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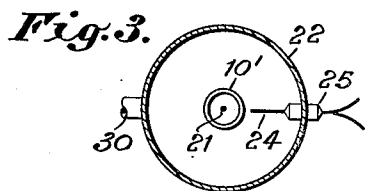
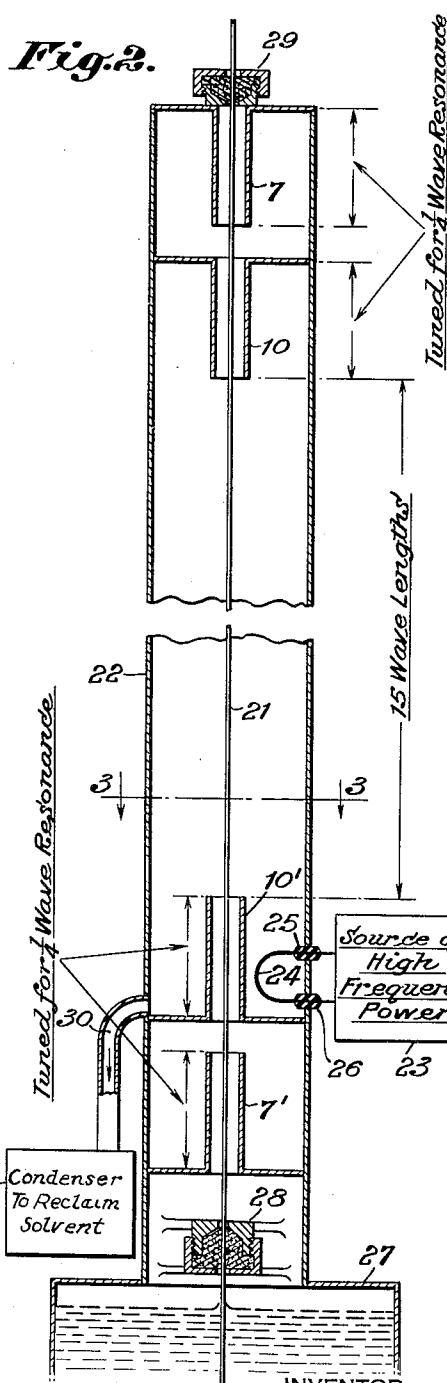
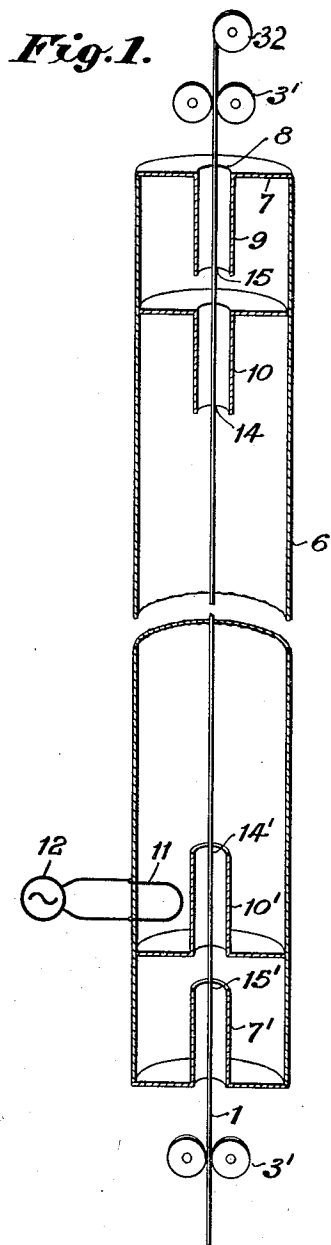
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2,364,526

HIGH FREQUENCY INDUCTION SYSTEM

Filed July 10, 1941

2 Sheets-Sheet 1



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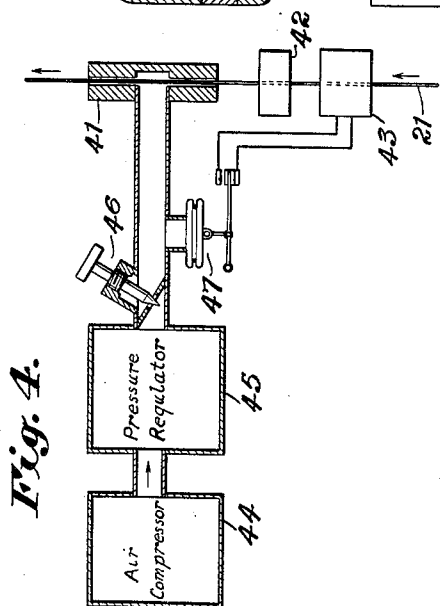
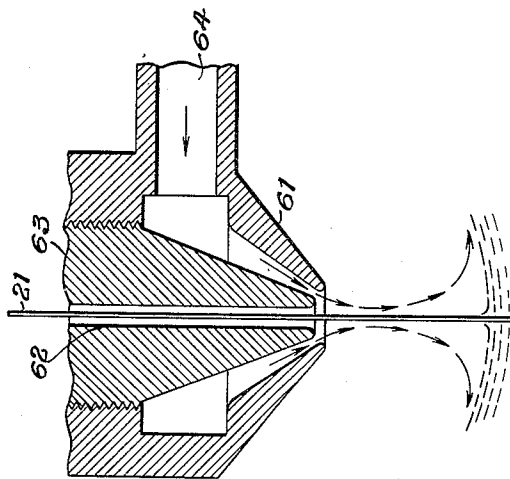
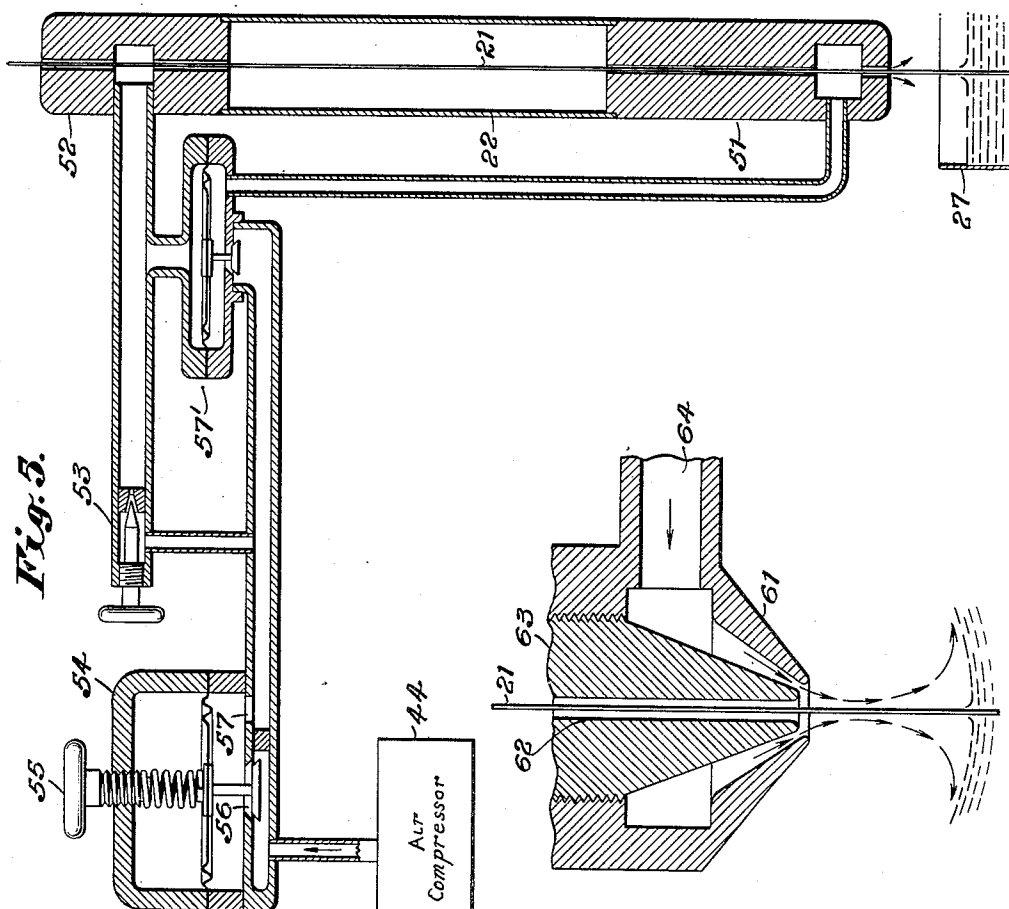
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HIGH FREQUENCY INDUCTION SYSTEM

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2 Sheets-Sheet 2



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HIGH FREQUENCY INDUCTION SYSTEM

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13 Claims. (Cl. 91—55)

This invention relates to a new and useful high frequency induction system and particularly to a system which forms a section of a high frequency concentric line.

An object of this invention is to simplify and improve high frequency induction systems generally.

Another object of this invention is to produce standing waves along a movable inner conductor of a high frequency concentric line which will be independent of the movement and rate of speed of the inner conductor.

Still another object of this invention is to provide a means of limiting the length of a fixed or movable conductor, forming a part of the induction system, to any desired portion of the conductor without requiring any physical connection at the ends of the limited portion.

A further object of this invention is to apply heat to the inner conductor for practical industrial applications, one of which will be explained in more detail throughout the specification.

A feature of this invention is the novel arrangement of a section of a concentric line having a movable conductor which is electrically terminated by high impedance means.

Briefly, by means of my improved induction system, high frequency currents are made to flow in the inner conductor which may be movable or fixed, the current flow being accomplished by means of electro-magnetic coupling through the air. The movable inner conductor is arranged within an outer conductor forming a section of a concentric line simulating a transmission line in such a way that it will not be necessary to make any physical or direct electrical connection to the inner conductor. The length of the portion of inner conductor contained within the outer conductor is tuned to a high frequency current in such a way that it will carry standing waves of potential and current. These waves will cause power to be dissipated in the movable inner conductor which is not uniform but which has a distribution along the wire which approximates a sine squared curve. When there is a continuous movement of the conductor in the direction of its length, then, because of its heat retentivity, the temperature rise will be less variable along the wire than the variation in power distribution. However, the faster the movement of the wire, the more uniformity of temperature will be obtained.

This invention will best be understood by referring to the accompanying drawings, in which:

Fig. 1 shows the physical arrangement of the electrical system of this invention;

Fig. 2 shows a longitudinal sectional view of a practical industrial application of this invention;

Fig. 3 shows a cross-section of Fig. 2 taken on the plane 3—3;

Fig. 4 is a detail of an air pressure means used in conjunction with the arrangement shown in Figs. 2 and 3;

Fig. 5 is another detail of an air pressure means as applied to the arrangement shown in Figs. 2 and 3; and

Fig. 6 is a detail of an adjustable nozzle used with the air pressure means shown in Figs. 4 and 5.

Fig. 1 shows an arrangement in which a movable conductor 1 is placed within a stationary cylindrical conductor 6, the two conductors forming a section of a concentric line simulating a transmission line. The inner, movable conductor or wire 1 is centrally arranged within tube 6 by means of pulleys 3' and by tension in the wire. At each end of outer conductor 6 an electrical filter 7 and 7' is provided. This filter is in the form of a disc having an aperture 8 therein, to which is soldered a relatively short metallic tube 9 which concentrically surrounds movable conductor 1. The electrical length of tube 9 is such as to be tuned to quarter-wave resonance at the frequency at which the main portion of the line is resonant and at which standing electrical waves are set up. Adjacent to the filters 7 and 7' are arranged a pair of filters 10 and 10'. The filters 10 and 10' are similar in construction to filters 7 and 7' and are likewise each tuned to a quarter-wave resonance. At some convenient point along the conductors, movable conductor 1 is electro-magnetically coupled to loop conductor 11, which is connected to a source of high frequency power 12. In practice, I prefer to couple to one of the inner quarter-wave filter sections, such as section 10', as shown. The filter section readily transfers the power to the remainder of the inner line section. It is to be understood that coupling to conductor 1 may be made at any position within the section of the concentric line, except near a point of maximum potential and minimum current. Instead of the inductive coupling loop 11, I may employ a capacitive coupling, applied at any point except near a point of minimum potential and maximum current.

It will be seen that, with a given line section formed of a wire 1 and pipe 6 which may be about fifty feet (approximately fifteen meters) long, if it is tuned to the frequency of the source 12, it will carry standing waves of potential and current. These waves will cause power to be dissipated in conductor 1, which is not uniform but which has a distribution along the conductor. Because of the continuous movement of the wire and its heat retentivity, the temperature rise will be much less variable along the wire than the variation in power distribution. Naturally, the faster the wire moves, the more uniform will be its temperature. The power dissipated in con-

ductor 1 will appear in the form of heat on the outer surface for the reason that, due to the well-known "skin effect," very high frequency current will flow only on the surface of conductor 1. Since the effective resistance of the conductor to the flow of high frequency current is very much greater than the resistance to the flow of low frequency current, less current will be required at high frequencies for a given power dissipation. To prevent loss of power and electromagnetic radiation from conductor 1, filters 7, 7', 10 and 10' are provided to offer a high impedance at points 14, 14', 15 and 15'.

It will be seen that with such an arrangement, high frequency currents are set up in a controllable manner in a length of movable wire, such as would be subject to a heating process, without making any physical connection with the wire. Furthermore, this is done without allowing appreciable high frequency power to escape from within tube 6, as the quarter-wave resonance filters offer a high impedance without any physical contact to the wire.

A practical industrial application of this system is shown by Figs. 2 and 3, in which copper wire is coated with enamel, and wherein a copper wire 21 is arranged to pass through a metallic tube 22 and the electrical filters 7, 7', 10 and 10'. A source of high frequency power 23 is coupled to a magnetic coupling or hairpin device 24, the leads of which pass through insulators 25 and 26. At the lower portion of the tube 22 is arranged an enamel tank 27 through which the wire to be enameled passes. Interposed between the enamel tank and filter 7', an adjustable die or wiper 28 is arranged so as to govern the enamel thickness. It is preferable that the wiper be automatically adjusted to give the diameter desired for the finished wire. At the upper portion of tube 22, an air-seal device 29 is arranged to prevent escape of the solvent and entrance to the surrounding air. In order that the surplus solvent and its vapors may not build up dangerous pressures, a vent 30 is provided which may be connected, if desired, to any suitable solvent reclaiming device, such as a condenser 31. The wire may then be wound on a spool 32.

In the operation of this device, it will be seen, as mentioned above, that high frequency currents may be made to flow in wire 21 by means of the electromagnetic couplings through the air, and therefore there will be no need to make any physical connection to the wire which would disturb the enamel. Also, because the heat is developed at the inside surface of the enamel, the drying will tend to be from the inside out; consequently, it will be possible to apply heavier enamel coats or to dry a given thickness of enamel more quickly than if the heat came from the outside, as is the method of enameling wire which is known in the prior art. Furthermore, since only the wire, itself, is heated, not an enveloping oven structure, as in the prior art, the power required for operating my enamel drying system is much less than it is in the prior systems.

By the improved process of this invention, there is less tendency for formation of a tight outer skin which can blister from evaporating solvent trapped under it during rapid drying. Instead, each infinitesimal layer as it hardens or dries is shrunk on the layers underneath it which are already hard and dry.

If higher resistance non-magnetic wire other than that of copper is to be enameled, the re-

quired heating current and therefore the potential gradient would be reduced in inverse proportion to the square root of the resistivity. Iron wire, or strip steel, due to its magnetic properties and very great skin effect, as well as high resistivity, would require relatively low current and potential gradients.

Figs. 4, 5 and 6 show several arrangements for automatic pneumatic control of the thickness of the enamel by air pressure, the simplest form of which is disclosed in Fig. 4, wherein a movable wire or strip 21 passes first through the automatically adjusted die or wiper 43, then through the drying chamber 42 (which is similar to Fig. 2) then through a split sleeve 41 which is arranged to be a loose fit around the finished wire. The air leak between wire 21 and sleeve 41, and therefore the pressure applied to the pressure motor control and relay 47, is governed by the finished wire diameter. If the thickness of enamel, and therefore the diameter of the finished wire, becomes too great, the pressure rises and reduces the effective diameter of the motor controlled wiper 43. Likewise, if the finished wire diameter is too small, the pressure falls and through the relay 47 and the motor increases the effective diameter of the wiper 43. Air compressed in compressor 44 passes through an automatic pressure regulator 45 to needle valve 46 and thence into the connection between relay 47 and the split sleeve air leak 41. With this arrangement, the exact diameter of the finished wire is controllable over a considerable range by adjustment of the setting of needle valve 46. When the arrangement has been set up for one particular wire size, the needle valve 46 provides the means by which operating personnel adjust the exact value of the finished wire diameter to keep it within allowable tolerances. To a certain degree, the speed of the wire and the amount of high frequency electrical power fed into the drying chamber 42 affect the finished wire diameter. Therefore, wire speed, power input, the setting of needle valve 46, the enamel composition, original wire and enamel temperatures and other factors are all coordinated to obtain a desired result.

Fig. 5 shows in more detail, a further arrangement of controlling the enamel thickness by means of compressed air, in which the movable wire 21 passes upward through a chamber 51 from the enamel tank 27, thence through the drying chamber 22 and then up through an air chamber 52 which is connected to a valve 53 which controls the pressure for determining the finished outside diameter of the enamel. Connected from the compressed air input tank 44, a pressure regulating device 54 is arranged to be in fluid communication with valve 53 and member 51. The pressure in member 54 is regulated by means of a valve handle 55 which provides an adjustable spring pressure upon a movable diaphragm on which is mounted valve or regulating member 56, which regulates the pressure entering an aperture 57. The air flow through members 51 and 52 is regulated by a suitable amplifying air flow regulator 57'.

In operation of the device, air leaking in through adjustable needle valve 53 builds up a pressure on the upper side of the diaphragm of amplifying air flow regulator 57', the amount of which is dependent upon the finished wire diameter, and therefore the rate of air leakage through member 52. This pressure regulates the pressure delivered by amplifying regulator 57' to member 51, which in turn regulates the amount of enamel

taken up by the wire and by this means holds the finished wire diameter substantially constant at a value adjusted by needle valve 53.

Fig. 6 shows in detail an arrangement wherein an adjustable nozzle 61 is arranged to control the thickness of the enamel on the movable wire 21 by means of an air blast, wherein wire 21 passes through an aperture 62 in a threaded spindle 63, the air entering the adjustable nozzle at a point 64. This arrangement, as well as others, may be used for element 51 of Fig. 5.

The advantages of this system over that of the prior art methods of enameling wire is that high frequency currents can be set up in the wires in a practical manner without making any physical or direct electrical connection to them. Low frequency currents cannot be used because the enamel prevents physical connection if it is desired to have a continuous enameling process. Another advantage of this invention is that by applying heat from the inside, the enamel layer dries faster than can be accomplished by prior art methods and without the danger of blistering due to the formation of an outer enamel skin having a solvent trapped beneath it. Also, by drying the wire from the inside out, it is possible for the enamel to be applied in fewer coats, or even in a single coat, instead of five or six coats, as previously employed. The method greatly reduces the amount of wire bending in the enameling process and also reduces factory space to process the wire. Likewise, by means of this invention, the manufacturing operations will be speeded and thus the production output of enamel wire will be increased.

While only one major industrial application of this system is shown, it is to be distinctly understood that this system may be used for other applications, such as raising and controlling the temperature of wire or strip to be annealed or tempered in a continuous process as described in my Patent #2,123,776. It may be employed not alone for drying enamel containing a solvent, but also may be used for applying materials in liquid or paste form which harden when heated and cooled without evaporating a solvent. It may be employed to apply glazed enamels continuously to metal wire, rods or tube by drying or decomposing a vehicle liquid or paste and fusing together ground glazing particles. It may be used to apply metal coatings to other materials, as for example, applying platinum or gold by reduction of a solution of the chloride of the metal. It may be used for continuous case hardening of moving wire or strip either by rapid heating and cooling of an outer layer, or by heating in an atmosphere which changes the chemical composition of the surface layer. Also, the system of this invention may be applied to form an antenna transmission line having a moving conductor.

What is claimed is:

1. Apparatus for providing an elongated, electrical conductor with a coating, said apparatus comprising, in combination, a tube of electrically conductive material forming the outer conductor of a concentric line, said tube being provided with resonant filter elements at each end through which said conductor passes without direct electrical contact therewith, a source of high frequency power for setting up electrical currents in said conductor, means for drawing said conductor through said tube, means for applying a coating on said conductor before it passes through said tube, and automatic, pneumatic

means responsive to the dimensions of the finished conductor as it leaves said tube associated with said conductor at a point between said coating applying means and said tube for controlling the thickness of coating adhering to said conductor before it enters said tube.

2. Apparatus for providing an elongated wire conductor with an insulated coating, said apparatus comprising, in combination, a tank containing a liquid insulating material capable of becoming hard when heated to a suitable temperature, a relatively short, electrically conductive tube, means for moving said wire first through said tank whereby to apply thereto a coating of said material and then longitudinally through said tube in concentric relation therewith, said tube and said wire cooperating jointly as a concentric transmission line of which said tube acts as an outer conductor and said wire as an inner conductor, means for applying to said line a high frequency current of sufficient magnitude to heat the portion of said wire instantaneously within said tube to said temperature whereby to effect hardening of the insulating material coating around said portion, and pneumatic means associated with said wire and automatically operable in response to the thickness of said hard coating to control the thickness of coating on said wire prior to entry of succeeding portions thereof into said tube.

3. Apparatus for producing heating current in a movable conductor which comprises, in combination, a hollow, electrically conductive member of finite length adapted to act as one element of a conductive line simulating a transmission line and along which said movable conductor is adapted to be moved in spaced relation thereto, said movable conductor constituting a second element of said line in association with said conductive member, means associated with said line for coupling said line to a source of alternating electrical energy, and impedance means connected to said member and associated with said movable conductor for confining the current produced in said line by said coupling means to a predetermined portion of said line.

4. Apparatus for producing heating current in a movable conductor which comprises, in combination, a hollow, electrically conductive member of finite length adapted to act as one element of a conductive line simulating a transmission line and along which said movable conductor is adapted to be moved in spaced relation thereto, said movable conductor constituting a second element of said line in association with said conductive member, means coupled to said line at a point intermediate the ends thereof for coupling said line to a source of high frequency energy, and impedance means connected to said member in proximity to the ends thereof in association with said movable conductor for confining the high frequency current produced in said line to substantially that portion thereof which lies between said impedance means.

5. Apparatus according to claim 4 characterized in that said means for coupling said line to said source comprises a reactive element.

6. Apparatus according to claim 4 characterized in that said means for coupling said line to said source comprises an inductive element.

7. Apparatus according to claim 4 characterized in that said means for coupling said line to said source comprises an inductive element, and characterized further in that said inductive ele-

ment is inductively coupled to said line at one of said impedance means.

8. Apparatus according to claim 4 characterized in that said hollow member is constituted by a tubular conductor, and characterized further in that said movable conductor is constituted by a wire of greater length than said tubular conductor, said wire being arranged for passage concentrically through said tubular conductor whereby to form therewith a concentric line.

9. Apparatus for inducing heating current in a movable conductor which comprises, in combination, electrically conductive means providing a stationary chamber through which said conductor is adapted to be moved and in association with which said conductor constitutes one element of a conductive line simulating a transmission line, means associated with said line at a point intermediate its ends for inductively coupling said line to a source of high frequency energy to thereby induce a high frequency current in that portion of said conductor which is instantaneously within said chamber, and impedance means at each end of said chamber associated with said conductor for confining said high frequency current to substantially that portion of said conductor which lies instantaneously between said impedance means.

10. Apparatus according to claim 9 characterized in that said chamber providing means comprises a tubular conductor of finite length, characterized further in that said movable conductor comprises a wire of much greater length, said wire being arranged concentrically with said tubular conductor in its passage therethrough whereby to provide a concentric line, and characterized still further in that the length of said line is so related to the frequency of said source that standing waves are set up along a predetermined portion of said line between said impedance means.

11. Apparatus according to claim 9 characterized in that said chamber providing means comprises a tubular conductor of finite length, characterized further in that said movable conductor comprises a wire of much greater length, said

wire being arranged concentrically with said tubular conductor in its passage therethrough whereby to provide a concentric line, said line being tuned to resonance at the frequency of said source, and characterized further in that said impedance means comprises means tuned electrically to quarter wave length resonance at said frequency.

12. In apparatus for providing an elongated conductive member with a coating of insulating material, the combination of means for advancing said member along a predetermined path, means at one point in said path for applying to said member a coating of insulating material which is adapted to become set upon being heated to a suitable temperature, means at a succeeding point in said path for heating said coating to effect setting thereof, and automatic, pneumatic means associated with said member and responsive to the dimensions of the set coating for controlling the thickness of the coating applied to said member at said first named point.

13. In apparatus for providing an elongated conductive member with a coating of insulating material, the combination of means for advancing said member along a predetermined path past a plurality of operating stations, means at a first one of said stations for applying to said member a coating of insulating material which is adapted to become set upon being heated to a suitable temperature, means at a second station for heating said coating to effect setting thereof, and cooperative pneumatic means associated with said member at a third station intermediate said first and second named stations and also at a fourth station beyond said second station in the direction of movement of said member, the pneumatic means at said fourth station being responsive to the dimensions of the set coating for automatically rendering the pneumatic means at said third station effective to control the thickness of the coating adhering to said member as it leaves said third named station.

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