

June 27, 1967

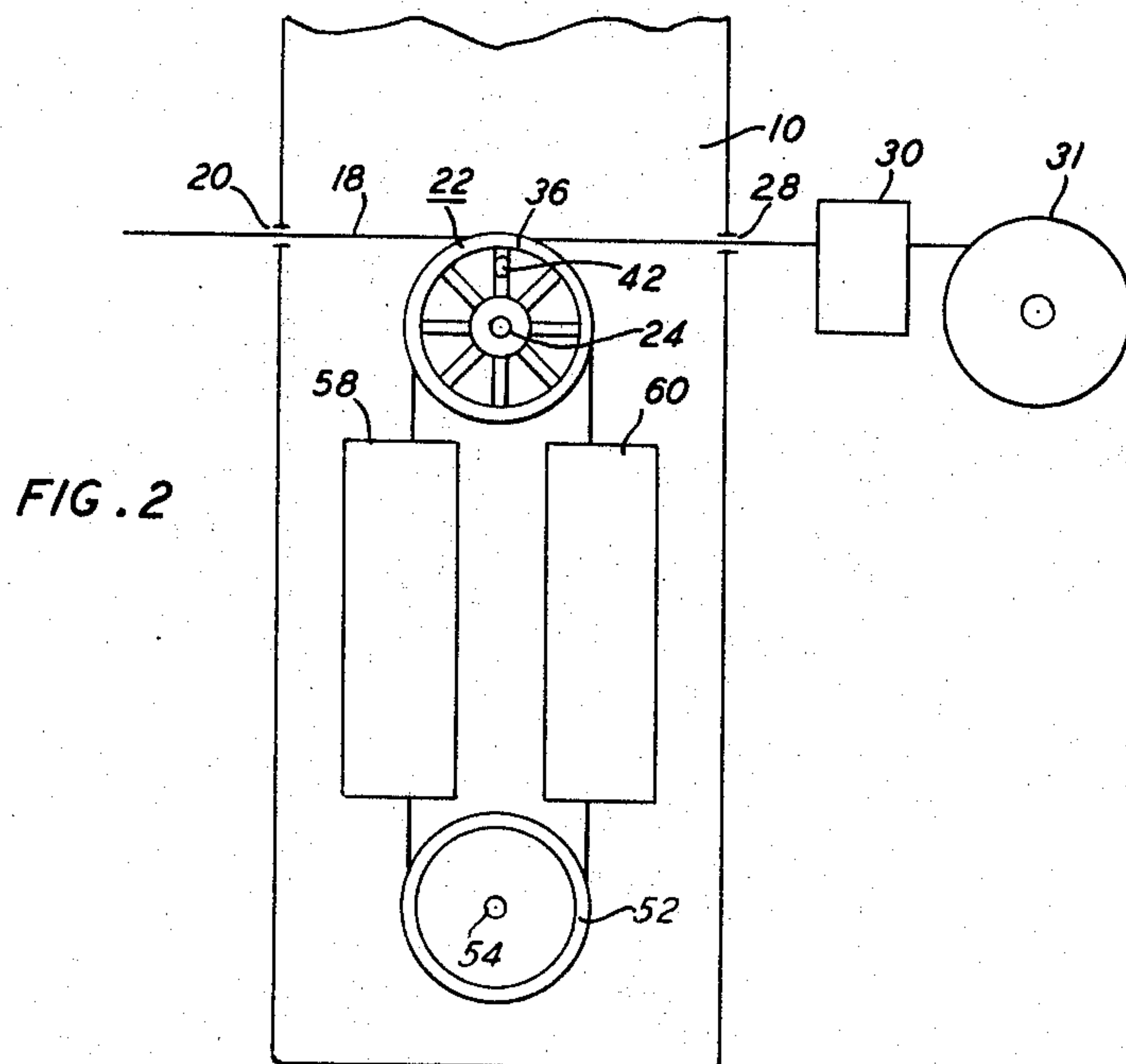
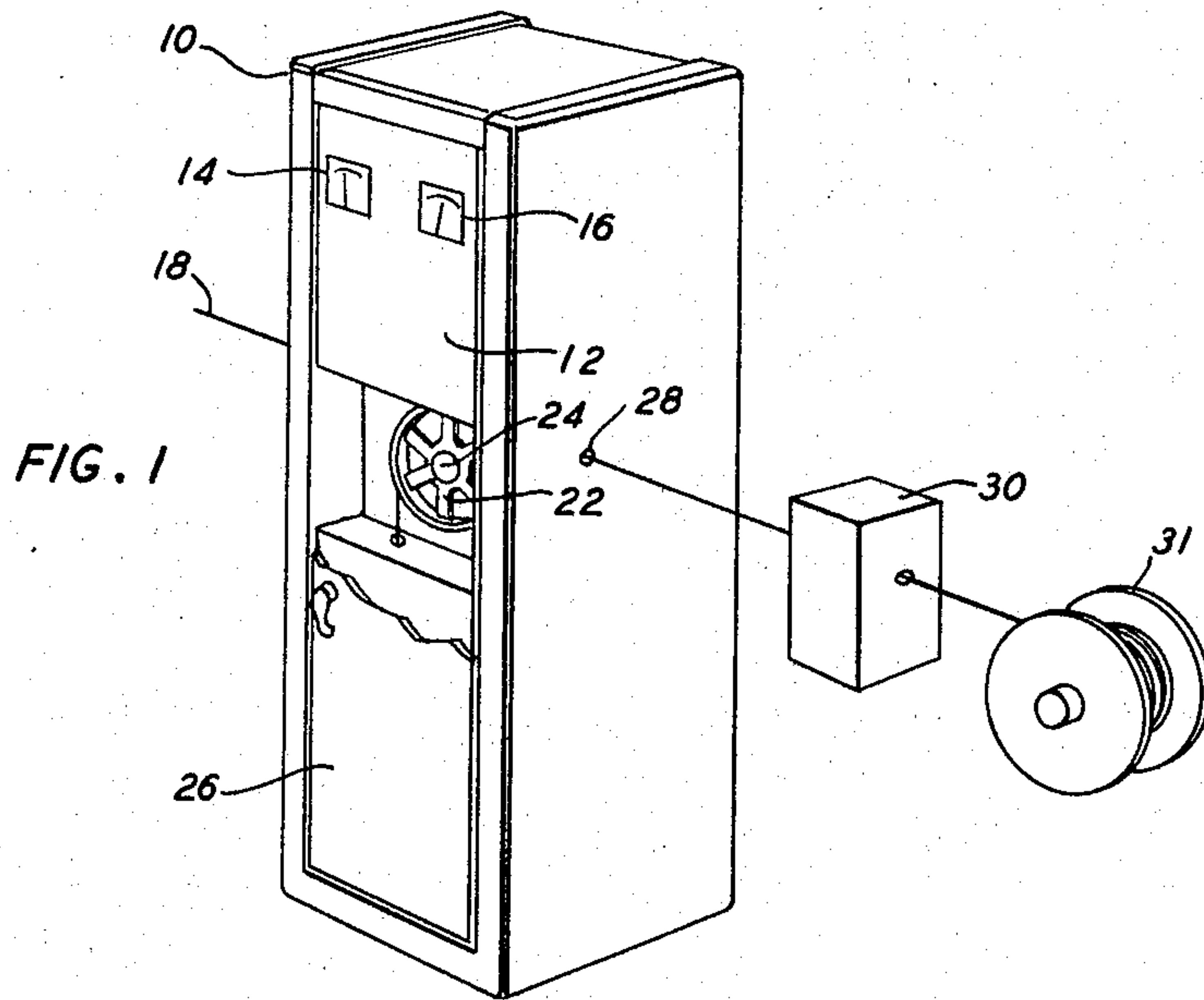
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3,328,554

WIRE HEATER

Filed Sept. 25, 1964

3 Sheets-Sheet 1



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June 27, 1967

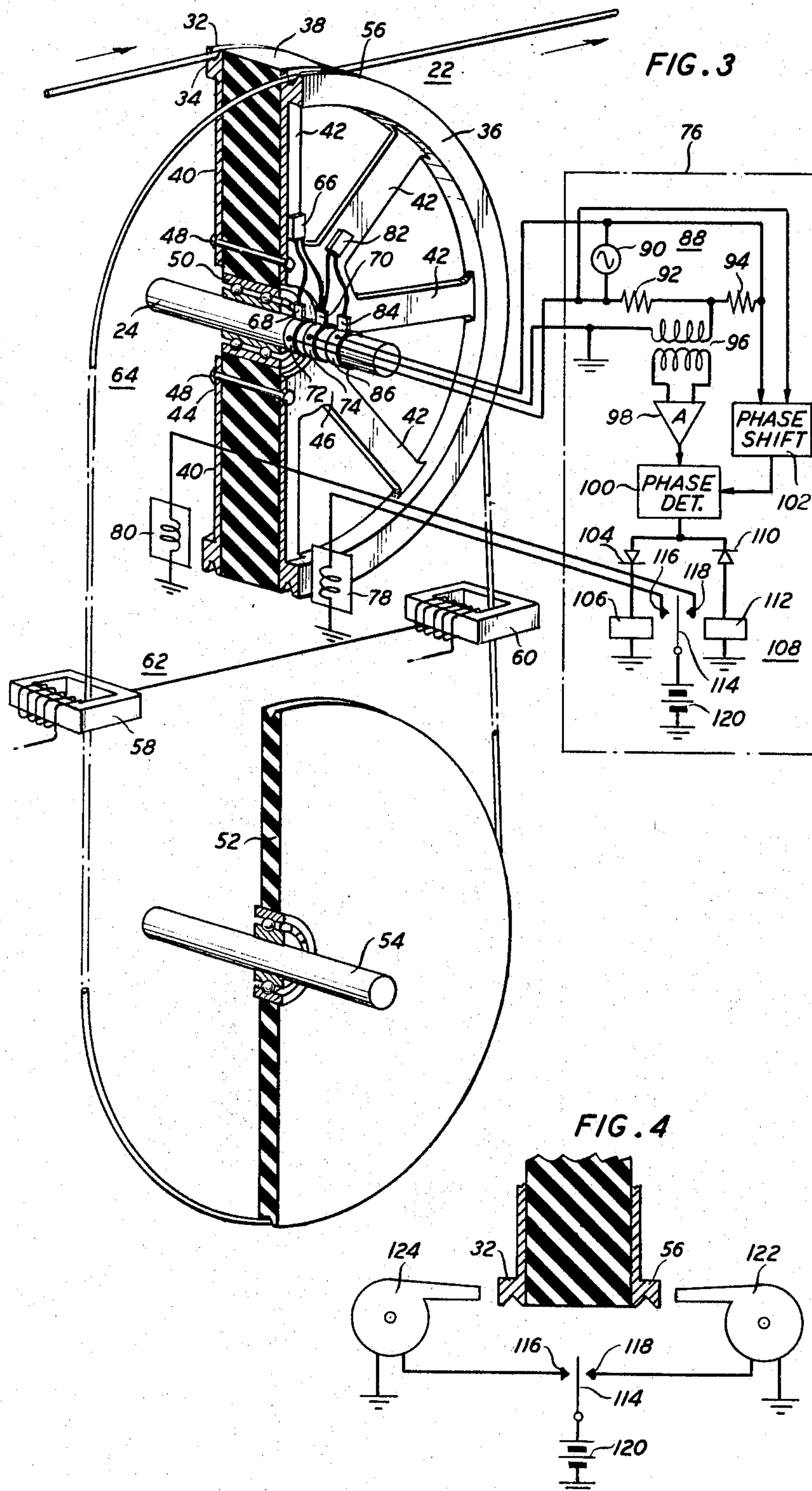
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Filed Sept. 25, 1964

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WIRE HEATER

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Filed Sept. 25, 1964, Ser. No. 399,168

13 Claims. (Cl. 219—10.61)

This invention relates to heating of bare electrical wires, and particularly to heating of continuously moving wires as a treatment preceding another operation such as coating the moving wires with plastic insulation in an extruder.

One especially suitable apparatus for preheating a moving wire forms a short-circuit loop of the wire by passing it over a rotatable and conductive sheave, then around a rotatable idler wheel, then back over the rotatable sheave, and to a capstan drawing the wire. An energized transformer winding inductively linked with this wire induces current in the loop and thereby heats the wire. It is essential in this apparatus that the wire maintain rolling contact with the sheave. That is, at the points of engagement between the wire and the sheave there must be no relative motion. Any sliding contact along the wire initiates arcing that detrimentally affects the wire, the heat produced, or the heating apparatus.

Unfortunately, such apparatus frequently experiences this sliding contact because the heating of metal wire elongates it. This increases the speed with which the heated wire is drawn from the sheave as compared to the speed of the cold wire passing into rolling contact with the sheave. As a result, the outgoing hot wire and the incoming cold wire tend to turn the sheave at different speeds and ultimately slide on its surface.

Separate, independently revolving sheaves can alleviate the sliding problem. However, the bearings holding the sheaves and connecting the sheaves electrically increase wire tension because of friction and create undesirably high and erratic impedances between the incoming cold wire and the outgoing hot wire. These impedances affect the heating adversely.

An object of this invention is to avoid the shortcomings of present equipment.

A more general object is to improve methods and apparatus for heating bare wire.

Still another object of the invention is to preheat bare metal wire by inducing current into the wire forming part of a shorted loop without causing arcing or undesirable impedances.

To these ends and according to a principle of the invention, wire is preheated by looping it about a rotatable sheave, an idler wheel, and back over the sheave, and then inducing currents in the wire. However, here the sheave is electrically split into two heat-isolated, electrically-interconnected and rigidly-interlocked members having conductive rims. One rim is in rolling contact with the incoming cold wire and the other in rolling contact with the outgoing hot wire.

The outgoing hot wire heats the rim which it contacts and thereby enlarges the latter so that its peripheral speed corresponds to the linear speed of the outgoing wire. The speed of the cold incoming wire and the peripheral speed of its rim remain matched to each other, while the two rims operating at the same angular speed are electrically interconnected by a direct rigid contact.

In the event that the heated rim overcompensates or undercompensates for the heating of the wire, it is possible further regulate the temperature of the rim. This is done by providing the members with radial spokes extending inwardly from the rims and mounting on a spoke a gauge that measures the strain applied thereto by the

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rim as soon as the heated wire tends to retard or advance the rim speed beyond its usual value determined by the cold wire. This strain gauge then regulates a heater or cooling device directed at either rim to change the peripheral diameter until no strain is detected by the gauge.

More generally, according to the invention a short-circuit loop of wire is formed by looping means and wire contacting means, wherein the wire contacting means define two cyclically-movable electrically-interconnected and electrically-conductive endless portions joined for movement in unison, wherein the first portion contacts the wire before the looping means and the second portion contacts the wire after the looping means. Means are provided to induce heating currents in the wire.

These and other features of the invention, both broader and more specific, are pointed out in the claims forming a part of this specification. Other objects and advantages of the invention will be mentioned or become obvious in the following detailed description when read in light of the accompanying drawing, wherein:

FIG. 1 is a perspective and partially broken away view of a preheater embodying features of the invention;

FIG. 2 is a front elevation of a portion of the preheater in FIG. 1;

FIG. 3 is a perspective and partially sectional and partially schematic diagram of the loop portion and electrical portion of FIGS. 1 and 2;

FIG. 4 is a schematic diagram of another embodiment of the temperature controls in FIG. 3; and

FIG. 5 is another embodiment of the invention as illustrated in FIG. 3.

In FIG. 1 a rectangular cabinet 10 enclosing the preheating apparatus has a front panel 12 that displays current and voltage indicating instruments 14 and 16. Bare wire 18 enters the cabinet 10 through an opening 20 in its left wall (see FIG. 2) and passes over a sheave 22 rotatable about a shaft 24 behind a door 26, shown partially broken away, in the front panel. The wire 18 after being heated passes off the sheave 22 and out of the cabinet through an opening 28 in the right wall.

The apparatus in FIG. 1 heats the wire. The latter is then drawn from the sheave 22 through an extruding machine 30, shown schematically as a box, by a capstan 31 at a speed of from 200 to 4,000 feet per minute. The extruding machine coats the wire with plastic or rubber insulation.

FIGS. 2 and 3 illustrate the operation of the preheating device shown in FIG. 1. Here, the wire 18 enters the cabinet 10 through the left wall opening 20 and contacts approximately ninety degrees of a grooved copper rim 32 on a wheel-shaped face member 34. The face member 34 and another face member 36, its mirror image, sandwich between them an electrical and heat insulating disc 38. The face members 34 and 36 each include eight radial spokes designated 40 and 42 respectively, extending from respective hubs 44 and 46. Securing the face members 34 and 36 onto the disc 38 to form the sheave 22 are a plurality of conductive bolts 48 of sufficient size to carry considerable current between the face members without affecting significantly the heat isolation established by the insulating disc 38 between the face members 34 and 36. The sheave 22 rotates freely about the shaft 24 upon a bearing 50 which is electrically isolated from the face members 34 and 36.

After passing over the rim 32 and turning the sheave 22 by its movement, the wire 18 passes vertically downward and one hundred eighty degrees around an insulating idler wheel 52 freely rotatable about a shaft 54. The wire 18 then passes vertically upward until it engages the grooved rim designated 56 of the face member 36. There it follows the rim 56 ninety degrees around its

periphery and passes horizontally outward from the cabinet 10 through the opening 28, through the extruding machine 30, and to the capstan 31.

Surrounding the individual vertical sections of the wire 18 between the sheave 22 and the idler wheel 52 are two iron cores 58 and 60 and primary windings of a transformer 62. The transformer induces currents which pass with low resistance through the wire 18 between the rims 32 and 56 through the spokes 40 and 42 and the bolts 48. The transformer secondary constitutes a loop 64, formed by the wire 18 as it contacts the rim 32, passes around the idler wheel 52, and contacts the rim 56. The transformer induces currents in the wire 18 which pass with low resistance between the rims 32 and 56 through the bolts 48.

The currents passing through the wire loop 64 rapidly heat the wire so that the outgoing wire over rim 56 is at the desired temperature. Means such as saturable reactors can control the currents in the primary windings and induced into the loop and hence the outgoing temperature measurements of the outgoing wire 18. The heated wire elongates in response to its temperature rise. If a constant pull is applied by the capstan 31 the translatory speed of the heated wire is greater at the rim 56 than the translatory speed of the incoming cooler wire at rim 32. This difference, if sufficient, could cause slippage at the rim 56. However, the heated wire, by contacting ninety degrees of the rim 56, heats the rim. The latter then expands so that its peripheral dimension also expands. Its peripheral speed then increases despite the fact that its angular speed remains the same as the rim 32. Its increased peripheral speed accommodates the increased translatory speed of the heated wire.

The disc 38 substantially prevents the heat in the rim 56 from affecting the temperature of the rim 32. The only contact between these two rims is through the conductive bolts 48 which are of comparatively small cross section as far as heat is concerned.

It is possible that the heat expansion of the rim 56 may overcompensate or undercompensate for the heat elongation of the wire 18. However, once the rim 56 has been heated, the differences in speed are far less than if no compensation existed. Any speed difference manifests itself in a peripheral force applied by the elongated wire 18 upon the periphery of the rim 56. A resistive strain gauge 66 secured to a spoke 42 on the face member 36 changes its electrical resistance in response to this force.

A pair of rotating brushes 68 and 70 connected to the strain gauge 66 and slidably connected to slip rings 72 and 74 stationarily mounted on the shaft 24 transmit this information to an electrical control circuit 76. The latter regulates the operation of two compensating heater elements 78 and 80 located adjacent the respective rims 32 and 56 for the purpose of heating them. The heater element 78 is adjacent the rim 56 and the heater element 80 adjacent the rim 32.

In addition to responding to strain, the gauge 66 also responds to the temperature of the face member 36 to the extent that heat is transmitted through the spokes 42. To cancel this temperature dependence a dummy gauge 82, identical to gauge 66, is mounted on another spoke 42, the same distance from the rim 56, but in such a manner as to respond only to the face member temperature. Thus, as long as the temperatures of gauges 66 and 82 are equal and no strain is applied to gauge 66, their resistances remain equal. The output lines from the gauge 82 pass to two brushes 70 and 84, the former of which slides on the ring 74 and the latter brush 84 slides on another stationary slip ring 86.

The control circuit 76 compares the resistances of gauges 66 and 82 with each other in a resistance bridge 88. The latter includes the gauges 66 and 82 forming a junction at the slip ring 74 which is grounded, and form-

ing a series current flow path, through the slip rings 72 and 86, across a 2,000 cycle source 90. Forming a second path for current from the source 90 and forming the remaining branches of the bridge 88 are two series-connected and equal resistors 92 and 94. The primary winding of a transformer 96 connects the junction of resistors 92 and 94 to the grounded junction between the gauges 66 and 82 to complete the bridge. The transformer 96 detects unbalance in voltage between the junction of the equal resistors 92 and 94 and the grounded junction of the gauges 66 and 82. Such unbalance is caused by differences in the resistances of the gauges and produces current flow in the primary as well as the secondary windings of the transformer 96.

Whether the phase of this error current is in phase or out of phase with the voltage in the source 90 is indicative of whether the gauge 66 resistance has increased or decreased relative to dummy gauge 82 in response to strain thereon. Therefore, the phase is indicative of whether the wire 18 is applying an advancing or retarding force on the rim 56.

An amplifier 98 passes the error current to a phase detector 100 that compares the error phase with the phase of the source 90. Between the source 90 and the phase detector 100 is a correcting phase shifter 102. The latter adjusts the phase of the source 90 voltage relative to the error voltage for obtaining in phase or contraphase conditions between these voltages, and thereby correcting slight extraneous phase shifts. The phase detector 100 produces a positive direct voltage output for the phase condition corresponding to the wire 18 placing an advancing torque on the gauge 66, thereby revealing that rim 56 has not expanded sufficiently. A negative direct voltage output is indicative of a retarding torque by the wire 18 on the gauge 66, revealing thereby that the rim 56 has expanded excessively.

A diode 104 selectively passes any positive direct current from the phase detector 100 to a grounded coil 106 of a relay generally designated 108. A diode 110 passes any negative direct currents to a grounded relay coil 112 of the same relay 108. The relay 108 possesses an armature 114 which in the event of the strain gauges 66 and 82 having no or inconsequential differences in resistance and thereby producing no or inconsequential currents in either of the coils is urged into a center position. Current through the coil 106, indicating undercompensation of rim 56, draws the armature 114 into contact with a contact member 116. Current through the coil 112, indicating overcompensation of the rim 56, draws the armature 114 into contact with a contact member 118. Contact with the contact member 116 closes the path from a source 120 to energize the heater element 78 so as to heat the rim 56 still further and alleviate the advancing torque that has produced the current in relay coil 106. Drawing the armature 114 against the contact member 118 passes current from the source 120 through the heater element 80. This heats and expands the rim 32 so as to reduce the speed of the rim 56 relative to the speed of the wire 18 and thereby obviate the overcompensating heating of the rim 56 which has placed the strain on the gauge 66.

It is contemplated that the elements 78 and 80 be substituted by cool air blowers 122 and 124 as shown in FIG. 4. In that case closing of the circuit at contact member 116 energizes the cool air blower 124 directed at the rim 32 and closing the contact member 118 energizes the cool air blower 122 directed at the rim 56.

In general, it is expected that the heated wire 18 will heat the rim 56 to such an extent as to overcompensate for the speed of the elongated wire 18 so that the heater element 78 and coil 106 may be dispensed with. In FIG. 4 cool air blower 124 will also then be unnecessary.

In summary, operation of the illustrated device in FIGS. 1 to 4 is as follows: Bare wire 18 passes through an opening in the left wall of the cabinet 10 and engages

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the rim 32 of sheave 22 with rolling movement, passes through one portion of transformer 62 around an idler wheel 52, upwardly through another portion of the transformer 62, and ninety degrees around the rim 56 of sheave 22. The short circuit produced by the electrically conducting bolts 48 and the contact between the rims 32 and 56 with the wire 18 produces a short circuit loop 64. The transformer 62 induces current in the looped wire 18, thereby heating the wire, so that when it is drawn away for extrusion and coating with plastic material, it is at the right preheat temperature. The hot wire engaging the rim 56 heats and expands that rim so that its peripheral speed corresponds to the translatory speed of the wire.

As the rim 56 starts becoming too hot and thus too large, the wire 18 places a retarding force on the rim periphery, which is sensed by the strain gauge 66. The latter unbalances the bridge 88 and energizes a transformer 96. A phase detector 100 then compares the phase of the error voltage with the source 90 and energizes the relay 112. This closes the circuit from source 120 to heater element 80. The rim 32 heats up sufficiently so as to lower the differences between the peripheral speeds of the rim 32 and the enlarged rim 56 until substantially no strain is sensed by the gauge 66. In the event of undercompensation, the relay coil 106 is energized due to phase shift of the error voltage in amplifier 98 in the other direction, thereby closing the circuit from the source 120 through the heater element 78 so that extra heat is applied to enlarge the rim 56. This enlarges the rim 56 until substantially no strain is sensed by gauge 66. With cool air blowers 122 and 124 as shown in FIG. 4 each relay coil operates the blower directed at the rim opposite to the rim that a heater would have energized.

The apparatus thus preheats wire to its desired temperature without the disadvantage of wire slippage and arcing, which has been a problem in previous preheaters.

FIG. 5 illustrates a preheater arrangement corresponding to that of FIG. 3 but arranged so that the transformer 62 inductively links two series-connected turns of wire 18, the ends of the two turns being shorted as is the end of the single turn in FIG. 3. This arrangement is advantageous when the speed of wire 18 exceeds the ability of a transformer core to induce sufficient I^2R heating in one turn. In FIG. 5 like parts are designated with numerals corresponding to those of FIG. 3. In FIG. 5 the disc 38 of the sheave 22 has a radial recess 126 whose inner hub supports a ball bearing 128. Mounted for rotation on the ball bearing and within the recess 126 is an idler wheel 130. Upon the same shaft 54 as rotates the idler wheel 52 is a second freely rotating idler wheel 132. The wire 18 now passes in rolling engagement over the rim 32, ninety degrees around the rim 32, downwardly and one hundred eighty degrees around the wheel 132, upwardly and one hundred eighty degrees around the wheel 130, downwardly and one hundred eighty degrees around the wheel 52, and back ninety degrees over the rim 56. The wheels 130, 132, and 52 rotate freely while the rims 32 and 56 on face members 34 and 36 are still mechanically secured for common rotation and are electrically connected through spokes 40 and 42 by rigid bolts 48. The structure in FIG. 5 is distinct from the structure in FIG. 3 mainly in that portion thereof facilitating transformer linkage with a two-winding shorted loop. Such a double loop is of advantage if the wire speed were too high for a given set of transformer cores to induce sufficient I^2R heat in one turn. In FIG. 5 the same gauges 66 and 82 pass strain information to the circuit 76 which controls heater elements 78 and 80. FIG. 5 also contemplates the cool air blowers operating on its rims as shown in FIG. 4.

While various embodiments of the invention have been disclosed in detail, it will be obvious to those skilled in

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the art that the invention may be embodied otherwise within its scope.

What is claimed is:

1. An apparatus for heating a moving wire, comprising electrically-conductive wire contacting means for guiding the wire, looping means for guiding the wire off the contacting means and back to the contacting means to form a loop, and electrical means inductively linked with the wire between the looping means and contacting means for inducing heating current in the wire, said contacting means defining two cyclically-movable electrically-interconnected and electrically-conductive endless portions joined for movement in unison, one of said portions contacting the wire before said looping means, the other of said portions contacting the wire after said looping means, said portions being heat-isolated from each other but individually heat expansible.

2. A heater for a moving wire, comprising two conductive and electrically-connected wire engaging means for engaging the wire at successive points, each of said engaging means defining a cyclically-movable endless path contactable with the wire, wire looping means for forming a loop of said wire between points of engagement with said respective wire engaging means, mechanical means for locking said wire engaging means to each other so as to move in unison, transformer means linked with said loop for inducing heating currents in the wire, said engaging means being heat-isolated from each other, and temperature control means for varying the temperature of one of said engaging means in response to the force of the wire along the path of one of said engaging means.

3. A heater for a moving wire, comprising two electrically-conductive rotary roll means for contacting the wire with their respective peripheries, wheel means for receiving the wire from one of said roll means and paying it out over the other of said roll means, rotatable means rigidly secured to both of said roll means for keeping their rotation in unison, said rotatable means having electrical means for connecting said roll means and forming with the wire a closed loop, transformer winding means inductively linked with said loop for inducing heating currents in the wire, said roll means being heat-isolated from each other, and temperature control means for varying the temperatures of one of said roll means in response to the effect of the force of the wire upon the periphery of the roll means which the one wire portion engages after said wheel means.

4. A heater for a moving wire, comprising two conductive rotary roll means for contacting the wire with their respective peripheries, wheel means for receiving the wire from one of said roll means and paying it out over the other of said roll means, rotatable means rigidly secured to both of said roll means for keeping their rotation in unison, said rotatable means having electrical means for connecting said roll means and forming with the wire a closed loop, transformer winding means inductively linked with said loop for inducing heating currents therein, a strain gauge oriented on one of said roll means to detect the effect of tangential force on its periphery by the wire engaging it, and heating means responding to said strain gauge for heating the one of said roll means, said roll means being heat-isolated from each other.

5. A heater for a moving wire, comprising two mutually heat-isolated rotary roll means for advancing the wire with their respective peripheries, wheel means for receiving the wire from one of said roll means and paying it out over the other of said roll means, rotating means rigidly secured to both of said roll means for rotating them in unison, electrical means for connecting said roll means and forming with the wire a closed loop, transformer winding means inductively linked with said loop for heating it, a strain gauge oriented on one of said roll means to detect the effect of tangential force on its periphery by the wire engaging it, and cooling means respond-

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ing to said strain gauge for cooling the other of said roll means.

6. A preheater for moving wire, comprising a rotatable sheave, a pair of wire-contacting electrically-conductive and electrically-interconnected rims secured to said sheave and heat-isolated from each other, wheel means for guiding wire to be preheated and contacting one of said rims back onto the other of said rims so as to form a loop, electrical means for inducing heating currents in the loop, strain gauge means engaging one of said rims to measure the peripheral force exerted thereon by the wire, and temperature control means for varying the temperature of one of said rims in response to output of said strain gauge means.

7. A preheater for a moving wire, comprising a rotatable sheave for contacting the moving wire, wheel means for guiding wire to be preheated off one side of the sheave and back onto the other side of said sheave so as to form a loop, electrical means for inducing heating currents in the loop, a pair of electrically-conductive and electrically-interconnected rims secured to said sheave, said rims being heat-isolated from each other, said rims being mounted on said sheave by members having radial portions, strain gauge means mounted on one of said radial portions for sensing the force effect of said wire on the rim, and temperature control means for varying the temperature of one of said rims in response to output of said strain gauge means.

8. A preheater for a moving wire, comprising a rotatable sheave, a pair of mutually heat-isolated and electrically-conductive and electrically-interconnected rims secured to said sheave for contacting the moving wire, wheel means for guiding the wire off a first of said rims back onto a second of said rims so as to form a loop, electrical means for inducing heating currents in the loop, capstan means for drawing the wire off the other rim, and temperature control means connected to said second of said rims for varying the temperature of one of said rims in response to force exerted by the wire on the second of said rims.

9. A preheater for a moving wire, comprising a rotatable sheave, a pair of electrically-conductive and electrically-interconnected rims forming a part of said sheave and heat-isolated from each other, wheel means for guiding the wire off a first of said rims back onto a second of said rims so as to form a loop, electrical means for inducing heating currents in the loop, and temperature control means connected to said second of said rims for cooling it in response to force exerted by the wire on the second of said rims.

10. A preheater for a moving wire, comprising a rotatable sheave having opposing faces, a pair of wire-contacting electrically-conductive and electrically-interconnected rims secured to said sheave and heat-isolated from each other, said rims contacting the moving wire, wheel means for guiding the wire to be preheated off a first of said rims back onto a second of said rims so as to form a loop, electrical means for inducing heating current in the loop, said rims having members with portions along the faces of the sheave and being secured to the sheave, a strain

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gauge mounted on said portions forming a part of the second of said rims, and temperature control means responding to the output of said gauge for cooling the second of said rims.

11. A preheater for a moving wire, comprising a rotatable sheave having opposite faces, a pair of electrically-conductive wire-contacting and electrically-interconnected rims secured to said sheave and heat-isolated from each other, wheel means for guiding the wire off a first of said rims and back onto a second of said rims so as to form a loop, electrical means for inducing heating currents in the loop, said rims having members with portions along the faces of the sheave and being secured to the sheave, a strain gauge mounted on said portion forming a part of the second of said rims, and temperature control means responding to the output of said gauge for heating the first of said rims.

12. Apparatus for heating a moving wire, comprising electrically-conductive wire-contacting means for guiding the wire, said contacting means defining two cyclically-movable electrically-interconnected endless portions joined for movement in unison, said portions being heat-isolated from each other but individually heat expansible, a third endless portion insulated from the electrically connected portions and independently movable, looping means for guiding the wire off one electrically-connected portion and onto the third portion, second looping means for guiding the wire off the third portion and onto the other electrically-connected portion so as to form a shorted loop, and electrical means inductively linked with said wire for inducing heating currents therein.

13. A preheater for moving wire, comprising a rotatable sheave, a pair of wire-contacting electrically-conductive and electrically-interconnected rims secured to said sheave and heat-isolated from each other, wheel means for guiding wire to be preheated and contacting from one of said rims from that rim through two turns back onto the other of said rims so as to form a two-turn loop, said wheel means having three freely rotating wheels, electrical means for inducing heating currents in the loop, strain gauge means engaging one of said rims to measure the peripheral force exerted thereon by the wire, and temperature control means for varying the temperature of one of said rims in response to output of said strain gauge means, said sheave having a radial cavity, one of said wheels being freely rotatable through the radial cavity in said sheave.

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