Aug. 8, 1967 D. FERSCHL 3,335,260

ANNEALING APPARATUS FOR WIRE AND LIKE CONDUCTORS

Filed Oct. 20, 1965 2 Sheets-Sheet 1

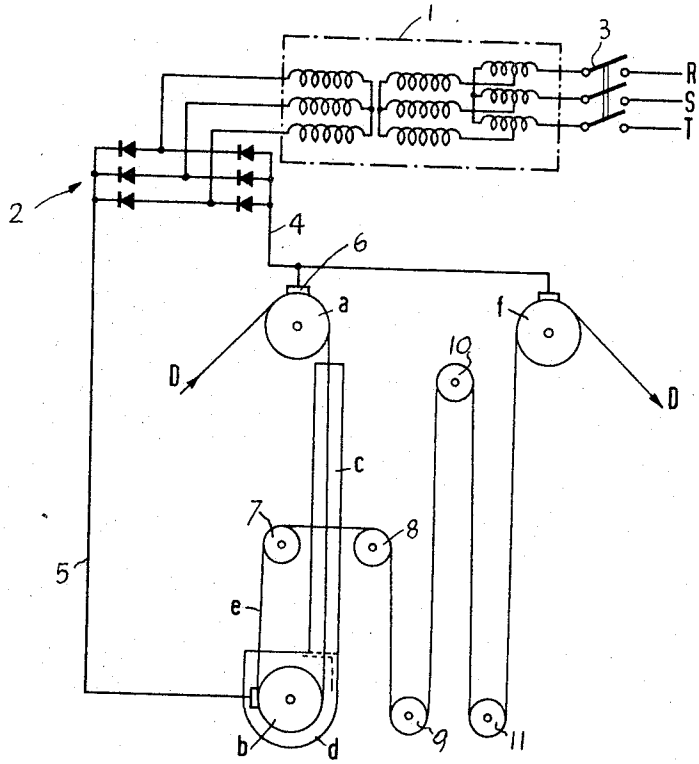


Fig. 1

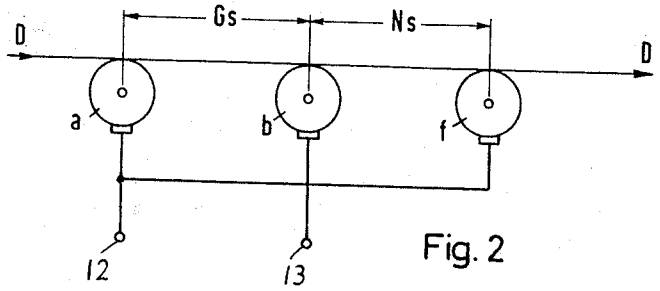


Fig. 2

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2 Sheets-Sheet 2

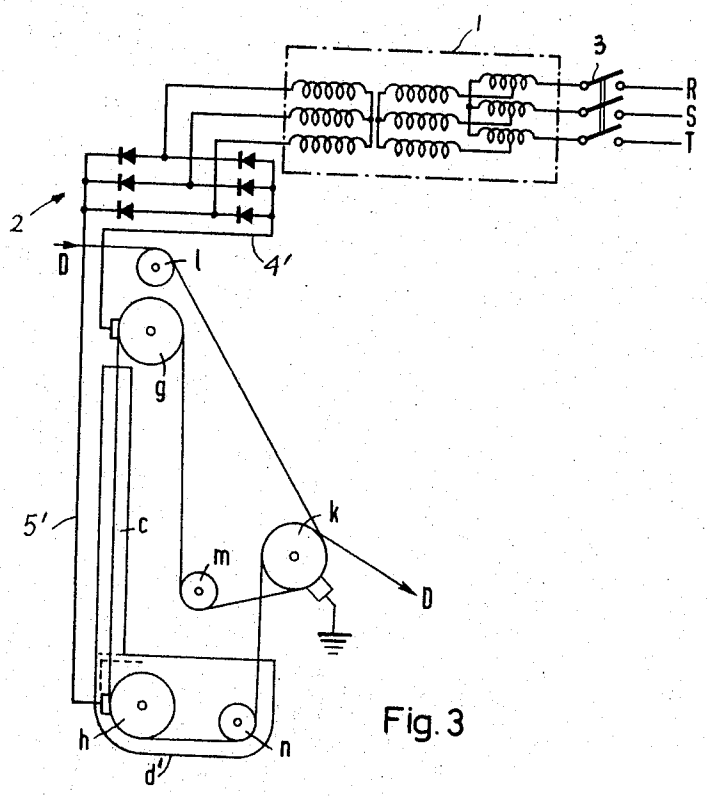


Fig. 3

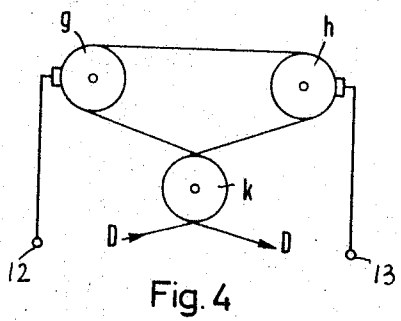


Fig. 4

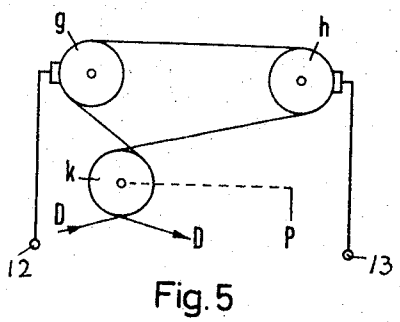


Fig. 5

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ANNEALING APPARATUS FOR WIRE AND LIKE CONDUCTORS

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7 Claims. (Cl. 219—155)

This invention relates to the annealing of wire and like conductors of essentially infinite length by electrical resistance heating, and particularly to a method of annealing thin copper wire and the like, and to apparatus for performing the method.

Copper wire is quickly and fully annealed by the passage of an electric current of sufficient strength to heat the wire to approximately 500° C. At that temperature, the wire oxidizes in air rapidly, and it is therefore conventional in continuous copper wire annealing apparatus to quench the wire in water as soon as it reaches annealing temperature thereby avoiding the need for maintaining a protective atmosphere about the wire while it is being cooled by slower means. Adhering water must be removed from the copper wire after quenching, and resistance heating of the quenched wire, hereinafter referred to as post-heating, to a temperature much lower than the annealing temperature is preferred for this purpose.

An object of the invention is the provision of an annealing method which permits such reheating to be done in a particularly simple and convenient manner.

Another object is the provision of apparatus for carrying out the method.

A more specific object is the provision of an annealing apparatus whose post-heating section is short as compared to the annealing section, yet does not require the supply of current at two different voltages for heating the wire in the two zones.

An additional object is the provision of such apparatus in which the post-heating section is so short as to permit the number of guide pulleys and similar supports for the annealed wire to be reduced to a minimum, or to avoid the use of such supports.

With these and other objects in view, the invention resides in a method of annealing an elongated conductor by passage of electric current in which the conductor is continuously moved through longitudinally consecutive preheating, annealing, and post-heating zones, whereby three longitudinally consecutive portions of the conductor are simultaneously located in these zones respectively. An electric potential is applied to the ends of the conductor portion located in the annealing zone, while the ends of the conductor portions located in the preheating and post-heating zones and remote from the annealing zone are conductively connected. The afore-mentioned potential is thereby applied in parallel to the conductor portion in the annealing zone and to a series circuit which includes the conductor portions in the preheating and post-heating zones.

In another aspect the invention resides mainly in an annealing apparatus equipped with guide means for guiding a conductor longitudinally in sequence through a preheating zone, an annealing zone, and a post-heating zone. The apparatus also includes a source of electric potential, and means for applying the potential to the ends of a portion of the conductor in the annealing zone respectively adjacent the ends of the conductor portions in the preheating and post-heating zones. Linking means conductively connect the ends of the conductor portions in the preheating and post-heating zones remote from the annealing zone,

whereby the linking means and the conductor portions linked thereby constitute a series circuit to whose ends the afore-mentioned potential is being applied.

Other features and many of the attendant advantages of this invention will be readily appreciated from the following detailed description of a typical wire annealing installation of the prior art, and of a preferred embodiment of this invention as illustrated in the accompanying drawing in which:

FIG. 1 shows a known resistance annealing installation for copper wire partly in fragmentary elevation and partly in conventional diagram;

FIG. 2 is a simplified schematic of the annealing circuit in the apparatus of FIG. 1;

FIG. 3 illustrates a wire annealing installation of the invention in a view corresponding to that of FIG. 1;

FIG. 4 illustrates the electrical circuit of the apparatus of FIG. 3 in the manner of FIG. 2; and

FIG. 5 shows a modified annealing installation of the invention in a manner analogous to FIG. 4.

Referring now to the drawing in detail, and initially to FIG. 1, there is seen a conventional annealing plant for thin copper wire in which the wire is heated to its annealing temperature while traveling through the apparatus in continuous length.

The low-voltage direct current which passes through the wire is produced from three-phase line current of 220 volts drawn from a three-conductor system R, S, T by a transformer **1** and a full-wave rectifier **2** when a main switch **3** is closed. The conductors **4**, **5** of the low voltage D.C. system are heavy copper or aluminum bars.

The conductor **4** is connected by a brush **6** to a contact pulley *a* and by a similar brush to a contact pulley *f*. The conductor **5** is connected in an analogous manner to a contact pulley *b* which is rotatably mounted in a normally water-filled tank *d*.

A hard copper wire D is drawn into the annealing apparatus from a storage reel or directly from the draw bench. It is first trained over the contact pulley *a*, and it then travels in a relatively short straight path to the pulley *b*. This path portion is protected against atmospheric oxygen by a tube *c* of refractory material. The wire reaches its highest temperature in the tube *c*.

The wire leaving the water bath in the tank *d* passes a non-illustrated air jet at *e* and is then trained sequentially over five insulated idler pulleys **7** to **11** and ultimately over the contact pulley *f*. The length of the wire path portion between the contact pulleys *b* and *f* is about five times as long as the high temperature portion between the pulleys *a* and *b*.

When the switch **3** is closed and the wire D travels continuously through the known annealing installation in the direction from the pulley *a* to the pulley *f* as indicated by arrows, a major portion of the direct current flows between the pulleys *a* and *b* and heats the wire at least to its annealing temperature, and normally to red heat at 500° C. The hot wire is quenched in the water bath in the tank *d*, and the steam generated is discharged through the tube *c* to provide a protective atmosphere for the hot wire therein.

The wire leaving the tank *d* carries a film of water on its surface which is partly removed by the air jet at *e*, and partly evaporated at the somewhat elevated temperature maintained in the travelling wire by the relatively low current flowing between the pulleys *f* and *b*. The wire is pulled from the pulley *f* by non-illustrated drive rolls, a capstan, or the like. It is ready for reeling or for coating with thermoplastic insulating material which may be applied by spraying.

The large number of idler pulleys **7–11** is necessary in order to accommodate the relatively great length of

wire in the post-heating zone between the pulleys *b* and *f* within a reasonable space and to support the traveling wire. They must be insulated from each other.

The electrical circuit of the apparatus of FIG. 1 is shown in FIG. 2 wherein the source of annealing current is represented by two terminals **12, 13**. The annealing zone G*s* extends between the pulleys *a* and *b*, and a post-heating zone N*s* between the pulleys *b* and *f*. The lengths of wire simultaneously traveling in the two zones are in parallel circuit, and it is evident that the post-heating zone must be much longer in order to increase the ohmic resistance of the wire traveling therein, and thereby to reduce the current flow and to hold the wire temperature barely high enough to expedite complete evaporation of the residual cooling water and to prepare the wire for its plastic coating, but not higher. A wire temperature of about 100° C. is normally preferred in this zone.

It is not practical to install drives for the idler pulleys **7** to **11**, and the moving wire D provides the driving energy for the idlers. The stress imposed on fully annealed thin copper wire during start-up in accelerating the relatively heavy idler pulleys to an adequate circumferential speed is substantial, and may cause significant work hardening of the wire, or even wire breaks. It is desirable to pass the wire through the annealing apparatus with a minimum of tenison. The friction between the wire and the idler pulleys is directly related to the wire teinsion, and may be inadequate to overcome bearing friction at the idlers at otherwise desirable wire tension values. The resulting slip between the wire and the pulley grooves causes rapid wear of the pulleys, and they must be replaced when their surfaces become sufficiently irregular to damage the wire, and preferably sooner. Bearing friction at the idler pulleys **7** to **11** also reduces the contact pressure between the traveling wire D and the contact pulley *b*. This may cause arcing at the contact, and results in roughness of the wire surface.

Important problems of operation and maintenance in the apparatus shown in FIG. 1 are thus proportional in magnitude to the number of idler pulleys. Yet, this number cannot be reduced in the conventional apparatus.

An annealing installation of the invention is shown in FIG. 3. Its direct-current supply may be identical with that described above, and includes a main switch **3**, a transformer **1**, and a full-wave rectifier **2** which feeds low-voltage direct current through heavy conductors **4'**, **5'** to two contact pulleys *g* and *h*. The wire D travels between these pulleys in a refractory tube *c* in which a protective steam atmosphere is maintained by evaporation of water from a tank *d'* in which the pulley *h* is mounted.

The hard copper wire enters the apparatus over an idling guide pulley *l* and a conductive pulley *k* mounted on a grounded support in a manner not further illustrated. It is then guided over an idler pulley *m* to the contact pulley *g*.

The annealed wire leaves the tank *d'* over a submersed idler pulley *n* in the tank *d'* and is again trained over the pulley *k* which is provided with two axially spaced grooves for receiving the two portions of the wire D respectively. The annealed wire is drawn from the pulley *k* as described above.

In this arrangement, the annealed wire travels over only two idlers *n, k* after passing the contact pulley *h* at the end of the annealing zone. The pulley *n* is lubricated by water, and the pulley *k* may be mounted on an anti-friction bearing and grounded. The only idler pulley operating under conditions similar to those of the pulleys **7** to **11** in FIG. 1 is the pulley *m*, but it guides the wire prior to annealing, and the problems resulting in the known apparatus from the interaction of annealed wire and insulating pulleys do not exist in the arrangement of the invention.

FIG. 4 shows the electrical circuit of the annealing apparatus of FIG. 3 which permits the elimination of insulating pulleys from the post-heating zone. Current from the terminals **12, 13** flows between the two pulleys *g* and *h* in a continuous length of wire in an annealing zone. Current also flows between these two pulleys in a second circuit in which a wire portion undergoing post-heating, the pulley *k* and a wire portion undergoing preheating upon entering the annealing installation are arranged in series.

The post-heating zone therefore may be quite short and does not require multiple supports for the wire. Actually, the idling guide pulley *n* in the tank *d'* may be omitted, and the guide pulleys *i* and *m* are not needed if a supply reel for the hard copper wire is suitably located relative to the conductive pulley *k* which provides an electrical link between the wire portions in the preheating and post-heating zones. If so desired, such a link may be provided by a molten bath of low melting alloy or molten lead through which the wire D enters and leaves the annealing installation.

If the annealing installation supplies wire for different purposes requiring post-heating to different temperatures, the conductive pulley *k* is preferably mounted on a movable support which permits the effective distance between the pulley *k* and the contact pulleys *g, h* to be varied as diagrammatically illustrated in FIG. 5 in which a broken line *p* indicates the path of movement of the pulley *k*. A carrier similar to a tool slide of a lathe and guided in a dove-tailed groove of a supporting structure may be employed to provide the desired mobility of the pulley *k*, but other adjustable supports will readily suggest themselves to those skilled in the art. The path of the pulley *k* obviously need not be straight. As the pulley *k* travels along the line *p* in FIG. 5, the wire length in one of the preheating and post-heating zones increases while the wire length in the other zone decreases and vice versa. The temperature of the wire leaving the annealing installation may thereby be continuously varied as needed to suit a subsequent operation.

Other modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically disclosed.

What is claimed is:

1. An apparatus for annealing an elongated conductor in continuous operation comprising, in combination:

(a) guide means for guiding said conductor longitudinally in sequence through a preheating zone, an annealing zone, and a post-heating zone;

(b) a source of electric potential;

(c) means for applying said potential to the ends of a portion of said conductor in said annealing zone respectively adjacent the ends of conductor portions in said preheating and post-heating zones; and

(d) a body of conductive material, said guide means including means for holding the ends of the conductor portions in said preheating and post-heating zones remote from said annealing zone in direct electrical contact with said body, whereby said body and the conductor portions in said preheating and post-heating zones jointly constitute a series circuit, said potential being applied to the ends of said series circuit.

2. An apparatus as set forth in claim **1**, further comprising means for grounding said body.

3. An apparatus for annealing an elongated conductor in continuous operation comprising, in combination:

(a) guide means for guiding said conductor longitudinally in sequence through a preheating zone, an annealing zone, and a post-heating zone;

(b) a source of electric potential;

(c) means for applying said potential to the ends of a portion of said conductor in said annealing zone respectively adjacent the ends of conductor portions in said preheating and post-heating zones; and

(d) linking means for conductively linking the ends of the conductor portions in said preheating and post-heating zones remote from said annealing zone, whereby said linking means and the conductor portions linked thereby jointly constitute a series circuit, said potential being applied to the ends of said series circuit,

(1) said linking means including a conductive guide pulley located for guiding said conductor into said preheating zone upon entering the apparatus and for guiding the conductor upon leaving said post-heating zone.

4. An apparatus as set forth in claim 3, said guide pulley being formed with two axially spaced grooves adapted simultaneously to receive respective portions of said conductor.

5. An apparatus as set forth in claim 3, wherein said guide means include two contact pulleys defining said annealing zone therebetween and adapted to guide said conductor through the annealing zone, the apparatus further comprising means for shifting said guide pulley relative to said contact pulleys and for thereby shortening said preheating zone while lengthening the post-heating zone, and vice versa.

6. A method of annealing an elongated conductor by the passage of electric current which comprises:

(a) moving said conductor continuously through longitudinally consecutive preheating, annealing, and post-heating zones, whereby three longitudinally consecutive portions of said conductor are simultaneously located in respective ones of said zones;

(b) applying an electric potential to the ends of the conductor portion located in the annealing zone; and

(c) simultaneously conductively connecting the ends remote from said annealing zone of the conductor portions located in said preheating and post-heating zones, whereby said potential is applied in parallel to the conductor portion in said annealing zone and to a series circuit including the conductor portions in said preheating and post-heating zones; and

(d) cooling said conductor during movement thereof from said annealing zone to said post-heating zone.

7. An apparatus as set forth in claim 1, further comprising cooling means interposed between said annealing and post-heating zones, said guide means including means for guiding said conductor from said annealing zone to said cooling means and from said cooling means to said post-heating zone.

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