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McAmis et al.

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[54] **HIGH SPEED TANDEM WIRE DRAWING AND INSULATION SYSTEM**

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[73] Assignee: **Southwire Company,** Carrollton, Ga.

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[21] Appl. No.: **321,128**

[52] **U.S. Cl.**..... **29/527.4,** 29/203 C, 29/624, 72/46, 117/66, 118/75

[51] **Int. Cl.**..... **B44d 1/44**

[58] **Field of Search**..... 29/203 C, 624, 527.4; 204/183; 148/31, 31.5, 32, 11.5 A; 117/128, 128.4, 128.7, 132 R, 132 A, 115, 62, 66; 425/376, 378, 379, 380, 381, 381.2, 382, 382.2, 67, 68, 70, 71; 118/67, 68, 69, 109, 75; 72/274, 280, 282, 286, 289, 46, 342, 377, 378, 43, 39, 463, 47; 264/104, 255, 165, 174, 176 R, 176 F; 62/373, 390, 442, 171, 98; 65/348; 156/47, 48

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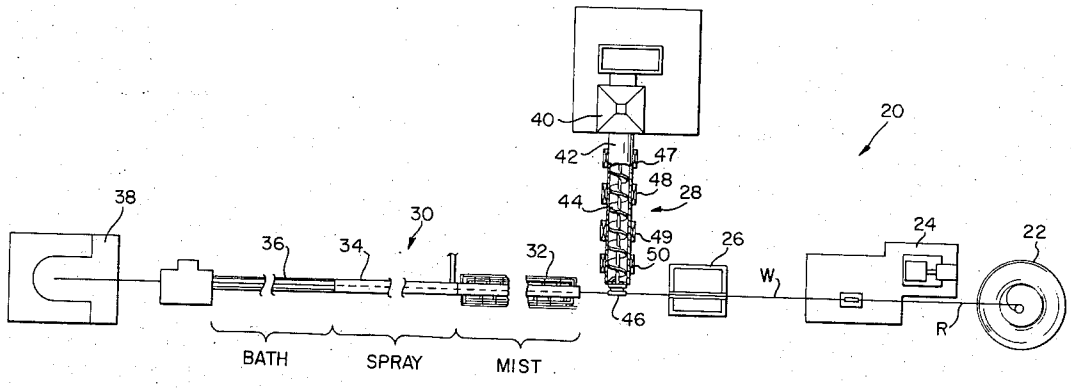
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Assistant Examiner—Joseph A. Walkowski
Attorney, Agent, or Firm—Herbert M. Hanegan; Van C. Wilks

[57] **ABSTRACT**

This disclosure relates to a method and apparatus for producing insulated wire from rod at speeds in excess of 2,500 feet per minute in a continuous in-line tandem system. The rod is drawn down into wire by combined drawing and annealing apparatus, and then conveyed directly to an in-line extruder where it is covered with a plastic coating. The coated wire is cooled in a three-stage system including a cooling mist, a cooling spray, and a cooling bath.

11 Claims, 11 Drawing Figures



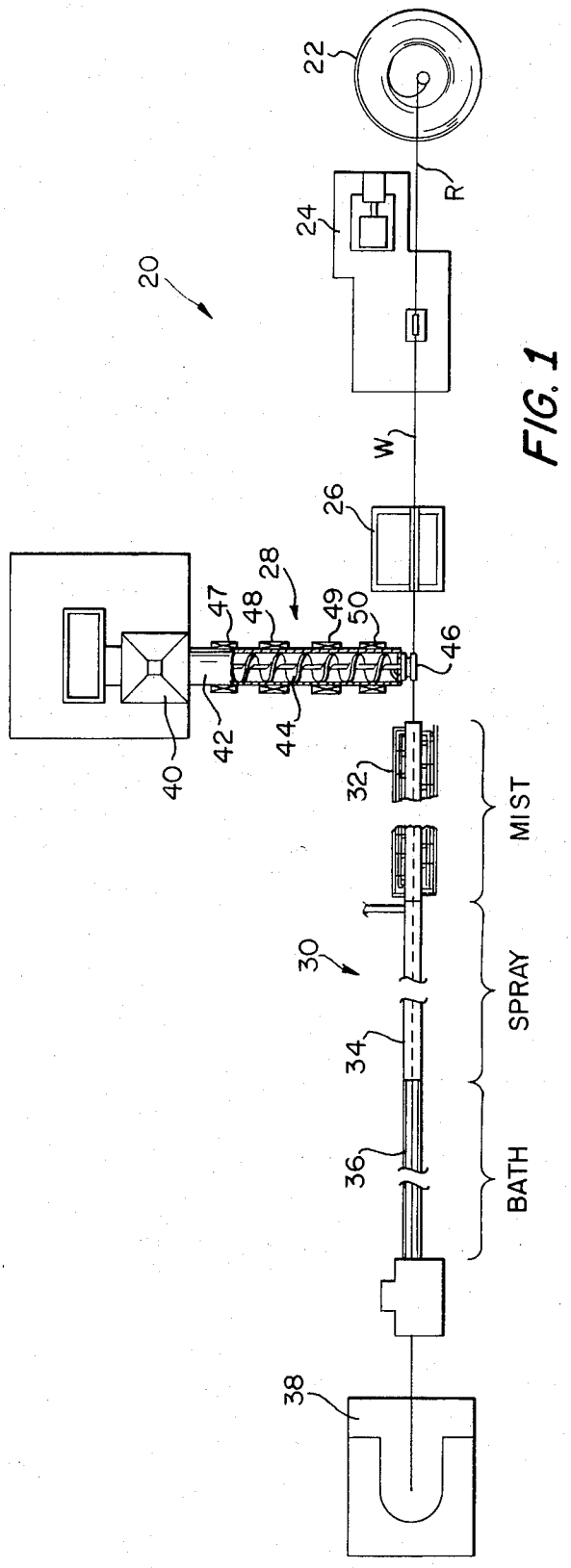
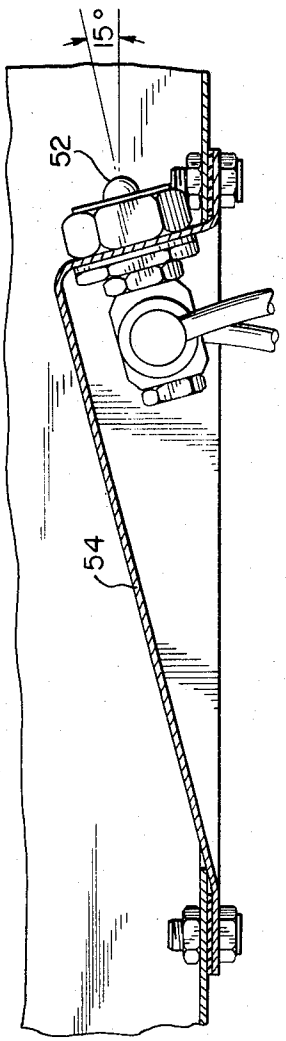

22
R
24
20
W
26
28
47
48
49
50
46
40
42
44
32
MIST
30
SPRAY
34
36
BATH
38

FIG. 1

FIG. 4


15°
52
54

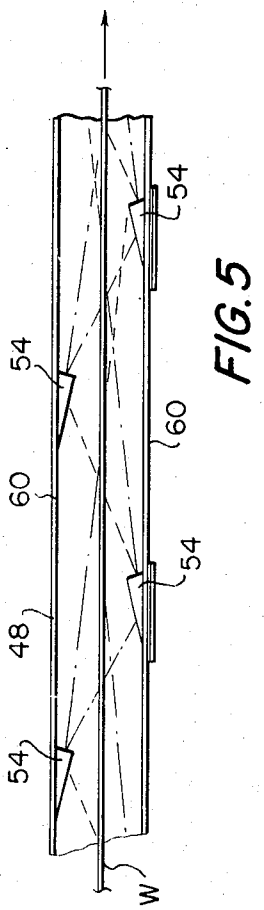


FIG. 5

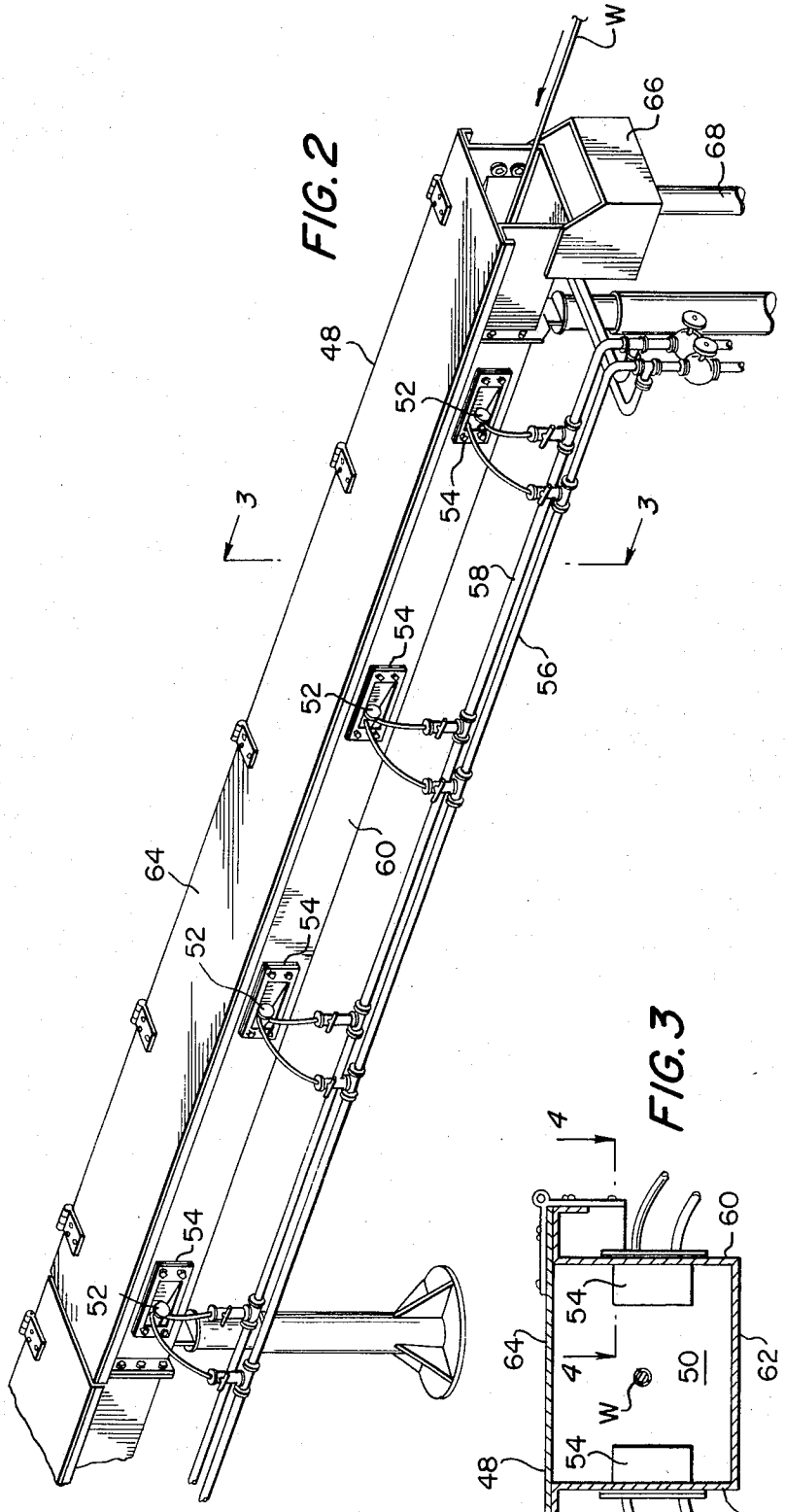


FIG. 2

FIG. 3

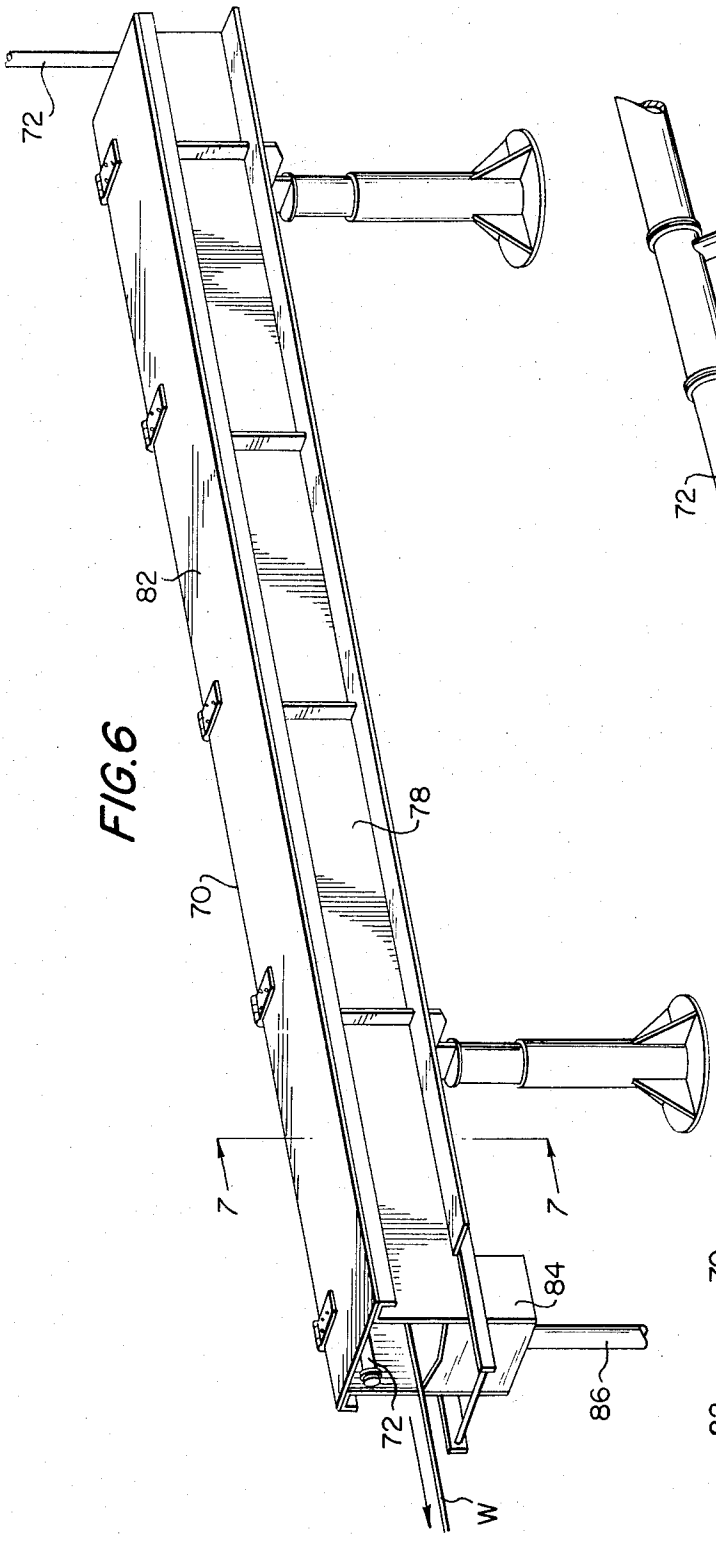


FIG.6

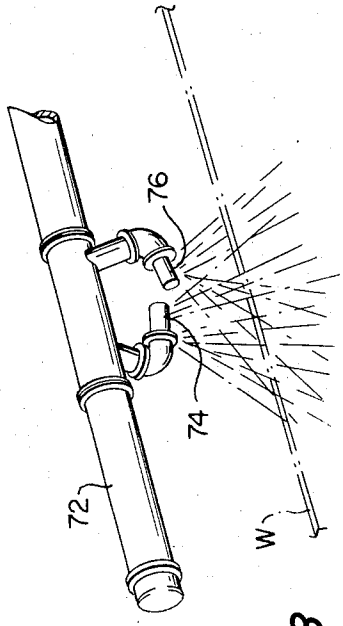


FIG.8

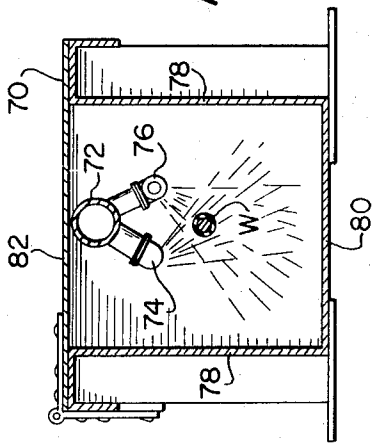


FIG.7

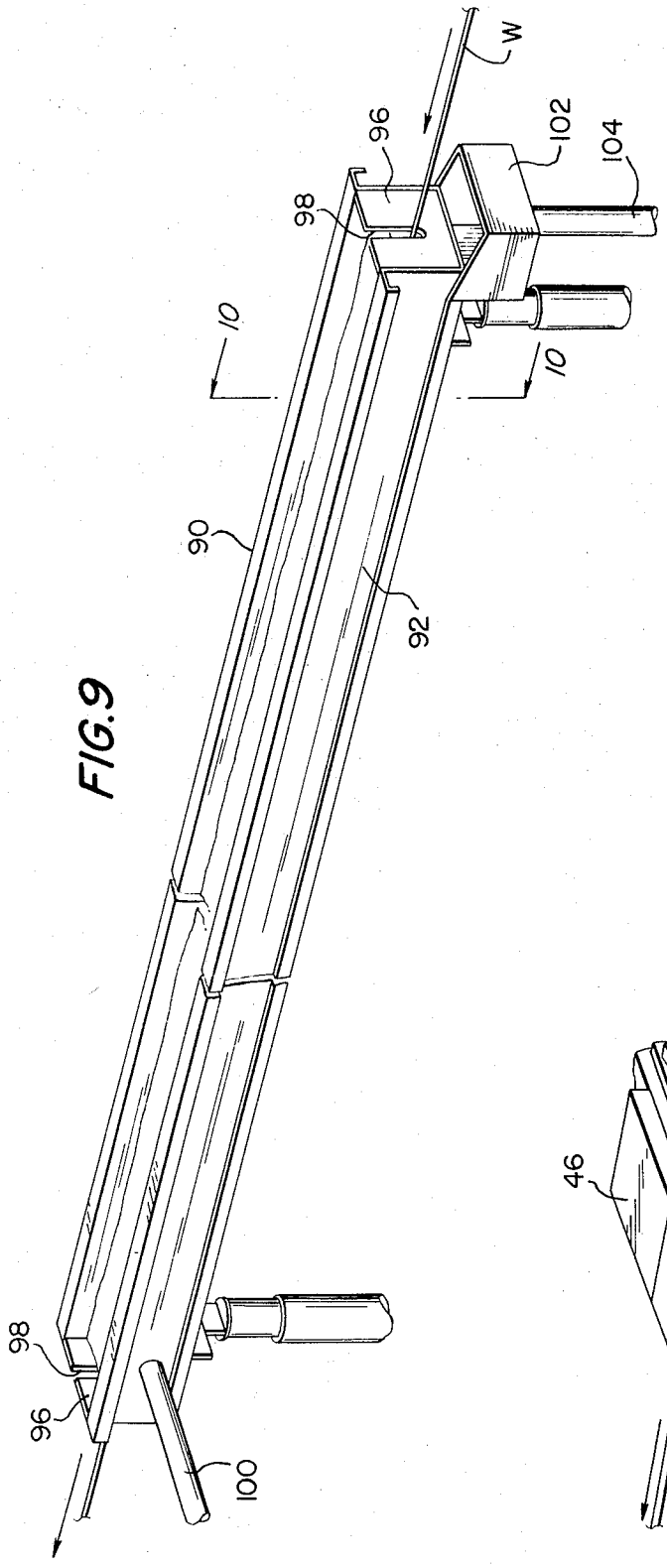


FIG. 9

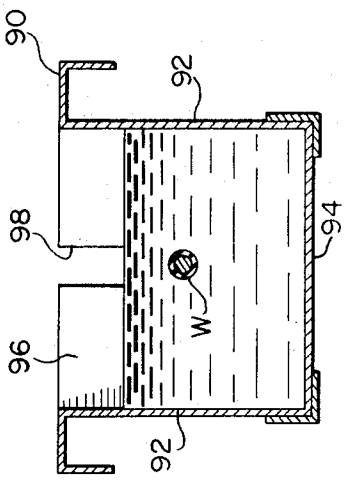


FIG. 10

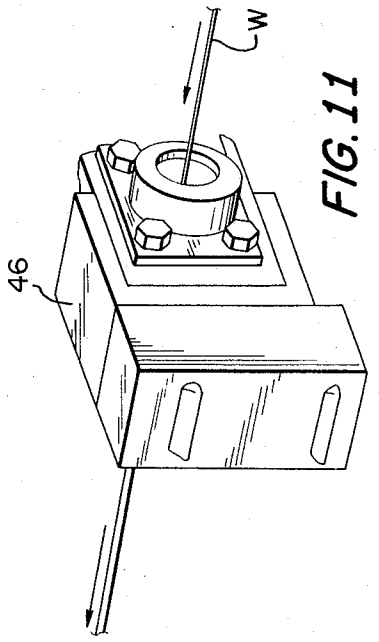


FIG. 11

HIGH SPEED TANDEM WIRE DRAWING AND INSULATION SYSTEM

This invention relates generally to the wire forming art, and more particularly to a method and apparatus for producing electrically conductive insulated wire from rod at high speeds in a tandem drawing and insulating system.

Heretofore, electrically conductive insulated wire has been produced in a series of separate manufacturing processes. The conductive metal, usually copper, aluminum or various alloys thereof, is first cast, preferably in a continuous operation, to provide a cast bar that is passed through a rolling mill to produce rod. The rolled rod, normally having a diameter of between 0.250 inches and 0.625 inches, is then coiled and stored for further processing.

When it is desired to produce wire, the rod is drawn in succession through a plurality of constricted drawing dies by means of which the diameter of the rod is reduced to wire of desired AWG size. The drawn wire may be processed with intermediate anneals between the various drawing stages, or may be annealed or partially annealed subsequent to the drawing operation according to the physical properties and electrical conductivity desired to be achieved. The wire may then be quenched and pickled, as desired, for cooling and cleaning, and then again coiled and stored for further processing.

The final operation in the prior art method of producing insulated wire was to cover the bare wire with an insulation coating. This is accomplished typically by uncoiling the wire from its spool and advancing it through the die of an extruder containing a molten plastic coating compound. As the wire passes through the die, the coating compound is forced under pressure to adhere to the wire and form a coating thereon. The wire thus leaves the extruder with a high temperature and covered with a soft plastic coating which must be immediately cooled so as to set and harden prior to being taken-up on a spool or otherwise coiled. The cooling was usually accomplished by advancing the insulated wire through long water-filled troughs. The length of the troughs was determined as a function of the speed of the wire passing therethrough.

It should be thus apparent that the prior art method of producing insulated wire consisted of a series of individual operations, each operation conducted separately in time and space and without regard to the subsequent operations that would follow. Thus, the casting and rolling, drawing and annealing, quenching and pickling, extruding, cooling, and coiling were, for the most part, accomplished individually at different locations and at different times such that when one operation was completed the material would have to be coiled and either stored for subsequent processing or transported to another location where the apparatus for performing the next operation was located. This method of production was, of course, time-consuming, costly, space-wasteful, and did not lend itself to the high-speed production of a quality product.

It is, therefore, a primary object of this invention to increase the production rate and product quality of electrically conductive insulated wire.

More particularly, it is an object of this invention to combine at least certain ones of the operations in the production of electrically conductive insulated wire into an in-line contiguous system.

Still more particularly, it is an object of this invention to provide a method and apparatus for drawing and insulating electrically conductive wire at high speeds in a continuous in-line tandem operation.

Briefly, these and other objects of the invention that will become hereinafter apparent, are accomplished in accordance with this invention by providing a novel tandem wire drawing and insulating system that is capable of producing Nos. 10, 12 and 14 AWG size plastic coated wire from 5/16-inch copper rod, and Nos. 10 and 12 AWG size plastic coated wire from ⅜-inch aluminum and aluminum alloy rod, in a continuous operation at wire speeds in excess of 2,500 feet per minute.

The system includes a drawing machine having a series of progressively constricted dies adapted to reduce the diameter of the rod to the desired AWG wire size. The drawing machine includes an in-line annealer whereby the wire is softened for easier handling. As the wire exits from the drawing machine, it may be quenched for cooling and then dried by means of an air wipe or other suitable means. It should be understood, however, that the quenching and cooling are not intended to form an essential part of the invention disclosed herein.

After the wire leaves the drawing machine and its associated apparatus, it is advanced directly through the die of an extruder containing a plastic coating compound. An accumulator may, however, be disposed between the drawing apparatus and the extruder whereby relatively slight variations in the speed of the wire passing through the drawing machine and the extruder may be compensated for by conventional means known to those skilled in the art. Because of the high speed of the wire passing through the die of the extruder, the temperature of the plastic melt in the coating zone must be high enough such that sufficient heat may be transferred to the wire in the short time interval as to effect adhesion of the coating compound thereto. For wire advancing at speeds in excess of 2,500 feet per minute, it has been determined in accordance with this invention that a melt temperature of approximately 400° F. in the coating zone is required to effect the adhesive process.

Immediately upon passing through the extruder the coated wire enters a novel cooling system that includes means to cool the insulated wire sufficiently is less than 0.5 seconds to substantially solidify the extruded plastic coating, as well as means to further cool the insulated wire from approximately 400° F. at the extruder to approximately 90° F. prior to its being taken-up in a coiling device. The novel cooling system which will be described in more detail hereinafter, will solidify the coating and cool the wire moving at speeds in excess of 2,500 feet per minute while achieving a smooth coated surface of superior quality.

It should be understood that the novel concept disclosed herein of combining the wire drawing apparatus and the coating extruding apparatus in a high speed tandem system amounts to more than a mere combining of known operations. Heretofore, it was considered impossible to combine these operations to produce high-quality insulated wire at speeds in excess of 2,500 feet per minute. While it was possible to draw and anneal wire at high speeds, the prior art disclosed no ex-

truding and cooling apparatus that could receive wire exiting a drawing machine at speeds in excess of 2,500 feet per minute. Two of the main reasons for this were, firstly, that the prior art did not teach any method for effectively coating a wire moving through the die of an extruder at those speeds, and, secondly, a soft-coated wire moving at those speeds through prior art cooling systems encountered too much fluid resistance and friction to enable the extruded coating to have a smooth, high-quality surface finish. Consequently, the drawing operation and the extruding operation were performed separately, with the wire moving through the extruder and cooling system at speeds commensurate with the available technology.

It is, therefore, a further object of this invention to facilitate a tandem system for drawing and insulating a wire at high speeds, by providing a method for extruding a plastic coating on a wire moving through the die of an extruder at speeds in excess of 2,500 feet per minute.

Another object of this invention is to facilitate a tandem system for drawing and insulating a wire at high speeds, by providing a cooling system that will solidify an extruded coating on a wire moving at speeds in excess of 2,500 feet per minute while providing minimal fluid resistance to the coated wire in its pre-set state, thereby resulting in a smooth, high-quality surface finish.

This is accomplished in accordance with this invention by providing a three-stage cooling system that will cool the insulated wire from its 400° F. temperature at the extruder to 90° F. prior to its being taken-up in a coiling apparatus. The first stage consists of a cooling mist wherein the coated wire with the plastic material still in a soft pliant state is passed through a chamber having a plurality of nozzles emitting an atomized mist of air and water therein which cools the wire from 400° to 200° F. in less than 0.5 seconds. The second stage consists of a liquid spray wherein the coated wire is sprayed with water to reduce its temperature from 200° to 150° F. After leaving the second stage, the plastic coating will be set sufficiently for the wire to pass into the third stage which consists of a long water-filled trough wherein the temperature will be reduced to 90° F. at which point it is ready to be taken-up by coiling apparatus.

With the above and other objects in view that may hereinafter become apparent, the nature of the invention may be more closely understood by reference to the several views illustrated in the accompanying drawings, the following detailed description thereof, and the appended claimed subject matter:

IN THE DRAWINGS

FIG. **1** is a highly schematic plan view of the tandem wire drawing and insulating system of this invention, and illustrates the rod supply coil, the drawing machine equipped with in-line annealer, the wire accumulator, the plastic coating extruder, the three-stage cooling system, and the insulated wire take-up apparatus;

FIG. **2** is a fragmentary perspective view of the cooling mist stage of the cooling system, and illustrates an elongated chamber having a plurality of spray stations disposed along the length thereof, each of the spray stations having a nozzle disposed therein with separate water and compressed air lines leading to each of the nozzles;

FIG. **3** is a vertical sectional view taken along line **3—3** of FIG. **2**, and depicts the disposition of the insulated wire within the mist chamber with spray stations disposed on either side thereof;

FIG. **4** is an enlarged sectional view taken along line **4—4** of FIG. **3**, and depicts a nozzle in a single spray station of the mist chamber;

FIG. **5** is a fragmentary schematic plan view of the interior of the mist chamber, and illustrates the staggered relationship of the spray stations therein and the angular disposition of the nozzles to the direction of movement of the wire therethrough;

FIG. **6** is a perspective view of the cooling spray stage of the three-stage cooling system, and illustrates an elongated housing having a spray header pipe running longitudinally therethrough;

FIG. **7** is a vertical sectional view taken along line **7—7** of FIG. **6**, and illustrates a pair of oppositely directed spray nozzles depending from the header pipe and emitting a spray of cooling fluid directly on the insulated wire passing therethrough;

FIG. **8** is a fragmentary perspective view of a pair of spray nozzles depending from the header pipe in the spray stage housing;

FIG. **9** is a fragmentary perspective view of the cooling bath stage of the three-stage cooling system, and illustrates a water-filled trough through which the coated wire is passed, including water inlet means and drain means which receives water overflowing the wire inlet opening;

FIG. **10** is a vertical sectional view taken along line **10—10** of FIG. **9**, and depicts the coated wire being submerged in the water-filled trough; and

FIG. **11** is a fragmentary perspective view of a portion of the plastic coating extruder apparatus, and depicts the bare wire entering the die of the extruder on one side thereof and the coated wire exiting on the other side thereof.

Referring now to the drawings in detail, there is illustrated in FIG. **1** the tandem wire drawing and insulating system of this invention designated generally by the numeral **20.** The system **20** includes a rod supply or payout apparatus **22** from which rod R, such as ⅜-inch aluminum or aluminum alloy rod or 5/16-inch copper rod, is pulled through a drawing machine **24** equipped with an in-line annealer in which the rod R is drawn into wire W having finished ASTM annealed specifications. Typically, the ⅜-inch aluminum or aluminum alloy rod will be drawn into No. 10 or No. 12 AWG size wire, while the 5/16-inch copper rod will be drawn into Nos. 10, 12 or 14 AWG size wire. The drawing machine **24** may be of any commercially available type such as a Syncro 13 die drawing machine manufactured by Syncro Machine Co.

The drawing wire W may then pass through a quench and wipe system (not shown), and then into an accumulator apparatus **26** which may include a plurality of resiliently mounted pulleys (not shown) by means of which relatively minor variations in the speed of the wire W between various points in the system **20** may be compensated for.

The wire W then passes through an extruder apparatus **28** at speeds in excess of 2,500 feet per minute where a plastic insulation coating, such as a PVC base compound is applied to the wire W in a continuous manner. The extruder apparatus **28,** which will be described in more detail hereinafter, may be basically a

Davis-Standard 20/1 or 24/1 LD Thermatic Extruder having certain control modifications in accordance with this invention which render the high-speed operation feasible.

After passing through the extruder **28**, the coated wire W passes through a three-stage cooling system **30** wherein the plastic insulation coating is set as its temperature is reduced from approximately 400° F. to approximately 90° F. The cooling system **30** includes a first mist stage **32**, a second spray stage **34**, and a third bath stage **36**. After passing through the cooling system **30** the insulated wire W is taken up by means of conventional coiling apparatus **38** well known to those skilled in the art. The coiling apparatus **38** also provides the motive force for advancing the wire W at high speeds through the system **20**.

The extruder apparatus **28** includes a hopper **40** into which the coating compound formulation is admitted in the form of a dry, homogeneous pellet. The compound is preferably a polyvinyl chloride based resin including plasticizers, fillers and lubricant-stabilizers that will yield a 60° C. U.L. rated insulation coating meeting U.L. standards for compression strength, low temperature flexibility, tensile strength, elongation, and surface quality. It has been determined in accordance with this invention that the foregoing characteristics can be obtained in an insulation coating applied to wire moving at speeds in excess of 2,500 feet per minute by using a compound as sold by Southwire Company under their designation SW1001.

The compound is melted in the hopper **40** and maintained at a temperature of approximately 225° F. from where it is admitted into a pressure chamber **42** where it is advanced by means of a screw **44** towards a die housing **46**. The pressure chamber **42** includes several distinct heating zones depicted as **47, 48, 49, 50** including calrod heating elements or the like which progressively raise the temperature of the melt to approximately 400° F. in the die housing **46**. The friction of the screw **44** also serves to heat the melt.

Because the wire W is advancing through the die housing **46** of the extruder **28** at high speeds — 2,500 feet per minute and above — it has been determined in accordance with this invention that the temperature of the melt in the coating zone (i.e., in the die housing **46**) must be unusually high — preferably approximately 400° F. — in order to effect the necessary heat transfer to the high speed wire in the relatively short coating zone so as to facilitate adhesion of the plastic coating thereto. Consequently, in order that the finished coating provide protection at low temperatures, preferably to −25° C., a low temperature plasticizer must be used in the compound formulation that will not volatilize and lose its low temperature characteristics in the high temperatures of thte coating zone which are necessitated by the high-speed operation.

Referring particularly to FIG. **11**, there is illustrated the die housing **46** which contains an extrusion die (not shown) through which the wire W passes and wherein a plastic coating is concentrically extruded thereabout under pressure from the extrusion screw **44** (FIG. **1**). As seen in FIG. **11**, the wire W enters the die housing **46** at speeds in excess of 2,500 feet per minute as a bare wire and leaves it covered with a soft plastic coating at a temperature of 400° F.

The coated wire then immediately enters the first mist stage **32** of the cooling system **30** where the coating substantially sets in less than 0.5 seconds as its temperature is reduced from 400° to 200° F. As seen in FIGS. **2, 3** and **5**, the mist stage **32** consists of an elongated housing **48**, preferably approximately 20 feet in length, which defines a mist chamber **50** into which an atomized mist of a gas and liquid cooling mixture is admitted from a plurality of spray nozzles **52** disposed in spray stations **54** arranged in staggered relationship along the length of the housing **48**.

Preferably, the atomized mist consists of compressed air and water at 50° F. which are conducted separately to each nozzle **52** through piping **56** and **58**, respectively, where they are mixed and admitted into the chamber **50** as a fine atomized mist of sufficient density to cool the wire W to 200° F. in less than 0.5 seconds without providing sufficient fluid resistance to the wire W which would deform the soft plastic coating. The coating is thus enabled to set substantially without deformation or impairment of its finish even though the wire is moving at speeds in excess of 2,500 feet per minute.

The housing **48** includes side walls **60** in which the spray stations **54** are disposed, a bottom wall **62**, and a hinged top cover **64** which permits access into the chamber **50**. The housing **48** may also include a drain box **66** and piping **68** for conducting mist condensate from the chamber **50**.

As seen most clearly in FIGS. **4** and **5**, the spray stations **54** are staggered along the side walls **60** with the nozzles **52** disposed such that the axes of the mist spray cones are inclined at an angle of 15° to the direction of travel of the wire W through the housing **48**. It has been determined in accordance with this invention that this arrangement, coupled with positioning the tips of the nozzles **52** approximately 15 inches from the wire W as measured along the axes of the mist spray cones, results in maximum cooling of the wire commensurate with minimal fluidic resistance against the plastic coating.

AFter the wire W leaves the mist stage **32** in substantially set condition at 200° F., it immediately enters the spray stage **34** where its temperature is further reduced to 150° F. As seen in FIGS. **6, 7** and **8**, the spray stage **34** consists of an elongated housing **70**, preferably 10 feet in length, through which extends a spray header pipe **72** having a plurality of oppositely disposed spray nozzles **74, 76** depending therefrom along the length thereof. The spray nozzles **74, 76** are adapted to emit a relatively heavy shower of cooling liquid such as water at 75° F. directly onto the moving wire W. While the spray shown in the housing **70** is substantially more dense than the atomized mist in the mist stage **32**, it still provides substantially less fluidic resistance than would occur were the wire pulled through a water-filled trough. Consequently, the spray stage **34** provides increased cooling capacity to substantially completely set the plastic coating, while not providing undue resistance against it which would tend to mar its smooth finish.

The housing **70** may be constructed similarly to the housing **48** and includes side walls **78**, a bottom wall **80**, and a hinged top cover **82**. A drain box **84** and drain piping **86** may also be provided for return of the sprayed liquid.

After the wire W leaves the spray stage **34** it immediately enters the final cooling bath stage **36** where its temperature is reduced from 150° F. to 90° F. As seen in FIGS. **9** and **10**, the bath stage **36** consists of an elon-

gated water-filled trough **90** through which the wire W travels in a submerged condition. Preferably, the trough **90** is 100 feet long and the wire W will be turned to travel through the trough **90** eight times for a total traverse of 800 feet. Thus, the water bath **36** provides maximum heat transfer capacity for completely setting the coating and cooling the wire W to its final temperature of 90° F. prior to being coiled in the apparatus **38.** Because the coating has been substantially set in the preliminary cooling stages **32** and **34** without impairment of its surface quality, the coated wire W can tolerate the more severe turbulence and fluid resistance in the bath stage **36.**

The trough **90** includes side walls **92,** a bottom wall **94,** and end plates **96** having slotted opeings **98** formed therein through which the wire W may pass. Water is admitted to the interior of the trough **90** through a supply conduit **100** at a rate which will maintain a constant level in the trough **90** as the water spills out of the openings **98.** Drain boxes **102** and drain pipes **104** are provided for recirculation of the bath water.

It should be apparent, therefore, that there is provided in accordance with this invention a novel method and apparatus for producing insulated wire at speeds in excess of 2,500 feet per minute. The method of extruding a plastic insulating coating at high temperatures and the three-stage cooling system disclosed herein facilitates a high-speed operation for drawing rod into wire and then continuously coating the wire in a tandem system. The tandem system thus provides a process which takes rod and continuously draws, anneals, quenches, insulates, cools and coils to a finished wire product all in one production line at speeds in excess of 2,500 feet per minute. The novel method and apparatus obviously increases the production rate of a quality product meeting all U.L. standards for gauge wire and having a surface quality of exceptional smoothness and symmetry.

While the invention has been specifically described herein with reference to a particular embodiment thereof, it should be understood that minor variations may be made therein without departing from the spirit of the invention.

It is claimed:

1. Apparatus for continuous high-speed drawing and insulating of wire from rod comprising a rod supply means, means for drawing the rod into wire including means for substantially reducing the cross-sectional area of the rod, means for annealing the wire, means for continuously extruding an insulating coating onto the wire, means for moving the wire through said extruding means at a speed of at least 2,500 feet per minute, means for cooling the insulated wire including means for initially contacting the insulated wire with an atomized cooling mist to at least partially set the coating with substantially no deformation thereof, and means for taking up the insulated wire.

2. Apparatus as defined in claim **1** wherein said cooling means comprises a three-stage cooling system including a cooling mist stage, a cooling spray stage and a cooling bath stage.

3. Apparatus as defined in claim **2** wherein said cooling mist stage comprises an elongated chamber having a plurality of spray stations spaced along the length thereof, each of said spray stations having nozzle means disposed therein, first conduit means connected to each of said nozzle means for conducting a cooling liquid thereto, second conduit means connected to each of said nozzle means for conducting compressed air thereto, and means associated with each of said nozzle means for mixing the cooling liquid and the compressed air and for emitting an atomized mist thereof into said chamber for cooling insulated wire passing therethrough.

4. Apparatus as defined in claim **3** wherein said elongated chamber includes top, bottom and side walls, said spray stations being disposed in said side walls and staggered alternately along the length of said chamber.

5. Apparatus as defined in claim **4** wherein said nozzle means are disposed at an angle of approximately 15° to the direction of movement of the wire passing through said chamber.

6. Apparatus as defined in claim **1** wherein said means for substantially reducing the cross-sectional area of the rod includes means for reducing the cross-sectional area by at least 20 percent.

7. A method of producing insulated wire having a minimum diameter corresponding to number 14 AWG size from rod of up to ⅜-inch diameter at speeds in excess of 2,500 feet per minute in a continuous in-line tandem system comprising the steps of drawing and annealing the rod into wire, extruding a plastic coating onto the wire at 400°F., cooling the insulated wire from 400° to 90°F. including initially contacting the insulated wire with an atomized coolant mist to at least partially set the coating with substantially no deformation thereof, and taking up the cooled insulated wire.

8. A method as defined in claim **6** wherein the step of cooling the insulated wire further comprises passing the wire through a liquid coolant spray to further cool and set the plastic coating, and then passing the wire through a liquid coolant bath to cool the coating to its final setting temperature.

9. A method as defined in claim **8** wherein the coolant mist is of a density sufficient to cool the coated wire from 400° to 200° F. in less than 0.5 seconds.

10. A method as defined in claim **8** wherein the temperature of the coated wire is reduced from 200° to 150° F. as it passes through the liquid coolant spray.

11. A method as defined in claim **7** including the step of providing a 60° C. U.L. rated PVC base coating compound formulation having −25° C. rated protection, the compound including resins, plasticizers, fillers and lubricant-stabilizers, wherein the plasticizers include a low temperature plasticizer that will not volatilize at 400° F.

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