July 18, 1961 T. T. BUNCH ET AL 2,993,114

METHODS OF AND APPARATUS FOR HANDLING ELECTRICALLY CONDUCTIVE STRAND MATERIAL

Filed Oct. 7, 1959 2 Sheets-Sheet 1

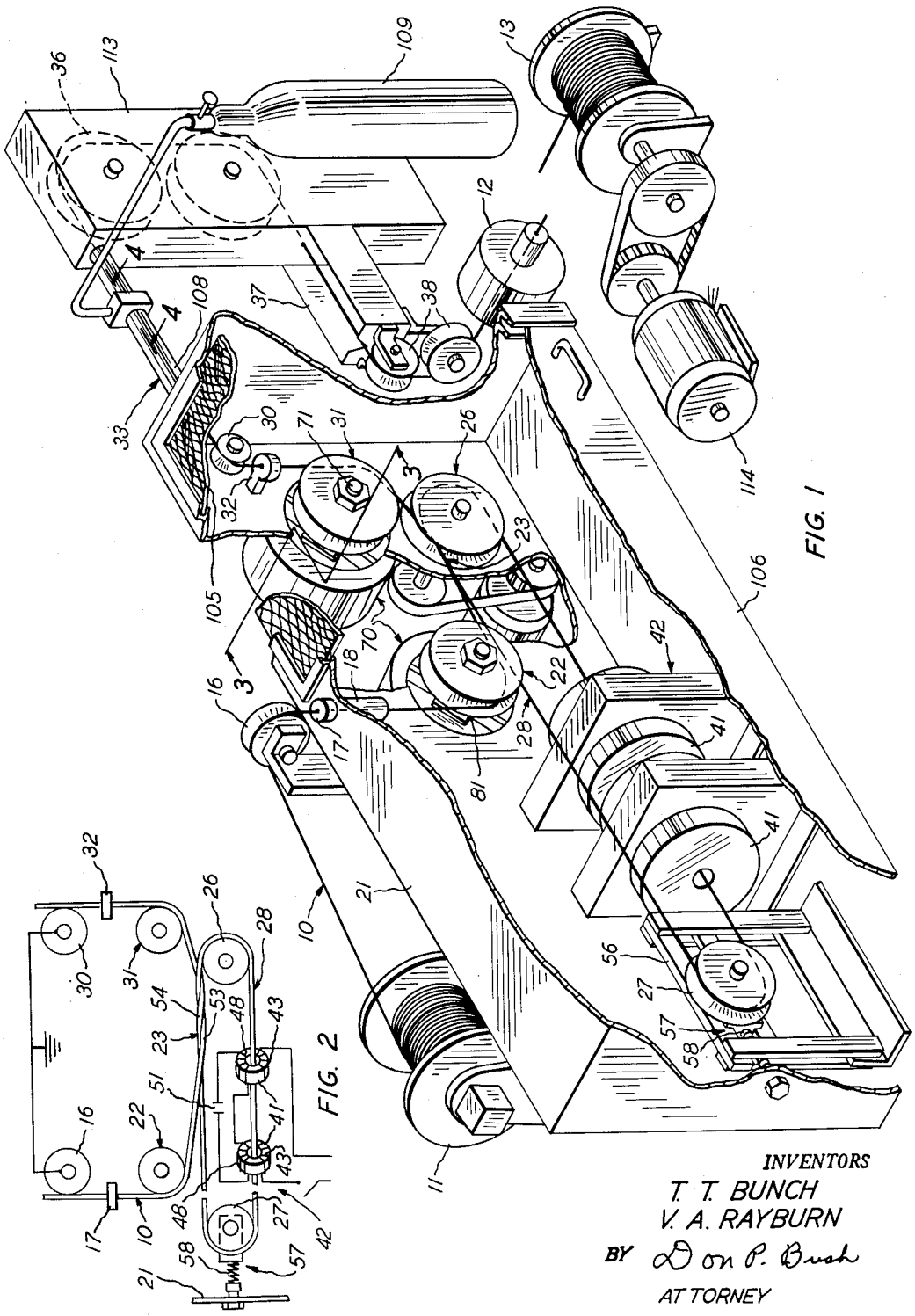


FIG. 1

FIG. 2

INVENTORS
T. T. BUNCH
V. A. RAYBURN
BY Don P. Bush
ATTORNEY

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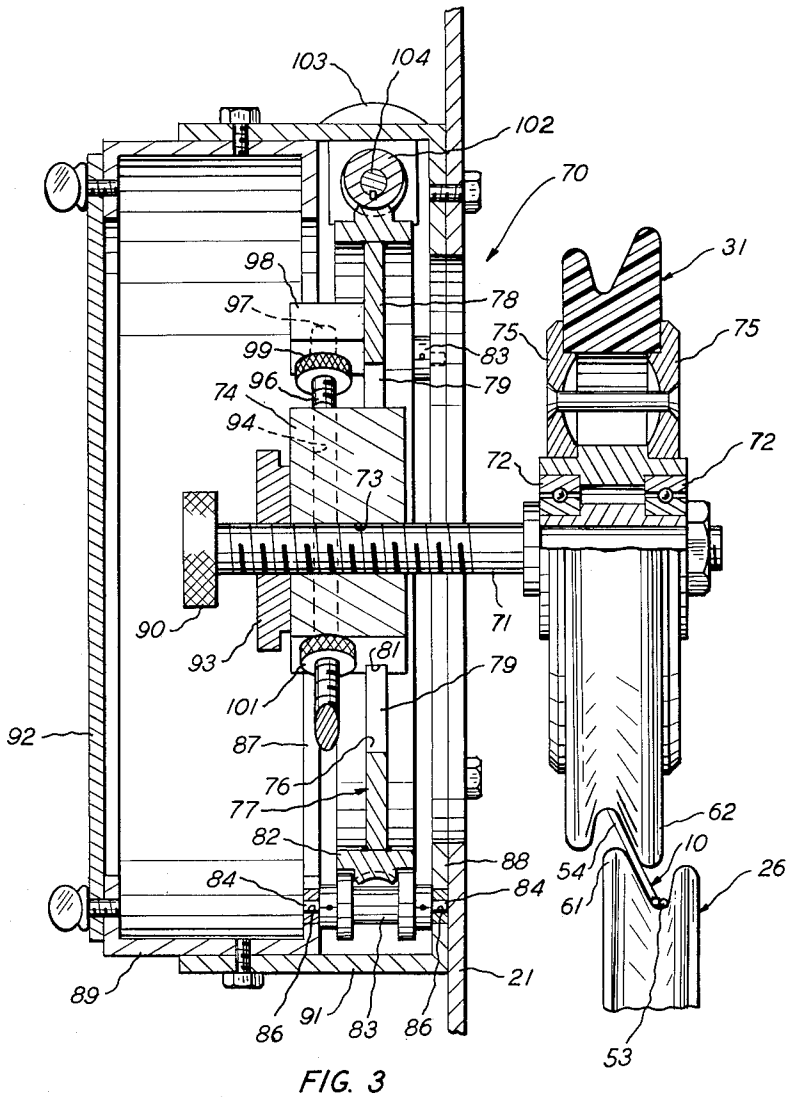


FIG. 3

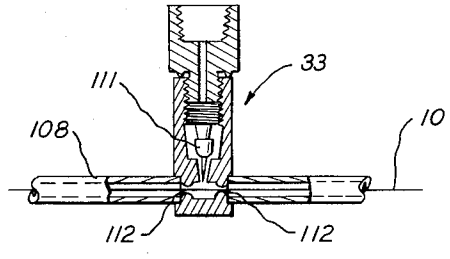


FIG. 4

INVENTORS
T. T. BUNCH
V. A. RAYBURN
BY Don P. Bush
ATTORNEY

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2,993,114
METHODS OF AND APPARATUS FOR HANDLING ELECTRICALLY CONDUCTIVE STRAND MATERIAL

Tillman T. Bunch, Princeton, N.J., and Vincent A. Rayburn, Baltimore, Md., assignors to Western Electric Company, Incorporated, New York, N.Y., a corporation of New York

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11 Claims. (Cl. 219—155)

The present invention relates to methods of and apparatus for handling electrically conductive strand material and more particularly, although not exclusively, to methods of and apparatus for inductively heating electrically conductive strand material passing through a continuously changing, closed loop formed of successive portions of a continuously moving length of strand material. The loop is closed by guiding successive portions of the strand material entering into and exiting from the loop in juxtaposed, spirated paths to form a running overhand tie.

This invention is particularly applicable for electrically heating a continuously moving length of electrically conductive strand material which is moving lengthwise between a strand supply and coating apparatus, such as a plastics extruder. The conductive strand material may be a copper conductor which has become hardened due to the cold-working thereof in a prior drawing operation.

Although continuous strand heating devices have been used in the industry for many years, such strand heating devices generally include undesirable extraneous elements of high and uncertain electrical resistances, such as current-collecting brushes, slip rings, contact sheaves, etc., which are subject to wearing and pitting and deteriorate with time. Further, extra electrical energy must be provided to supply the wattage which is normally lost in these extraneous elements. Therefore, in order to promote more uniform heating of the conductive strand material in the strand heating device, it is desirable to eliminate extraneous points of high and uncertain electrical resistances such as brushes, slip rings and contact sheaves.

It is an object of the present invention to provide new and improved methods of and apparatus for handling electrically conductive strand material.

It is another object of the present invention to provide new and improved methods of and apparatus for inductively heating electrically conductive strand material passing through a continuously changing, closed loop formed of successive portions of an indefinite length of electrically conductive, filamentary strand material.

It is a further object of the present invention to provide new and improved methods of and apparatus for heating a continuously moving copper conductor to anneal the same by employing a continuously closed loop, formed by successive portions of the conductor, which is positioned in an inductive relationship with a primary coil of a transformer.

A still further object of the present invention is to provide new and improved methods of and apparatus for forming a running tie to close the loop formed by successive portions of a continuously moving strand of electrically conductive material.

A yet still further object of the present invention is to provide new and improved methods of and apparatus for establishing and maintaining direct electrical contact between two continuously moving portions of electrically conductive strand material.

A method of establishing and maintaining electrical contact between two continuously moving portions of electrically conductive strand material, embodying certain features of the present invention, may include the steps of wrapping the portions of conductive strand material together to form a running overhand tie, maintaining the position of the running tie substantially stationary throughout the entire operation, and causing both portions of the conductive strand material to move through the tie in the same direction to prevent excessive friction between and wearing of the conductive strand material. In this way, the two portions of conductive strand material roll relative to each other as they pass through the running tie and every point on each portion of the conductive strand material touches some point on the other portion at some time while passing through the tie, thus causing uniform distribution of any current passing between the portions of the conductive strand material as they contact each other while passing through the running tie.

An apparatus for establishing and maintaining electrical contact between two continuously moving portions of electrically conductive strand material, embodying certain features of the present invention, may include means for causing the portions of strand material to be mutually, spirally intertwined in the form of a running overhand tie, means for advancing the portions of strand material through the running tie, and means for maintaining the running tie in a substantially stationary position throughout the entire operation while the portions of strand material are advanced therethrough. In this manner, the two portions of strand material roll relative to each other as they pass through the running tie and every point on each portion of the conductive strand material touches some point on the other portion of the strand material at some time while passing through the tie.

The apparatus for establishing and maintaining electrical contact between two continuously moving portions of electrically conductive strand material may be utilized to close a conductive loop of strand material which is maintained in an inductive relationship with the primary winding of a transformer to cause the strand material to be heated as a result of its resistance to the flow of current therein caused by a secondary voltage induced in the closed loop.

Other objects and features of the present invention will be more readily understood from the following detailed description of a specific embodiment thereof when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a fragmentary, diagrammatic view, in perspective, of an apparatus for electrically heating continuously moving strand material embodying certain features of the present invention with portions thereof broken away for purposes of clarity;

FIG. 2 is a fragmentary, diagrammatic view of the electrical portion of the apparatus of FIG. 1;

FIG. 3 is an enlarged, fragmentary, sectional view of the apparatus of FIG. 1 taken along line 3—3 thereof, and

FIG. 4 is a fragmentary, sectional view of a portion of a cooling device of the apparatus of FIG. 1 taken along line 4—4 thereof.

Referring now to the drawings and more particularly to FIG. 1 thereof, there is shown an annealing apparatus designed for electrically heating a continuously moving strand, designated generally by the numeral 10, of electrically conductive material, such as a strand of copper wire. The strand 10 is withdrawn from a supply 11 thereof, such as a brake-retarded supply reel, annealed, cooled, cleaned, passed through a coating apparatus, illustrated diagrammatically as a plastics extruder 12, and then taken up on motor-driven take-up reel 13. The strand 10 is passed partially around a grounded, electrically conductive sheave 16, through an inductive choke 17, through a seal 18 in a housing 21 and then to and partially around a nonconductive lead-on sheave, desig-

nated generally by the numeral 22. The strand 10 is then directed through a running overhand tie, designated generally by the numeral 23, partially around a motor-driven, nonconductive head sheave, designated generally by the numeral 26, partially around a nonconductive tail sheave 27, and back to the running overhand tie 23 to form a closed conductive loop, designated generally by the numeral 28.

After the strand 10 leaves the running tie 23, it is directed upwardly to and partially around a nonconductive lead-off sheave, designated generally by the numeral 31, through an inductive choke 32 and partially around a grounded, conductive, idler sheave 30. The strand 10 is then directed into a cooling system, designated generally by the numeral 33, and to an overrunning, slipping-type, strand-advancing capstan 36. The strand-advancing capstan 36 is designed to maintain a predetermined tension in the strand 10 and to compensate for length variations of the strand 10 due to expansion and contraction thereof during heating and cooling processes. The strand 10 is advanced from the capstan 36, through an electrolytic cleaning device 37, partially around a pair of sheaves 38—38, and through the plastics extruder 12 by the motor-driven take-up reel 13.

In the path of travel of the strand 10 between the sheaves 26 and 27, the strand 10 is passed through eyes of one or more toroidally wound magnetic cores 41—41 of a transformer, designated generally by the numeral 42. The magnetizing current, in a pair of primary coils 43—43 of the transformer 42 (FIG. 2), may be made independent of the current in the closed loop 28 of the strand 10 being heated, if the current is circulated in a resonant tank circuit to maintain a unity or other desirable power factor. The resonant tank circuit may be formed by placing a large condenser (not shown) in parallel with the input of the primary windings 43—43 of the transformer 42 or by providing auxiliary primary windings 48—48, which are connected in series with a condenser 51 of a smaller value than the condenser (not shown) that would be necessary in parallel with the input primary windings 43—43.

If more than one of the cores 41—41 are used in series, as is illustrated in the drawings, the primary windings 43—43 may be connected in series and the auxiliary primary windings 48—48 may be connected in series with the condenser 51 of the required capacitance and voltage rating. By using a plurality of small toroidal cores 41—41 instead of one large one, the primary windings 43 and 48 on each core 41 may be fewer in number which are shorter and thus a minimum of copper is needed. Also, the conductors forming the primary windings 43—43 and 48—48 need only be large enough to carry the current necessary to heat the strand 10 and not large enough to carry current lost in extraneous elements such as current-collecting brushes, slip rings, contact sheaves, etc., since these extraneous elements have been eliminated. By utilizing the above-described transformer circuit, the heating system may be regulated by the primaries 43—43 thereof being designed to give constant or variable voltage input, or the length or speed of the strand 10 in the closed loop 28 being heated or any of these in combination may be varied to control the amount of heating thereof.

The loop 28 is closed physically and electrically with the running tie 23, by having successive ingoing portions 53—53 of the strand 10 wrapped in a partial turn or more together with successive outgoing portions 54—54 of the strand 10 to provide a wiping contact between mutually intertwined, spirated portions 53 and 54 of strand 10 in running tie 23. As the ingoing portions 53—53 and the outgoing portions 54—54 of the strand 10 are passed through the running tie 23, they roll around each other so that every point on each portion 53 of the strand 10 touches some point on the other portion 54 at some time, both while entering and leaving the tie 23 and both of the portions 53 and 54 of the strand 10 move through the tie 23 in the same direction, at almost the same velocity. Some velocity difference results from the temperature difference between the two portions 53 and 54.

The slow wiping contact produced by the velocity difference and the pulling contact between the two portions 53 and 54 formed by the tie 23 eliminates extraneous points of high and uncertain resistances, such as brushes, slip rings, contact sheaves, etc., and promotes uniform heating of the strand of copper wire 10 since there is a constant renewal of the contact portion of the secondary circuit. In this way, the contact portion of the secondary circuit does not wear cumulatively or deteriorate with time and all of the electrical power supplied thereto is utilized to heat the strand 10 and none is dissipated as heat in extraneous elements. By eliminating the necessity of providing power which is normally lost in extraneous elements, no additional amount of iron in the cores 41—41 of the transformer 42 is required beyond that needed to induce voltage in the closed loop 28 formed by successive portions of the strand 10, which may be of the order of hundreds of volts.

The electrical circuit of the secondary loop 28 is closed with the running over-hand tie 23 which makes helical contact between the ingoing portion 53 and the outgoing portion 54 of the strand 10. The length of the helical contact between the portions 53 and 54 depends on the tension in the strand 10 and the relative positions of the adjustable lead-on sheave 22 and the adjustable lead-off sheave 31 with respect to the positions of the head sheave 26 and the tail sheave 27. However, since the sheave 26 is relatively stationary and the sheave 27 is substantially stationary, raising the sheaves 22 and 31 or moving them closer together decreases the length of helical contact between the portions 53 and 54, thereby increasing the helix angle and the wire-to-wire contact pressure.

There is, however, a limit on increasing the helix angle. If the running tie 23 is too short and the helix angle is too great, the ingoing portions 53 and outgoing portions 54 of the strand 10 in the tie 23 will be excessively deformed and will not unwrap readily. In the event that there is excessive deformation of the strand 10 in the tie 23, the outgoing portion 54 may be pinched by the ingoing portion 53 and carried onto the head sheave 26 before it is freed from the tie 23. It is preferable to have as long a running tie 23 as possible provided the desired wire-to-wire contact pressure exists therein. The wire-to-wire contact pressure in the tie 23 may be increased by increasing the tension in the portion 53 of the strand 10 entering the tie and the portion 54 exiting therefrom.

The amount of current that the tie 23 will pass without excessive sparking or heating depends on both the length of contact and the contact pressure. However, as the length of the interwire contact increases, the interwire contact pressure decreases; and conversely, as the length of interwire contact decreases, the interwire contact pressure increases. Even though the contact pressure and the length vary inversely, the contact pressure and the length do not vary in a straight-line relationship. Accordingly, the current carrying capacity of the tie 23 crests gradually over a range of complementary contact lengths and pressures where neither are maximum. Consequently, there is a region in which the voltage drop in the running tie does not vary, to any appreciable extent, even when the length of the helical contact and the wire-to-wire contact pressure fluctuate as a result of vibrations in the strand 10.

The portion of current induced in the secondary loop 28 which does not flow from one portion of the strand 10 to the other in the running overhand tie will pass through the strand 10 to the grounded sheaves 16 and 30 by way of the successive respective ingoing portions 53—53 and outgoing portions 54—54 of the strand 10. Whether the inductive chokes 17 and 32 will be required to minimize current drain-off to ground through sheave bearings or other machine elements will depend on the

resistance of the running overhand tie 23. But, if inductive chokes 17 and 32 are necessary, they will be required solely to protect operators or mechanical equipment remote from the heating system. All current induced in the secondary loop 28 will have accomplished its purpose of heating the strand 10 whether the current path is completed through the tie 23, or through ground, or through any combination of the two.

At the tie juncture, the ingoing cold portion 53 of the strand 10 is preheated by thermal conduction when it contacts the warm outgoing portion 54 of the strand 10. Similarly, the warm outgoing portion 54 of the strand 10 is precooled. While this heat exchange is taking place, heat is being generated in both the ingoing portion 53 and the outgoing portion 54 of the strand 10 by the current passing through the two in the tie 23. Consequently, there is unlikely to be much net cooling of the outgoing portion 54 until the juncture of the tie 23 is passed and the portion of the strand 10 leaves its intertwining helical path.

The apparatus of the present invention heats the strand 10 as it travels at a comparatively high rate of speed and the temperature required to heat the strand 10 is generally so high that the tensile strength thereof is greatly reduced. Therefore, it is preferable to prevent the strand 10 from being stressed beyond its elastic limit by propelling the strand 10 positively at both sides of the loop 28 and in the loop 28 and thus reduce the tension in the heated portions of the strand 10 to a minimum to avoid stretching the soft portion of the strand 10. This may be accomplished by having all of the sheaves driven at desired speeds which are calculated to compensate for the expansion and contractions of portions of the strand 10 during heating and cooling thereof.

The portion of the strand 10 in the closed loop 28 is advanced by pull exerted on the outgoing portion 54 by frictional contact with the portion 53, pulled by the sheave 26, and pull exerted by the capstan 36 to the recess side of the tie 23. However, the pull that the outgoing portion 54 of the strand 10 will tolerate without necking down or stretching out is of concern only in determining if the head sheave 26 need be power-driven to assist in advancing the strand 10 and relieve the pull on the heated outgoing portion 54 of the strand 10. For relatively small strands 10, it may be necessary also to drive the tail sheave 27, but this is to be avoided if possible because of mechanical complications arising from thermal expansion of the strand 10 in the closed loop 28.

It is preferable that the tail sheave 27 be mounted slidably in a support 56 on an adjustable, spring-loaded take-up carriage, designated generally by the numeral 57. The movement of the carriage 57, by a tension spring 58, will compensate for linear expansion of the loop 28, as a result of the heating of the strand 10 therein, to maintain uniform tension in the loop 28 and stabilize contact pressure in the running tie 23. It should be noted that variations in the length of the loop 28 are not desirable due to consequent variations in the resistance of the strand 10 in the loop. However, variations in the length of the loop 28 with resultant changes in the resistance of the strand 10 in the loop will be insignificant as compared to the change in the resistance of the strand 10 as a result of the variation in the temperature of the strand 10. Further, during any given annealing process operating under uniform conditions the variation in the length of the loop 28 would be insignificant. The sheaves 22, 26, 27 and 31 cooperate to steady the electrical resistances of the running tie 23 and keep it at a minimum relative to the conductor resistance of the remainder of strand 10 in the loop 28.

Because of its greater stiffness, the relatively cool ingoing portion 53 of the strand 10 may force the softer relatively warm outgoing portion 54 to assume most of the helical wrap at the tie 23 and pull it past the tangent point on the head sheave 26. If this is allowed to happen, the warm, outgoing portion 54 will be pinched between the cool portion 53 of the strand 10 and the sheave 26 which may cause the strand 10 to break. To forestall this, the lead-off sheave 41 may be raised and off-set laterally a small amount to pull the outgoing portion 54 of the strand 10 out of the tie 23 ahead of the tangent point on the head sheave 26 (FIG. 3). It also helps to flare the inside of the adjacent flanges 61 and 62 of the respective sheaves 26 and 31, forming the adjacent sides of the grooves therein, more acutely. Also, the same thing may be accomplished by canting both the head sheave 26 and the lead-off sheave 31 so that they toe-in on the tie 23, or approach side.

The sheaves 22, 26, 27 and 31, are made of an electrically nonconductive material which is relatively highly resistant to wear, such as "Heanium." "Heanium" is a hard, alumina, ceramic material manufactured by the Heany Industrial Ceramics Corporation, New Haven, Connecticut. In order that the sheaves 22 and 31 may be adjusted up and down vertically, forward and backward horizontally, and in and out laterally to change the path of travel of the respective intertwined portions 53 and 54 of the strand 10 entering and exiting from the running overhand tie 23, an adjustable mounting device, designated generally by the numeral 70, is provided for each of the sheaves 22 and 31. Preferably, the adjustable mounting devices 70—70 (FIG. 3) should permit the position of the sheaves 22 and 31 to be adjusted while the strand 10 is in motion, since only at that time can judgment as to the degree of adjustment be made positively and accurately.

Preferably the sheaves 22 and 31 are each mounted rotatably on a threaded nonmagnetic shaft 71 by sectional mounting means 75—75 and suitable split-type bearings 72—72 to prevent inductive build up. Each of the shafts 71—71 is secured in a threaded aperture 73 in an associated block 74. The block 74 is slidable in a diametrical slot 76 in a circular plate, designated generally by the numeral 77. Portions 78 and 79 of the plate 77 forming opposite sides of the slot 76 project into grooves 81—81 on opposite sides of the block 74. The circular plate 77 is welded to the inside surface of a ring gear 82 which, in turn, is mounted rotatably on a plurality of rollers 83—83. The rollers 83—83 are mounted rotatably at opposite ends 84—84 thereof in apertures 86—86 in radially inwardly projecting flanges 87 and 88 on adjacent ends of interconnected, concentric cylinders 89 and 91, respectively. The cylinder 91 is secured at one end thereof to the housing 21 and the opposite end of the other cylinder 89 has a hatch 92 secured thereto. The hatch 92 permits operating personnel to have free access to adjusting means for the associated sheave 22 or 31. Each of the hatches 92—92 cooperates with the associated cylinders 89 and 91 to make the housing 21 susbtantially air tight around each of the mounting devices 70—70 to prevent gases from escaping from the housing 21 through the adjustable mounting devices 70—70.

A knurled knob 90 is provided to turn the shaft 71 with respect to the block 74 to change the effective length of the shaft 71 and move the sheave 22 or 31 toward and away from the block 74. A locking nut 93 is utilized to cooperate with the block 74 for locking the shaft 71 in any desired position in the block 74.

The block 74 is provided with a threaded bore 94 which extends parallel to the slot 76 in the plate 77. A screw rod 96 is secured threadedly in the threaded bore 94 in the block 74. The rod 96 is mounted rotatably, parallel to the slot 76 in the plate 77, by positioning a non-threaded portion 97 on each end of the rod 96 in an aperture in an associated bearing block 98 secured to the plate 77 and the inside surface of the ring gear 82. A knurled knob 99 is secured rigidly to the rod 96 adjacent to each bearing block 98 to facilitate turning the screw rod 96 for adjusting the position of the block 74 along the slot

76. A locking nut 101 is provided to cooperate with the block 74 to lock the block 74 in a fixed position on the screw rod 96. The ring gear 82 is adjustable to any desired position by rotating a cooperating worm gear 102 by a handle 103 secured to one end of a shaft 104 on which the worm gear 102 is keyed.

A wire-glass or "Plexiglas" section 105 is provided in the top of the housing 21 (FIG. 1) so that the operating personnel may observe adjustments being made from the back of the housing 21. By rotating the ring gear 82 and thus the circular plate 77 and sliding the block 74 along the slot 76 in the plate 77, the rotational axis of the shaft 71 may be moved to any position in the circular area generated by rotating the effective length of the slot 76. The position of the associated sheave 22 or 31 along the axis of rotation of the shaft 71 may be varied by loosening the locking nut 93 and turning the knurled knob 92 in the desired direction to move the shaft 71 and the associated sheave 22 or 31 toward or away from the block 74.

Although not illustrated in the drawings, if it is desirable to cant the sheave 22 or 31 adjustably with respect to a plane containing the closed loop 28, the shaft 71 may be mounted for universal pivotable movement in any of many well-known ways, such as with a ball and clamping-type socket.

A siliding door 106 is provided on the front of the housing 21 to give the operating personnel free access to the apparatus during string-up operations. The sheaves 22, 26 and 31 are constructed with flange portions on one side thereof which are smaller in diameter and thus do not project radially outwardly as far as the flange on the opposite side to facilitate stringing up of the apparatus.

Successive portions of the heated continuously advancing strand 10 are cooled and cleaned by passing the strand 10 through a tube 108, forming part of the cooling device 33. As a suitable cooling medium, such as liquid carbon dioxide containing some carbon monoxide, acting as a scavenger for any oxygen which may be present, is introduced under high pressure (approximately 900 p.s.i.) from a supply thereof 109, into the tube 108 having a predetermined amount of clearance therein. The expansion of the liquid carbon dioxide into gas will cause rapid cooling of the strand 10 and the carbon monoxide will deoxidize the copper. As much as twenty-five percent water also may be dissolved in the carbon dioxide.

The liquid carbon dioxide is introduced into the tube 108, surrounding successive portions of the continuously advancing strand 10, by a suitable nozzle 111 (FIG. 4), such as a hypodermic needle. The amount of cooling of the strand 10 will be influenced by the amount of clearance between the strand 10 and an internal surface of orifices 112—112 in the tube 108. The amount of cooling of the strand 10 may also be regulated by changing the liquid pressure and velocity of the liquid carbon dioxide being fed into the tube 108 through the nozzle 111.

The velocities of the expanding gaseous mixture, passing through the tube 108 and gas discharging from the end of the tube 108 into the housing 21 and a substantially, air-tight housing 113 enclosing the capstan 36, are regulated to cause turbulent flow thereof to assist heat transfer from the strand 10 to the gas and to clean the strand 10 during relative movement between the strand 10 and the gas.

The surface of the conductive strand 10 exposed to atmospheric conditions has a tendency to tarnish or oxidize which is greatly accelerated when the strand is heated to relatively high temperatures. While the strand 10 is at an elevated temperature, it is important to protect it from oxidation from the atmosphere and to cool the surface of the strand 10 to a temperature below the point at which it discolors when the strand 10 comes into contact with the atmosphere. This is accomplished by enclosing the heating system in the substantially air-tight housing 21 into which gaseous carbon dioxide and carbon monoxide (less than 100 p.p.m.) from the cooling device 33 discharges. In this way the strand 10 is always maintained in a relatively inert atmosphere when the temperature thereof is such that excessive oxidation would take place.

Immediately after emerging from the housing 113 containing the capstan 36, any foreign material which remains on the strand 10 is removed by the electrolytic cleaning device 37, which may be a conventional electrolytic cleaner such as that disclosed in K. M. Huston Patent 2,422,902. Clean, annealed strand 10 may be delivered to a subsequent coating apparatus, such as an electroplating device, but is herein illustrated as being delivered to the extruder 12. The extruder 12 is utilized for placing a plastic insulating covering, such as polyethylene, polyvinyl chloride or the like, on the annealed strand 10. The insulated strand is then taken up on the take-up reel 13 driven by a motor 114.

Operation

In the operation of the present invention, the strand 10 is withdrawn from the supply reel 11 and passed over the grounded, conductive sheave 16, through the inductive choke 17 and around the insulated lead-on sheave 22. The lead-on sheave 22 directs the strand 10 into the running overhand tie 23. The strand 10 is passed from the tie 23 to and partially around the insulated head sheave 26, through the eyes of the toroidal solenoids 41—41 of the transformer 42, to and partially around the insulated tail sheave 27 and back to the running tie 23 to form the physically and electrically closed loop 28 of the strand material 10.

The transformer field induces current to flow in the successive portions of the strand 10 forming the closed loop 28, which is closed electrically by the running tie 23. Induced voltage in successive portions of the continuously moving strand 10 of electrically conductive material forming the loop 28, which loop is maintained in an inductive relationship with the primary coils 43—43 of the transformer 42, causes a current flow which heats the strand 10 as a result of the resistance of the strand material to the flow of current therein resulting from the induced voltage.

In order to provide a more compact design, several toroidal cores 41—41 are utilized by connecting the primary windings 43—43 (FIG. 2) in series and the auxiliary primary windings 48—48 in series and closing the auxiliary primary windings with the condenser 51 of the required capacitance and voltage rating, to form a tank circuit of the desired power factor. The regulation of the heating system is accomplished by maintaining a desired constant or variable power input on the primary of the transformer 42 or by regulating the length of the loop 28 or the speed of the strand 10.

The strand 10 is passed from the running tie 23 partially around the nonconductive lead-off sheave 31, through the inductive choke 32, over the grounded sheave 30 and through the cooling device 33. The strand 10 is cooled and at least partially cleaned by liquid carbon dioxide expanding to a gas in the cooling device 33 and is then passed over the over-running, slipping, strand-advancing capstan 36 to compensate for the linear thermal expansion of the strand 10 during the heating thereof. The strand 10 is then pulled through the electrolytic cleaner 37 and extruder 12 by a take-up capstan (not shown) and onto the motor-driven take-up reel 13.

It is to be understood that the above-described arrangements are simply illustrative of the application of the principles of the invention. Other arrangements may be devised by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof.

What is claimed is:

1. The method of establishing and maintaining electrical contact between two continuously moving portions of electrically conductive strand material, which comprises guiding portions of electrically conductive strand

material in mutually spirally intertwined paths to form a running tie, advancing the portions of the strand material through the running tie, and maintaining the running tie in a substantially stationary position while the portions of the strand material are advanced therethrough.

2. The method of establishing and maintaining electrical contact between two continuously moving portions of electrically conductive strand material, which comprises wrapping two continuously moving portions of conductive strand material together to form an overhand tie, maintaining the position of the tie substantially stationary, and causing both portions of the conductive strand material to move through the tie in the same direction to prevent excessive wearing of the conductive strand material, so that the two portions of conductive strand material roll relatively to each other as they are passed through the running tie and every point of each portion of the conductor touches some point on the other portion while passing through the tie thus causing uniform distribution of any current passing between the portions of the conductive strand material as they pass through the running tie.

3. The method of heating electrically conductive strand material, which comprises forming successive portions of an indefinite length of continuously advancing conductive strand material into a loop, closing the loop electrically with a running tie formed by successive ingoing and outgoing portions of the closed loop, maintaining the running tie substantially stationary throughout the entire operation, maintaining the loop in an inductive relationship with a primary of a transformer so that the loop forms a secondary of the transformer, and energizing the primary of the transformer to induce a voltage in the loop to cause a current to flow therein so that successive portions of the conductive strand material are heated to a predetermined temperature.

4. The method of heating electrically conductive strand material, which comprises forming successive portions of an indefinite length of continuously advancing conductive strand material into a continuously changing loop, closing the loop electrically by establishing and maintaining electrical contact between successive portions of the electrically conductive strand material entering and leaving the loop, the contact being made by wrapping the entering and leaving portions of conductive strand material spirally around each other to form a running tie thus causing the entering and leaving portions of conductive strand material to roll around each other as they are passed through the running tie so that every point of each portion of the conductive strand material touches some point on the other portion at some time both while entering and leaving the tie, maintaining the loop in an inductive relationship with a primary of a transformer so that the loop forms a secondary of the transformer, causing both entering and leaving portions of the conductive strand material to move through the tie in the same direction to prevent excessive wearing of the conductive strand material and to cause uniform distribution of any current passing between the portions of the conductive strand material as they pass through the running tie, maintaining the running tie in a substantially stationary position throughout the entire operation, and energizing the primary of the transformer to induce a voltage in the loop to cause current to flow therein so that successive portions of the conductive strand material are heated to a predetermined temperature.

5. Apparatus for establishing and maintaining electrical contact between two continuously moving portions of electrically conductive strand material, which comprises means for guiding two continuously moving portions of strand material in a mutually spirally intertwined relationship to form a running tie, means for advancing the portions of strand material through the running tie, and means for maintaining the running tie in a substantially

stationary position throughout the entire operation while the portions of strand material are advanced therethrough.

6. Apparatus for making electrical contact between moving portions of electrically conductive strand material, which comprises means for guiding successive portions of advancing strand material in juxtaposed centrosymetrically spirated paths to form a running overhand tie, and means for varying the length of the running tie and contact pressure between successive portions of the strand material passing through the running tie.

7. Apparatus for heating electrically conductive strand material, which comprises a source of supply of the strand material, a plurality of guide sheaves for directing successive portions of strand material through a running tie into a continuously changing closed loop of the strand material and out of the loop through the running tie, means for inducing voltage in the closed loop of strand material, means for varying the length of the closed loop, and means for varying the length of the running tie and contact pressure between successive portions of the strand material entering and leaving the closed loop.

8. Apparatus for heating electrically conductive strand material, which comprises means for advancing electrically conductive strand material through a predetermined path of travel, means for maintaining successive portions of the advancing strand material in the form of a loop, means for guiding the strand material entering and leaving the loop through intertwined paths to form a running tie which closes the loop electrically, and means for producing a magnetic field for inducing voltage in successive portions of the strand material forming the closed loop whereby successive portions of the strand material are heated to a predetermined temperature as a result of the resistance of the strand material to the flow of current therein resulting from the induced voltage.

9. Apparatus for heating electrically conductive strand material, which comprises an induction coil having a passage through which successive portions of electrically conductive strand material may be passed in an inductive relationship therewith, a source of electrical energy connected to the induction coil, means for directing successive portions of the strand material in the form of a loop in an inductive relationship with the induction coil, and means for guiding successive portions of the strand material entering the loop in a mutually intertwined path with successive portions of the strand material leaving the loop to form a running tie which closes the loop electrically so that induced voltage will cause current to flow in the loop causing heating of the successive portions of the strand material in the loop as a result of the resistance of the strand material to the flow of current therein.

10. Apparatus for heating electrically conductive strand material, which comprises a tank circuit formed by a series connection of an induction coil and a condenser, the induction coil having a passage through which successive portions of electrically conductive strand material may be passed in an inductive relationship therewith, a source of electrical energy connected to the induction coil, means for directing successive portions of the strand material in the form of a loop in an inductive relationship with the induction coil, and means for guiding successive portions of the strand material entering the loop in a mutually intertwined path with successive portions of the strand material leaving the loop to form a running tie which closes the loop electrically so that induced voltage will cause current to flow therein causing heating of the successive portions of the strand material in the loop.

11. Apparatus for heating electrically conductive strand material, which comprises means for advancing electrically conductive strand material through a predetermined path of travel, a primary induction coil of a transformer having a passage through which successive portions of the strand material may be passed in an inductive relationship therewith so that voltage is induced in the strand

material, an apertured core of magnetic material within the coil, a source of alternating current connected to the primary induction coil, means for guiding one side of a loop formed by the strand material through the aperture in the core to form a secondary coil of the transformer, means for guiding the strand material entering and leaving the loop in mutually intertwined paths to form a running tie which short circuits the loop thus causing current to flow in the successive portions of the strand material in the loop, means for compensating for the expansion of the strand material in the loop as it is heated as a result of the resistance of the strand material to the flow of current resulting from the induced voltage, and

means for varying the length of the running tie and contact pressure between successive portions of the intertwined strand material entering and leaving the closed loop.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,993,114 July 18, 1961

Tillman T. Bunch et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 54, after "continuously" insert -- changing --; column 6, line 4, for "41" read -- 31 --; column 7, line 26, for "siliding" read -- sliding --.

Signed and sealed this 19th day of December 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

USCOMM-DC

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