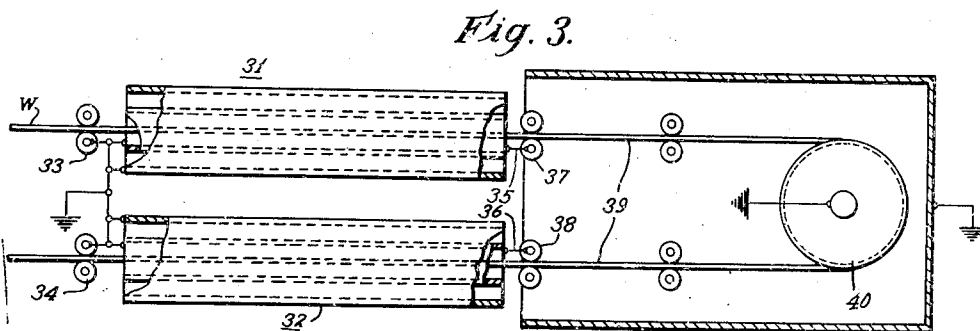
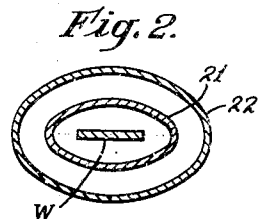
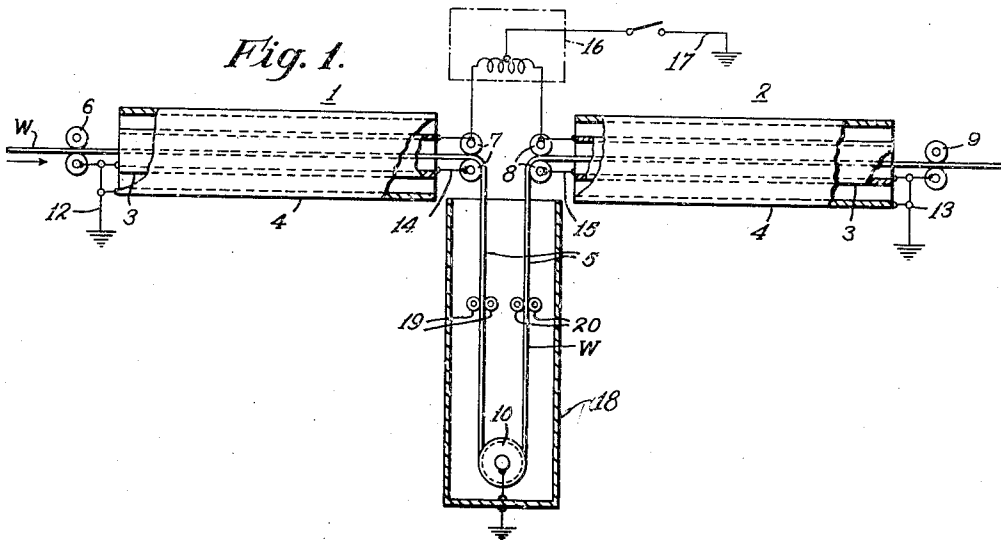


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MEANS FOR HIGH-FREQUENCY CONDUCTION HEATING
OF ELONGATED METALLIC MATERIAL
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WITNESSES:

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MEANS FOR HIGH-FREQUENCY CONDUCTION HEATING OF ELONGATED METALLIC MATERIAL

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My invention broadly relates to the high-frequency heating of elongated conductive material, such as one or more wires, strip and the like, as the material progressively moves. My invention more specifically relates to a type of heating system in which elongated material is fed through a high-frequency heating means in such a manner that the length of the material in the heating region is commensurate with the wave length corresponding to the frequency or frequencies of the current from an alternating-current power source, such as for example, a tube-oscillator power source, which feeds the heating means.

An object of my invention is to provide a conduction heating system for a fine wire.

Another object of my invention is to provide a small simple system for effectively and efficiently concentrating considerable power in a small part of a fine wire travelling at a high speed.

A further object of my invention is to introduce large heating power into a moving wire, strip, or the like, with minimum losses.

In accordance with my invention, a high-frequency system is provided for heating elongated material by conduction. The system, in effect, establishes standing wave patterns of voltage and current in the material, the total wave pattern being limited in length so as to prevent excessive power loss, and the heating being concentrated in a fraction of that distance where the current is highest. The system is especially suitable for heating travelling material because power can be supplied to it through conducting members located at the current nodal points. The conducting members are preferably guiding rollers.

Other objects, innovations and features of my invention will be discernible from the following description which is to be taken in conjunction with the accompanying schematic drawing, in which:

Figure 1 is a diagram of a simplified system representative of a preferred form of my invention;

Fig. 2 is a cross sectional view of a part of a system for heating a plurality of wires or a comparatively wide strip; and

Fig. 3 is a view, similar to that of Fig. 1, of a modified form of the invention.

The embodiment shown in Fig. 1 comprises a pair of similar axially-aligned quarter-wave-length isolating sections 1 and 2 each in the form of a coaxial transmission line comprising concentric hollow inner and outer cylinders or tubes

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3 and 4, respectively. The embodiment of Fig. 1 is intended to heat a single wire so that the cylinders are preferably circular in cross section. The work to be heated, in the form of round iron wire W, in tension, first passes axially through the inner tube 3 of the entrance section 1, then follows a loop 5 having straight sides between the sections 1 and 2, and finally passes axially through the inner tube 3 of the exit section 2. Preferably, the isolating sections are of copper or other material of much higher electrical conductivity than the work, or of much lower magnetic permeability than the work, or both. It is to be understood that the work, or the wire in this case, may be unrolled from a coil before passing through the heating means and then finally cut into lengths, rewound on a reel for forming a second coil, or otherwise handled. Other treating steps may be included along the path of travel of the work.

Metallic or conducting guiding rollers 6 position the wire at the entrance end of the section 1; conducting guiding rollers 7 and 8 respectively, insulated from ground, guide the wire at the exit end of the section 1 and at the entrance end of the section 2, in other words at the ends of the loop 5; and conducting guiding rollers 9 position the wire at the exit end of the section 2. The central point or middle of the loop 5 is wrapped around a grounded roller 10. The loop-length is the distance of one side of the loop 5, and the length of material between the isolating sections is at least twice this loop-length.

The rollers 6 and the ends of the tubes 3 and 4 at the wire-entrance end of section 1 are maintained at the same potential, preferably ground, by any suitable means, indicated as a grounded conductor 12; and a similar means, shown as a grounded conductor 13, maintains the rollers 9 and the ends of tubes 3 and 4 at the wire-exit end of the section 2, at the same potential, preferably ground. The portion of the wire W contacting the rollers 7 is kept, by a conductor 14, at the potential of the exit-end of the inner tube 3 of the section 1, and the portion of the wire 5 contacting the rollers 9 is kept, by a conductor 15, at the potential of the entrance end of the inner tube 3 of section 2.

The length of each of the isolating sections 1 and 2 is one quarter of the wave length which corresponds to the frequency of the power supply, and the total length of the wire comprising loop 5 is one-half of this wave length. Preferably the total length of the material in the loop should be equal to $2 + 4n$ quarter wave lengths,

where n is any positive integer, including zero. The corresponding loop-length would be $1+2n$ quarter wave lengths. A high-frequency power supply 16 is connected across the insulated ends of the inner tubes 3 or across the rollers 7 and 8. Preferably the voltage source is not grounded, so that the current flow into and from the wire takes place at the current nodal points at the rollers 7 and 8. However, the central point of the power source can, if desired, be grounded, as schematically indicated by the conductor 17 having a switch for interrupting the grounding connection.

In the embodiment shown, each half of the loop 5 electrically constitutes one conductor of a two-wire transmission line which is one-quarter of a wave-length long, the line being short-circuited at the roller 10 and, in effect, substantially open circuited at the rollers 7 and 8. The impedance of such a line, short-circuited at one end, varies from substantially zero at the short-circuited end to a relatively high magnitude at the open-circuited end. When such a line is connected to a source of power, the frequency of which corresponds to the electrical wave-length of the line, the current distribution along the line is non-uniform, having a maximum at the short-circuited end and a minimum, or nodal point, at the open-circuited end. Accordingly, when the open-circuited end of the loop 5 is connected to a source of power, current entering the loop at the connection points is of lower order of magnitude than the maximum current in the loop which would be along the center of the loop. Thus a current of high magnitude for heating is caused to flow through the central portion of the loop 5 while a current of relatively low magnitude flows between the wire and the rollers 7 and 8.

Power is dissipated and converted to heat in the loop 5 by reason of the ohmic losses and the hysteresis losses, if any, in the wire. A grounded cylindrical shield 18 around the loop 5 limits radiation of electromagnetic energy.

The wire is fed into and leaves the heating equipment at points of safe ground potential, because the wire-entering and wire-leaving ends of the quarter-wave isolating sections 1 and 2 are short-circuited and grounded, and are directly connected to the wire through the rollers 6 and 9, respectively.

The isolating sections prevent diversion of any appreciable amount of power into the wire except in that portion forming the loop 5. The current flow in the portion of the wire in the isolating sections 1 and 2 is substantially zero, as the current concentrates in the surrounding tubular members 3. Because the isolating sections 1 and 2 comprise members having relatively large surface areas and made of material of high conductivity and low permeability, the losses due to the current flowing in the members of these sections are sufficiently small that no significant portion of the power supplied is consumed in these sections. Also, because the electromagnetic fields associated with the currents in these sections are confined almost entirely to the space between the inner and outer members 3 and 4, respectively, power losses due to radiation from these sections are also negligible.

In order to more finely adjust the reflected impedance at the point where current is fed into the loop 5, auxiliary rollers or other contact making devices to which the power source may be connected, may be positioned at intermediate

points along the loop, as indicated by the rollers 19 and 20.

Fig. 2 is a cross section of a system using oval or oblong cylindrical members for the isolating sections. Each section may be comprised of an inner member 21 and an outer member 22. Such a form is useful when the work to be heated constitutes a comparatively wide strip or a plurality of individual parallel wires running through the sections.

Fig. 3 shows a further modified form of my invention in which the wire or work to be treated is given only one turn or bend. In this embodiment, the isolating sections 31 and 32 are arranged alongside of each other with the entrance and exit ends for the work connected at ground potential as indicated, through rollers 33 and 34. The other ends of the tubes of the isolating sections, which are at the loop for the work, are arranged as previously described, with each end of the inner tubular members of the sections maintained at the same potential as the portion of the wire thereat, by means of conductors 35 and 36, respectively, and rollers 37 and 38, respectively. The work loop 39 passes around a roller 40 which may be grounded. The electrical lengths of the isolating sections and half of the work loop are each one-quarter wave-length.

A particular advantage of the system described is that it is readily adaptable to various compact arrangements, as in Fig. 1, in which the loop of the material being heated is perpendicular to the isolating sections; and in Fig. 3, in which the system comprises two parallel sections. In each case, the shortest distance between the power-supply connection-points, such as rollers 7 and 8, is considerably less than the length of the material in the heating loop 5.

A wide range of frequencies, preferably in the megacycle range, is utilizable with my invention. Limiting factors for consideration include the heat gradient desired in the work, shorter loops giving steeper gradients and requiring higher frequencies; the physical size tolerable in the apparatus, the size decreasing with increasing frequency; and the dependency upon frequency of the efficiency of the current source, the output of which must be adequate.

While I have described my invention in forms which I believe to be preferred and desirable, it is obvious that the teachings of my invention are of broad scope and its principles applicable to forms other than that herein described.

I claim as my invention:

1. Conduction heating means comprising means for guiding progressively-movable elongated conductive material in a path providing a loop of material, said path providing portions for lengths of material at each end of said loop, means for conductively applying a high-frequency power source to said material on opposite sides of said loop, a tubular metallic isolating section at each of said path-portions, said lengths of material passing through said sections, each section being a quarter-wave length with respect to the wave-length of the power delivered by said power source, the material in the loop having a length which is substantially an even number of times the electrical length of said sections, and means for conductively connecting the material to the ends of said sections which are away from said loop.

2. Conduction heating means comprising a pair of spaced tubular sections, each section comprising a pair of nested metal tubes, means for guid-

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ing progressively-movable elongated material through the inner ones of said tubes of said sections, and providing a loop-length of material therebetween, and grounding means for grounding a point of said material, said grounding means comprising a grounding member between and spaced from said sections, said material being wrapped around said grounding member, ends of said sections facing said grounding member being effectively insulated, the other ends of said sections and the material thereat being grounded.

3. Conduction heating means comprising a pair of spaced tubular sections, each section comprising a pair of nested metal tubes, means for guiding progressively-movable elongated material through the inner ones of said tubes of said sections, and providing a length of material between opposite ends of said sections, means for applying a high-frequency current to the material, said sections being electrically a quarter wave length of the supplied current, said opposite ends of said sections having portions effectively insulated from ground means for maintaining the material at said opposite ends at the potential of such portions, the said length of material being substantially an even multiple of an odd number of quarter-wave-lengths corresponding to the frequency of said current, grounding means for the material at the other ends of said sections, and grounding means for grounding a central point of said length of material.

4. Conduction heating means for elongated progressively - movable material, comprising means for guiding said material, said means providing a loop in said material, the ends of the loop being insulated, means for grounding a central point of the loop, and means for conductively feeding high-frequency current to said loop at points other than said point of said loop, the frequency being such as to provide a standing wave-

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pattern of current along said loop having current nodal points substantially at the said points where the current is fed to said loop.

5. Conduction heating means for elongated progressively - movable material, comprising a pair of separated isolating sections, each comprising a pair of nested hollow metallic cylindrical members, means for guiding said material successively through the inner members of said sections, said sections being spaced to provide a loop of material therebetween, means for electrically tying the material-entrance-end and the material-exit-end of each of said inner members to the material thereat, the other ends of said inner members at said length of material being insulated, and a high-frequency power source having opposite supply terminals at spaced points on said loop for supplying high-frequency power thereto of such wave lengths as to make said sections quarter wave lengths electrically.

6. The invention of claim 5 having the further feature of means for grounding a central point of said loop of material.

7. An invention including that of claim 6 but characterized further by the outer ones of said members being grounded.

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