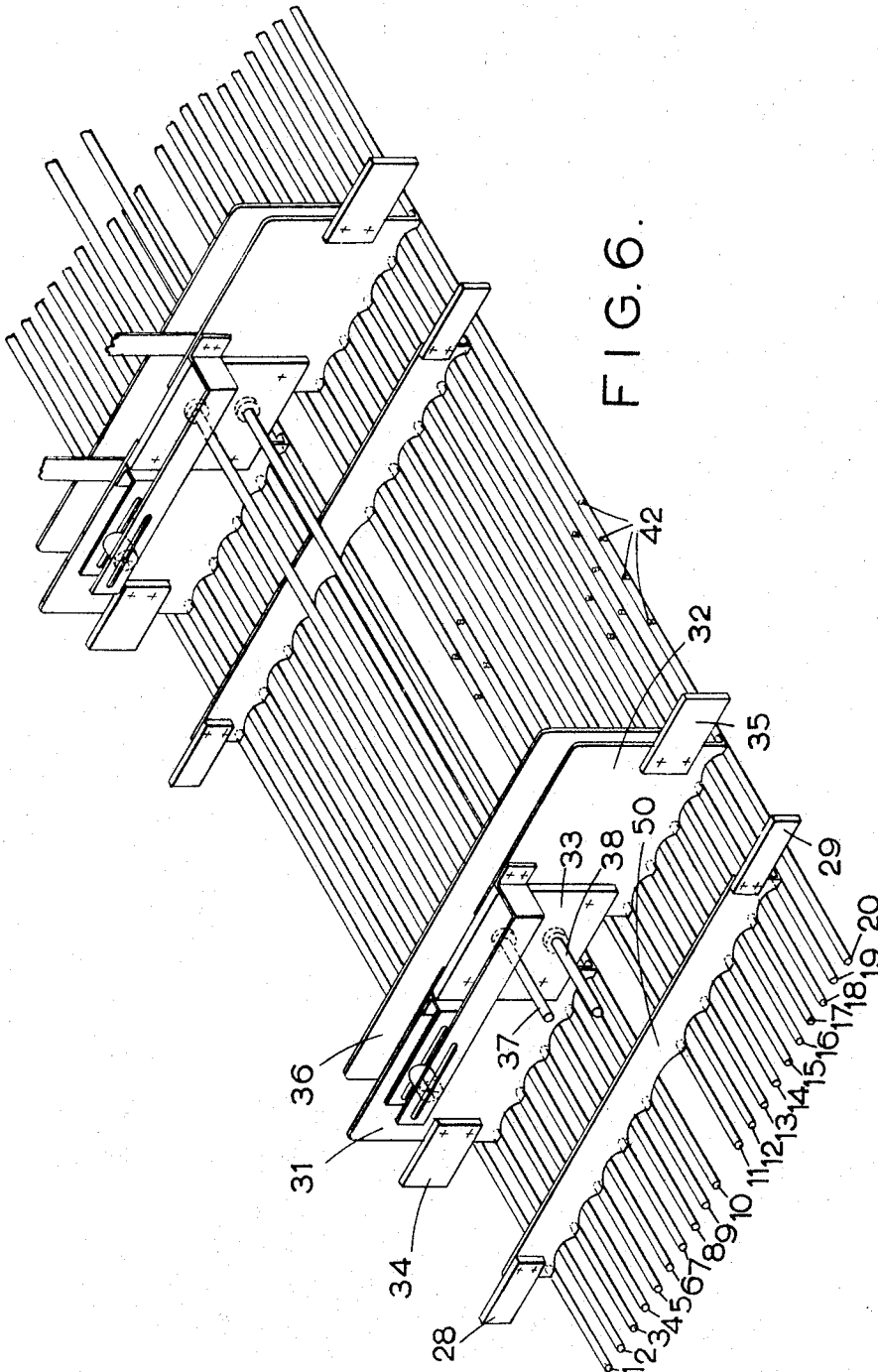
J. McDOUGALL CLARK

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HIGH-FREQUENCY HEATING APPARATUS

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5 Sheets-Sheet 5



INVENTOR

JOHN McDOUGALL CLARK

BY

Wolfe and Wolfe

ATTORNEYS

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3,329,797

HIGH-FREQUENCY HEATING APPARATUS

John McDougall Clark, Surbiton, Surrey, England, assignor to Intertherm Limited, London, England, a British company

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13 Claims. (Cl. 219—10.81)

This invention relates to high-frequency heating apparatus and is particularly concerned with H.F. heating apparatus employing stray-field platens.

Stray-field platens for dielectric heating purposes are known and generally comprise a plurality of non-ferrous rods equally spaced apart side-by-side. Alternate rods are supplied with H.F. current of a different polarity. This means that there is in effect a number of capacitors each having an air dielectric.

When a material to be heated is brought near to the platen, say within a distance which is 5 to 10% of the distance between adjacent rods of the platen, the field between the rods will divert to pass through the material and the amount of the field which will be diverted depends on the dielectric loss factor of the material, hence if it is a very lossy material a greater part of the field will be diverted. The material thus acts as a dielectric between two electrodes (the rods of the platen) and due to the rapidly alternating voltage difference between the rods, dielectric heating is produced in the material.

Stray-field platens have been used successfully in continuous flow-production techniques, particularly for the processing of thin materials, for example in the drying of leather, paper, carpets, etc. However, it has only been possible to achieve satisfactory uniform heating of material which has a relatively short width of under about four feet. Above this width difficulty has been experienced in obtaining an even heat distribution over the whole width, due to the creation of standing waves in the platen. It will be appreciated that the higher the H.F. frequency used the more acute the problem becomes.

Since the generator supplying power to the platen has usually a fixed frequency, it is common practice to incorporate into the apparatus means for tuning the work circuit rather than the generator and this tuning means can be arranged to compensate in part for standing waves. To date the most satisfactory method of tuning has been by using stub tuning inductors which are variable inductances connected in parallel with the work circuit to alter the resonant frequency. This method of tuning is very peaky and has the disadvantage that it makes the whole of the apparatus extremely sensitive to small variations in load capacitance, which might be brought about by surface irregularities, moisture content, differences in the thickness of parts of the workpiece, or change in dielectric properties, and this sensitivity is reflected in power changes in the workpiece being processed.

An object of the present invention is to provide high-frequency heating apparatus in which the problem of standing waves is substantially overcome in long stray-field platens, whilst being able to vary the power in the work circuit, and whereby the apparatus is not sensitive to small changes in load capacitance.

According to one of the important features of the present invention there is provided a high-frequency heating apparatus including a stray-field platen assembly comprising a plurality of rod-like electrodes in substantially coplanar arrangement. The electrodes are supplied alternately with high-frequency current. The electrodes are arranged in at least two similar groups. Variable capacitor means are directly mounted on the platen assembly for

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tuning the electric circuit of which it forms part. At least one rigid bus-bar is electrically connected to and mechanically supports alternate ones of the electrodes. The variable capacitor means include at least one fixed plate electrically connected to and mechanically supporting electrodes intermediate the alternate electrodes.

One of said groups may be arranged to be directly connected to one of the terminals of an H.F. current-supply source, the other group of electrodes being connected to a first fixed plate of said variable capacitor means, the latter also having a movable second plate serving as a linking element to couple in a series capacitive manner the two groups of electrodes.

The use of series capacitive coupling instead of parallel inductive coupling gives an apparatus in which standing waves can be substantially eliminated without making the apparatus too sensitive to small changes in load capacitance.

The variable capacitor means may include two series-connected capacitors of which at least one is variable, said capacitors being connected in parallel with the stray-field platen.

If only two groups of rods are used, the movable plate of the capacitance means can be made common to both groups. If, however as may be the case, a number of intermediate groups of rods are used between the two groups, then the second movable plate would link a group with an adjacent intermediate group and each of the intermediate groups would be similarly series capacitively coupled to its adjacent group.

In practice the variable capacitance means is preferably comprised of a number of parallel-connected variable capacitors spaced along the length of the platen and ganged together. The ganging can be such that all capacitors are varied by the same amount or, to introduce a wider control of variation, the ganging may be such that one capacitor is varied more than another. This latter arrangement can be achieved by a suitable mechanical gearing or linkage ratio arrangement.

The supply to the rods may be through the bus-bars which provide direct mechanical supports for the rods. In such a case the bus-bars are connected to alternate rods, and a gap exists between the bus-bar and the rod between two linked rods. This rod is of opposite polarity to the bus-bar and the distance between it and the rod is preferably equal to the distance between adjacent rods of the platen. The best way of achieving this is to make the gap of a semi-circular configuration having a radius substantially equal to the distance between adjacent rods.

Both the bus-bars and the capacitance means are preferably constructed as plates of rigid material and are disposed substantially perpendicularly to the general plane of the platen. The bus-bars and the capacitance means may be supported by any suitable means such as, for example, in an electrically insulated manner by brackets or arms which are part of the body of the apparatus.

Other objects and advantages of the invention will be appreciated and more fully understood with reference to the following description of two preferred embodiments of the invention, by way of example, when considered with the accompanying drawings, wherein part of a high-frequency heating apparatus is shown for curing a polyvinyl chloride backing of a broadloom type of carpet having a twelve foot width and manufactured on a continuous flow production system; more particularly.

FIG. 1 illustrates the general circuit layout of a first embodiment;

FIG. 2 is a plan view of part of the apparatus of the first embodiment;

FIG. 3 is an isometric view of the apparatus shown in FIG. 2;

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FIG. 4 illustrates the circuitry of a second embodiment; FIG. 5 is a plan view of part of the apparatus of the second embodiment; and

FIG. 6 is an isometric view of the apparatus shown in FIG. 5.

Referring now to FIGS. 1, 2 and 3, the preferred first embodiment of the apparatus according to the invention comprises a stray-field platen, under which the back of the carpet (not shown) passes, having twenty twelve-foot long electrode rods marked 1, 2, 3 . . . 20 and disposed over the width of the carpet. All rods are arranged in a horizontal plane and in two similar groups 1 to 10 and 11 to 20, of ten aluminum-alloy rods each, each of the rods in each group being separated from the adjacent rod by an air gap of $1\frac{1}{2}$ inches and the two groups of rods being separated by a larger air gap.

Considering the rods of the first group 1 to 10, to each odd-numbered rod (e.g. 1, 3, 5, etc.) of the group a supply bus-bar 21 is connected. This bus-bar comprises a strip of aluminum vertically arranged on edge and having a lug 22 by which it is screwed to each odd-numbered rod. A semi-circular air gap 23 exists between each of the even-numbered rods (e.g. 2, 4, 6, etc.) and the bus-bar 21 and this air gap has a radius of $1\frac{1}{2}$ inches.

The second group of rods 11 to 20 has its odd-numbered rods connected to a similar bus-bar 24. Each bus-bar 21, 24 has connected to it a separate lead 25, 26, respectively. The two bus-bars 21, 24 are joined by a rigid, electrically insulating member 27 and are supported at their ends by insulated fixing straps 28, 29.

Spaced along the length of the platen a vertically arranged aluminum plate 31 is fixed to the even-numbered rods of the first group 1 to 10 in a manner similar to the manner in which the bus-bar 21 is attached to the odd-numbered rods. A similar plate 32 is attached to the even-numbered rods of the second group 11 to 20. The fixed plates 31, 32 associated with each group of rods are joined together by an insulating plate 33. Both fixed plates 31, 32 are rigidly secured to the body of the apparatus by insulated mounting plates 34, 35, respectively.

A movable plate 36 of a variable capacitor, of which plates 31, 32 form part, is located on drive shafts 37, 38 journaled in the insulating plate 33 joining the two fixed plates 31, 32. This movable plate 36 is common to the two fixed plates 31, 32 and is parallel to them. The drive shafts 37, 38 are connected to a suitable mechanism (not shown) whereby the movable plate 36 can be moved towards or away from the fixed plates 31, 32 to vary the air gap and hence the capacitance between them.

An H.F. generator 41 operating at 40 mc./s. and 30 kw. is connected via lead 25 to the bus-bar 21 of the first group of rods and via lead 26 to the bus-bar 24 of the other group of rods. When the current is switched on and a carpet is passed beneath the platen, the field from the odd-numbered rods 1, 3, 5, 7, 9 of the first group passes through the P.V.C. backing to the carpet, in which it generates heat which cures the P.V.C., to the even-numbered rods 2, 4, 6, 8, 10, to the fixed plate 31 of the capacitor, through the capacitor which acts on account of the common movable plate 36 as a series connected link, to the fixed plate 32 of the second group, and hence to the other bus-bar 24 via the rods 11 to 20 and the carpet backing. To vary the tuning of the apparatus, to make it resonate at the correct frequency, the movable plate 36 is altered in position relative to the fixed plate and the control of the heat developed in the carpet is therefore dependent on the setting of the capacitor.

In practice a number of such capacitor and bus-bar arrangements, of which two are shown in FIG. 3, are situated along the length of the platen in a parallel arrangement. The drive shafts of the movable plates are common to all plates and are connected to a single drive mechanism. Provision is made at 42 on the rods for attaching the bus-bars and fixed plates at different positions dependent on operating conditions of the apparatus.

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Referring now to the second embodiment shown in FIGS. 4, 5 and 6, it will be noted from FIG. 4 that the load capacitors formed by the two groups of rod electrodes 1 to 10 and 11 to 20 are connected in series and that this series combination is connected in parallel across the generator 41 with the series combination formed by the variable capacitor comprising plates 31, 32, 36. All the odd-numbered rods are connected together by a common bus-bar 50 and the fixed plates 31, 32 are used not only as capacitor plates but also as bus-bars for the rods 2, 4, 6, 8, 10 of the first group, and 12, 14, 16, 18, 20 of the second group, respectively. The leads 25, 26 are respectively connected to these plates 31, 32.

This embodiment also incorporates a variable inductance 51 which is connected in parallel with tuning capacitors and the load and affords a means whereby the tuning may be preset to a certain degree before heating commences. The inductor 51 has been shown dotted in FIG. 4 since it is optional in the embodiment. It could be used as a coarse tuner while the variable capacitor is used as a fine tuner.

As is shown in FIG. 6, sets of capacitor plates are spaced along the platen connected to a common shaft. When the shafts 37, 38 are rotated, all the movable plates 36 move to alter the capacitance and hence the tuning of the resonant circuit. The shafts 37, 38 may be operated by hand or by a motor connected to a monitoring circuit. If the standing-wave pattern in the platen is found to be irregular it may be necessary to incorporate a geared linkage system to the drive shafts and movable plates, whereby the movable plates in, say, the middle of the platen are geared to move a greater distance than those at the ends of the platen for the same degree of rotation as the shafts 37, 38.

The embodiments described have been found in practice to substantially reduce the problems caused by standing waves in long stray-field platens without the apparatus being very sensitive to small changes in load capacitance.

The foregoing disclosure relates only to preferred embodiments of the invention, which is intended to include all changes and modifications of the examples described within the scope of the invention as set forth in the appended claims.

What I claim is:

1. A high-frequency heating apparatus comprising a stray-field platen assembly including a plurality of rod-like electrodes in substantially coplanar arrangement, means for supplying said electrodes alternately with high-frequency current, said electrodes being divided into at least two similar groups, variable capacitor means directly mounted on said platen assembly for tuning the electric circuit of which it forms part, and at least one rigid bus-bar electrically connected to and mechanically supporting alternate ones of said electrodes, said variable capacitor means including at least one fixed plate electrically connected to and mechanically supporting electrodes intermediate said alternate electrodes.

2. A high-frequency heating apparatus as claimed in claim 1, further comprising a high-frequency current supply source, a first rigid bus-bar electrically connected to and mechanically supporting alternate ones of a first group of said electrodes, a second rigid bus-bar electrically connected to and mechanically supporting alternate ones of a second group of said electrodes, said first and second bus-bars being electrically connected to opposite terminals of said high-frequency current supply source, and wherein said variable capacitor means comprises a first variable capacitor having a fixed plate electrically connected to and mechanically supporting electrodes intermediate said alternate electrodes of said first group, a second variable capacitor having a fixed plate electrically connected to and mechanically supporting electrodes intermediate said alternate electrodes of said second group, and a movable plate common to said first and second capacitors, said first and second capacitors

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being electrically connected in series between said first and second groups of electrodes.

3. A high-frequency heating apparatus as claimed in claim 2, wherein said first and second bus-bars are coplanar and a first rigid plate of insulating material mechanically interconnects said bus-bars, and wherein said fixed plates of said first and second capacitors are coplanar and a second rigid plate of insulating material mechanically interconnects said fixed plates.

4. A high-frequency heating apparatus as claimed in claim 1, further comprising a high-frequency current supply source, and wherein said bus-bar is electrically connected to and mechanically supports alternate ones of a first group of said electrodes and alternates ones of a second group of said electrodes, and said variable capacitor means comprises a first variable capacitor having a fixed plate electrically connected to and mechanically supporting electrodes intermediate said alternate electrodes of said first group, a second variable capacitor having a fixed plate electrically connected to and mechanically supporting electrodes intermediate said alternate electrodes of said second group, and a movable plate common to said first and second capacitors, said first and second groups of electrodes being electrically connected in series by means of said bus-bar, said first and second capacitors being electrically connected in series by means of said common movable plate, said series-connected first and second groups of electrodes being electrically connected in parallel with said series-connected first and second capacitors, said fixed plates of said first and second capacitors being electrically connected to opposite terminals of said high-frequency current supply source.

5. A high-frequency heating apparatus as claimed in claim 4, wherein said fixed plates of said first and second capacitors are coplanar and a rigid plate of insulating material mechanically interconnects said fixed plates.

6. A high-frequency heating apparatus as claimed in claim 2, wherein substantially semi-circular gaps are provided in said first and second bus-bars in the regions of electrodes intermediate said alternate electrodes and substantially semi-circular gaps are provided in said fixed plates of said first and second capacitors in the regions of said alternate electrodes.

7. A high-frequency heating apparatus as claimed in claim 4, wherein substantially semi-circular gaps are provided in said bus-bar in the regions of the electrodes intermediate said alternate electrodes and substantially semi-circular gaps are provided in said fixed plates of said first and second capacitors in the regions of said alternate electrodes.

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8. A high-frequency heating apparatus as claimed in claim 6, wherein the radius of each of said gaps is substantially equal to the distance separating adjacent ones of said electrodes.

9. A high-frequency heating apparatus as claimed in claim 7, wherein the radius of each of said gaps is substantially equal to the distance separating adjacent ones of said electrodes.

10. A high-frequency heating apparatus as claimed in claim 2, further comprising at least another set of rigid bus-bars and variable capacitors similar to said first-mentioned bus-bars and capacitors, respectively, and spaced apart therefrom, said other bus-bars and variable capacitors being electrically connected to and mechanically supporting said electrodes in similar manner to said first-mentioned bus-bars and capacitors, respectively, and driving means common to said first-mentioned capacitors and to said other capacitors for simultaneously varying the capacitance of said first-mentioned and other capacitors.

11. A high-frequency heating apparatus as claimed in claim 10, wherein said common driving means includes means for varying the capacitance of said other capacitors at a different rate from said first-mentioned capacitors.

12. A high-frequency heating apparatus as claimed in claim 4, comprising at least another set of a rigid bus-bar and variable capacitors similar to said first-mentioned bus-bar and capacitors, respectively, and spaced apart therefrom, said other bus-bar and variable capacitors being electrically connected to and mechanically supporting said electrodes in similar manner to said first-mentioned bus-bar and capacitors, respectively, and driving means common to said first-mentioned capacitors and to said other capacitors for simultaneously varying the capacitance of said first-mentioned and other capacitors.

13. A high-frequency heating apparatus as claimed in claim 12, wherein said common driving means includes means for varying the capacitance of said other capacitors at a different rate from said first-mentioned capacitors.

References Cited

UNITED STATES PATENTS

2,288,269	6/1942	Crandell	219—10.81 X
2,342,846	2/1944	Crandell	219—10.81 X
2,723,517	11/1955	Mittelmann	219—10.81

RICHARD M. WOOD, *Primary Examiner*.

ANTHONY BARTIS, *Examiner*.

L. H. BENDER, *Assistant Examiner*.