United States Patent [19]
Entringer

[11] 3,720,544
[45] March 13, 1973

[54] **HEAT TREATMENT OF HOT ROLLED STEEL WIRE RODS**

[75] Inventor: **Michel Entringer**, Hayange, France

[73] Assignee: **Societe Wendel Sidelor S.A.**, Hayange, France

[22] Filed: **March 4, 1970**

[21] Appl. No.: **16,542**

[30] **Foreign Application Priority Data**

March 5, 1969 France ........ 6905968
Sept. 3, 1969 France ........ 6931036

[52] **U.S. Cl.** ........ **148/14**, 148/134, 148/143, 148/153

[51] **Int. Cl.** ........ **C21d 9/64**, C21d 1/00

[58] **Field of Search** ....... 148/13.1, 14, 134, 143, 153, 148/155, 156, 157; 266/2, 3, 4, 5; 263/2, 3

[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,231,432 | 1/1966 | McLean et al. | 148/12 |
| 3,445,100 | 5/1969 | Bond | 266/3 |
| 3,484,310 | 12/1969 | Kocks | 148/155 X |
| 3,573,118 | 3/1971 | Kocks | 148/156 |

FOREIGN PATENTS OR APPLICATIONS

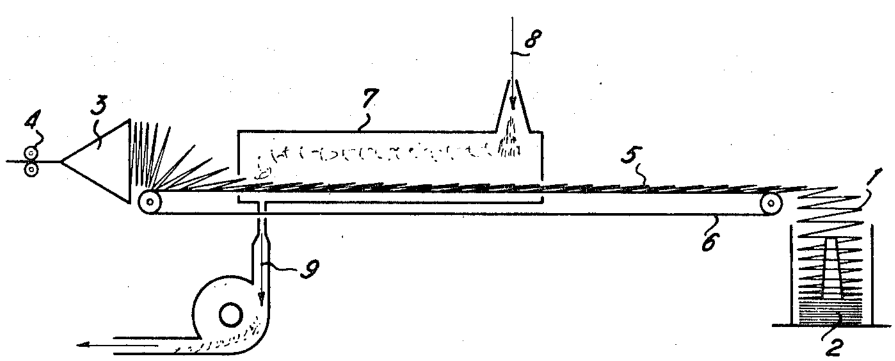
| | | | |
|---|---|---|---|
| 1,490,853 | 6/1967 | France | 148/14 |
| 1,158,942 | 7/1969 | Great Britain | 148/14 |

*Primary Examiner*—Charles N. Lovell
*Attorney*—Robert E. Burns and Emmanuel J. Lobato

[57] **ABSTRACT**

Process for heat treatment in line with a wire rod rolling mill, of a steel wire rod containing less than 0.15 per cent of carbon and which has been previously subjected after leaving a rolling mill to the cooling treatment of a known controlled cooling process and device. The wire rod is subjected to an isothermal holding at a temperature between 200°C and 400°C so that the intersticial atoms place in a supersaturated solution during the known controlled cooling gather together on sites other than dislocations which allows the phenomenon of anchoring of the dislocations to be avoided, this anchoring being partially responsible for the deterioration of the drawability for the fine drawing of such steel wire rods. This thus allows the direct drawing of the wire rod without subsequent heat treatment to a final very small diameter. The process thereby avoids decomposition of a thin layer of non-adhering wustite formed on the surface of the wire rod during the controlled cooling treatment into an adhering layer of a superior oxide difficult to remove before the drawing off the wire rod.

**5 Claims, 25 Drawing Figures**



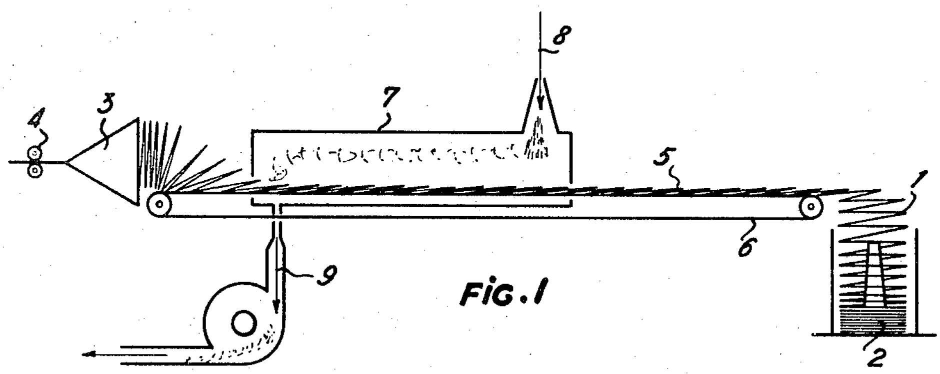



FIG. 1

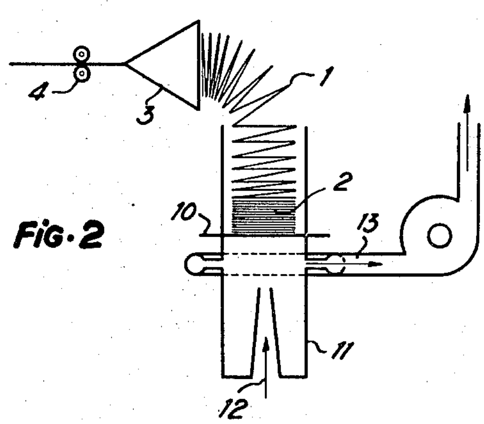



FIG. 2

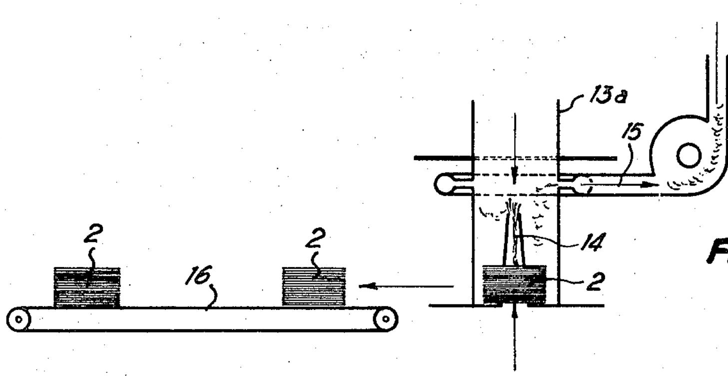



FIG. 3

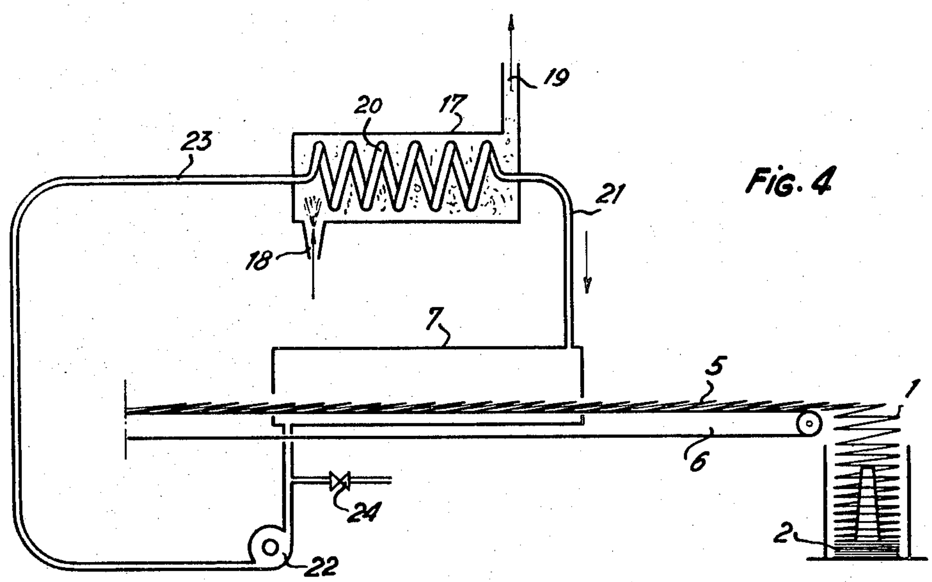



FIG. 4

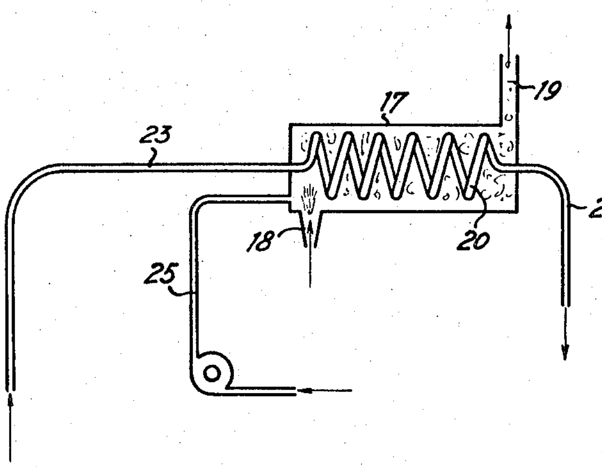



FIG. 5

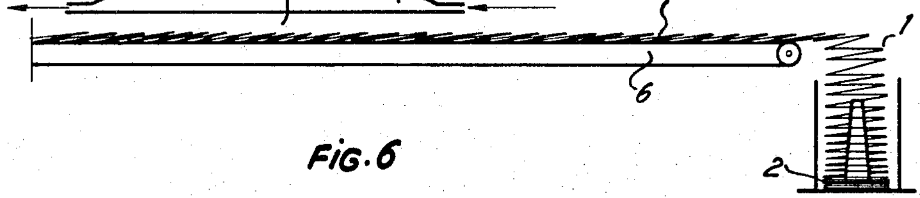



FIG. 6

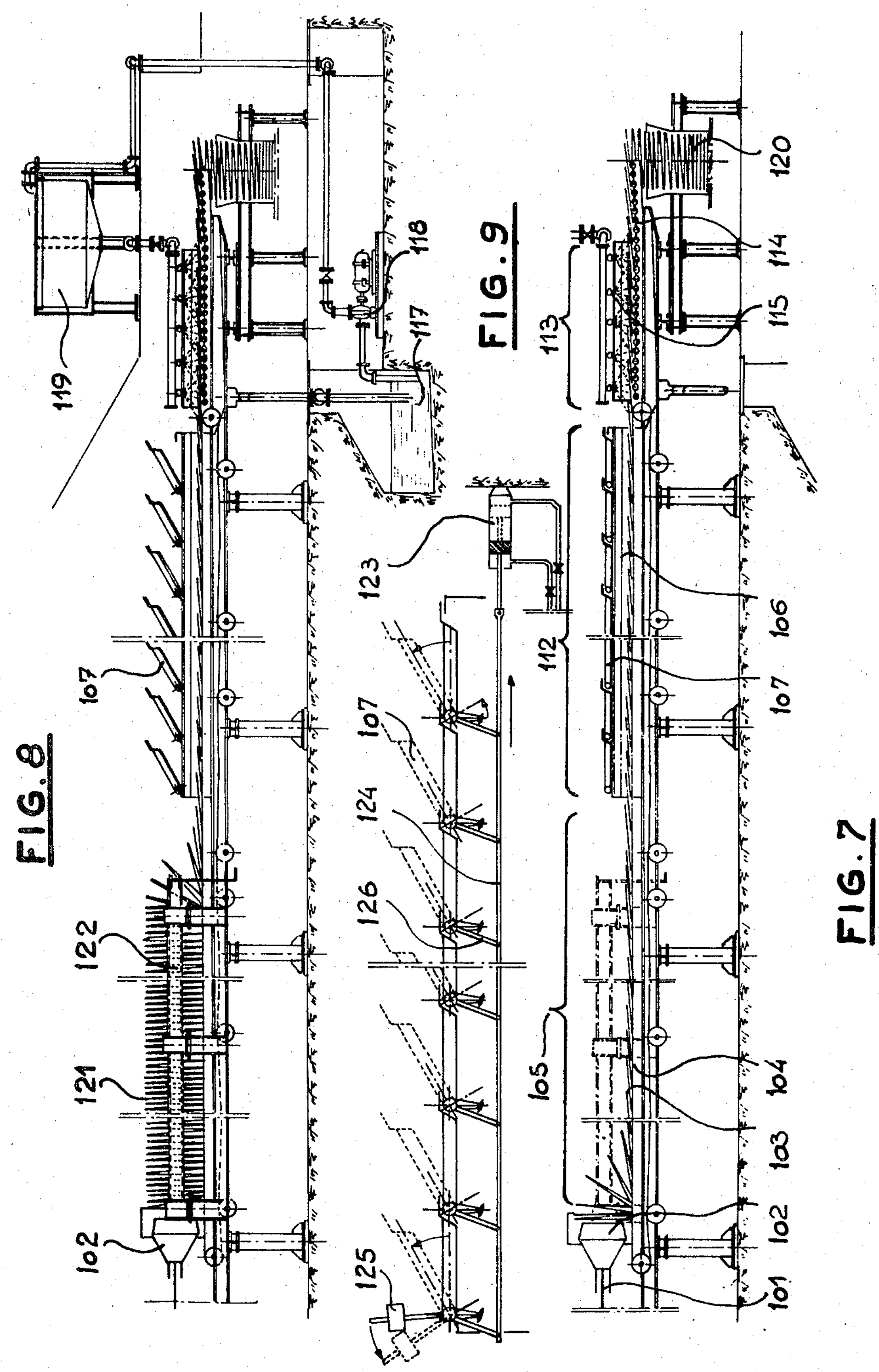


FIG. 8
FIG. 9
FIG. 7
119
107
122
121
102
123
118
117
112
107
124
126
125
105
120
114
115
113
106
107
104
103
102
101

FIG. 11

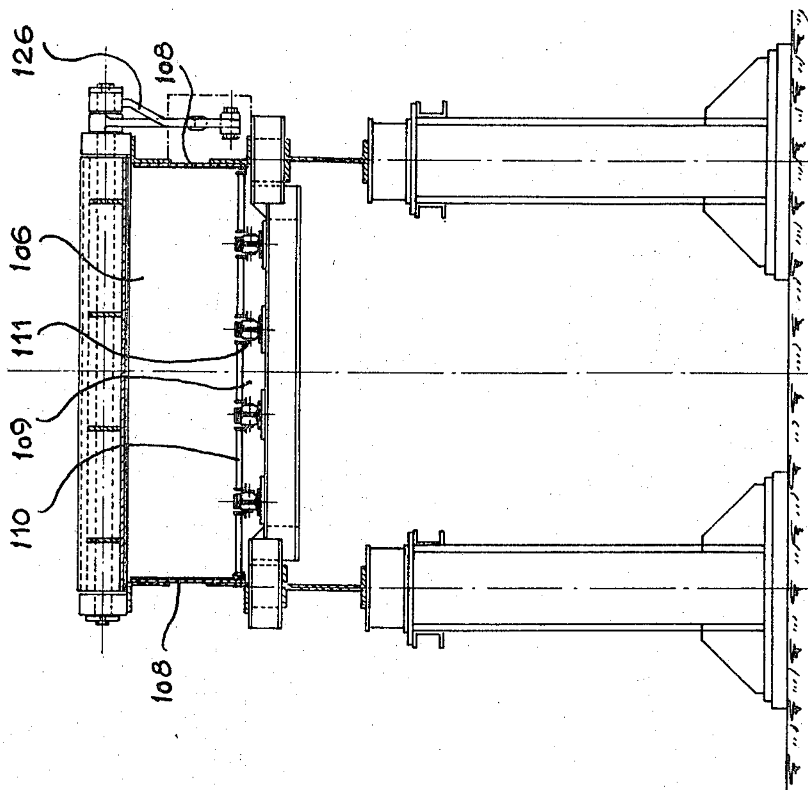



FIG. 10

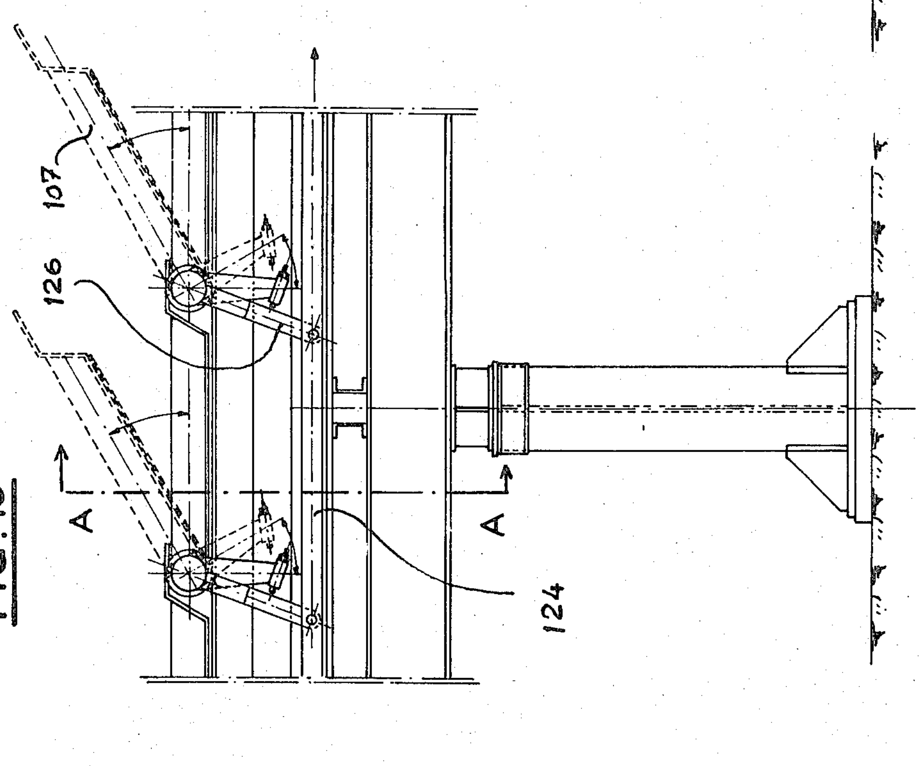


FIG. 12

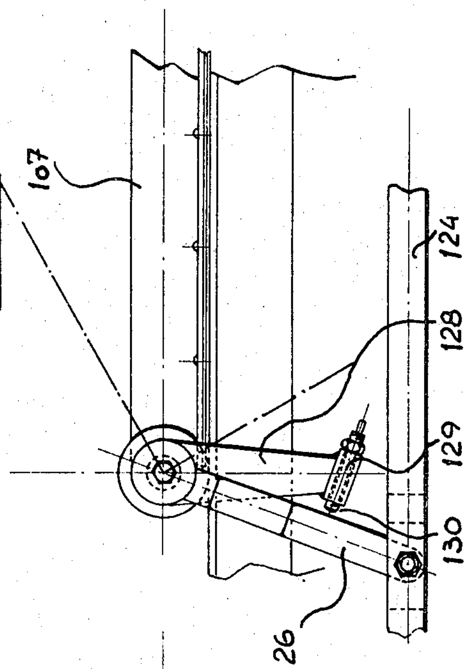



FIG. 13

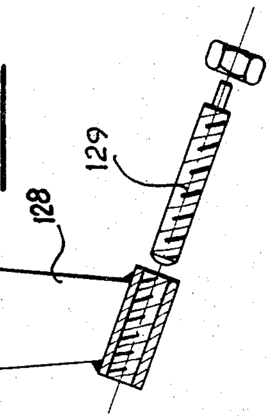



FIG. 14

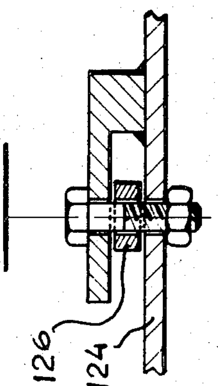



FIG. 15

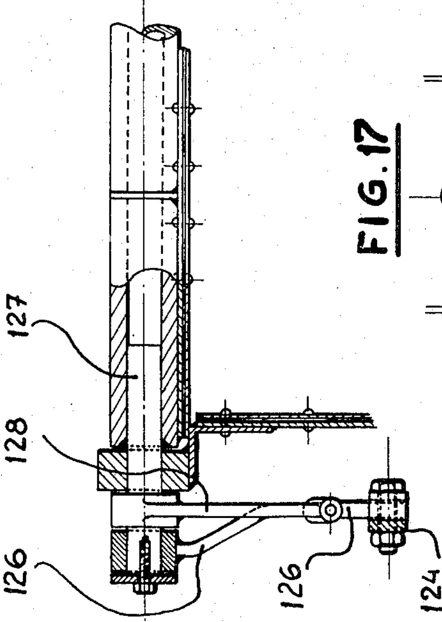



FIG. 17

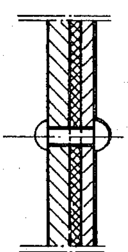


FIG. 16

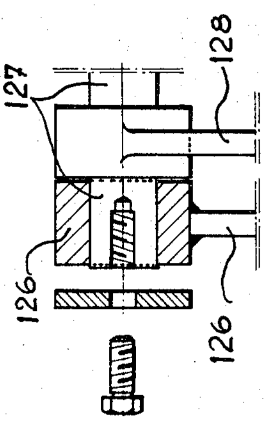


Fig 18

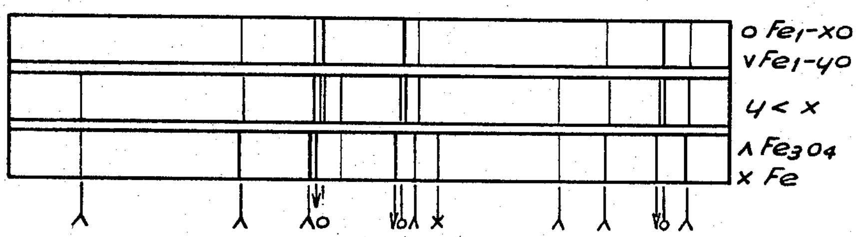
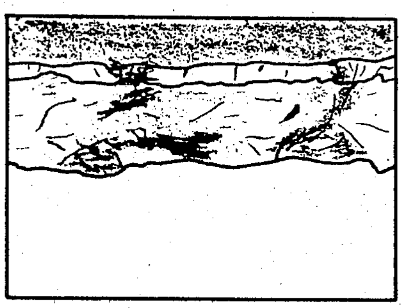
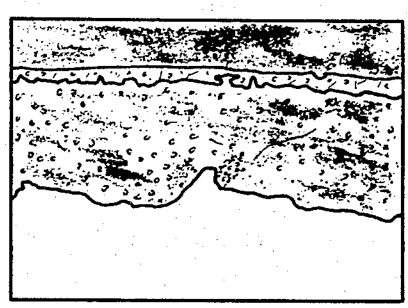



Fig 19



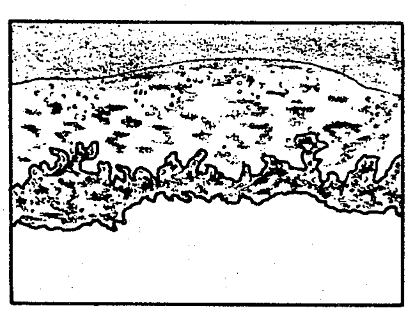
500x

Fig 20



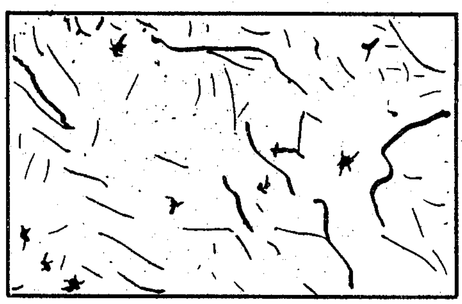
500x

Fig 21



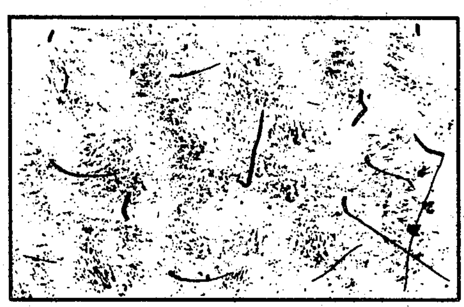
500x

Fig 22



12650 x

Fig 23

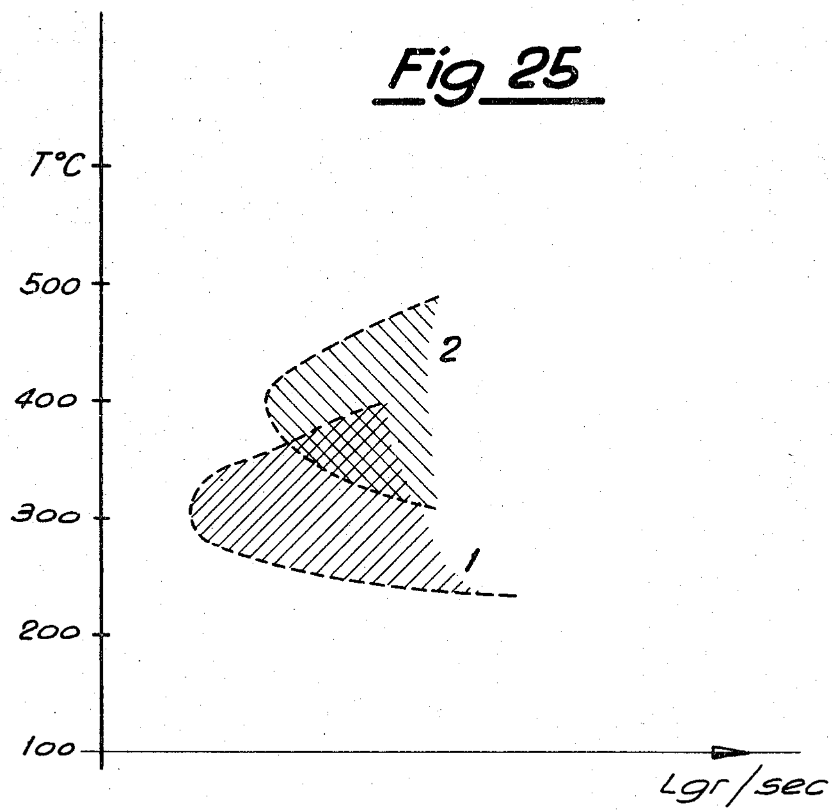


12650 x

Fig 24

9350x

Fig 25



## HEAT TREATMENT OF HOT ROLLED STEEL WIRE RODS

This invention relates to a process for heat treating hot rolled steel wire rod having a carbon content lower than 0.15 percent in line with the rod rolling mill so that the thus obtained steel wire rod a very good drawability.

The invention relates to the heat treatment of hot rolled mild steel wire rod composed of less than 0.15 percent of carbon and obtainable at present from wire rod or merchant bar rolling mills and the heat treatment complements the known controlled cooling processes and apparatus.

Until some years ago wire rod was delivered from the rolling mills at a temperature of about 900° to 1,000°C, and after a prior water-cooling, it was coiled at a temperature between 600°C and 800°C in tight several hundred kilogram coils. The cooling of the wire rod during the coiling in the reels was slow owing to the compactness of the formed coils.

After the forming of the rod into coils in the reels, the coils were hooked on a carrier at a temperature of about 500° to 600°C in order to cool down slowly in the open air. A considerable amount of iron oxide or scale was customarily formed during this cooling. This resulted in quite a noticeable loss of metal and high descaling or cleaning costs for the wire drawing industry.

Attempts have heretofore been made to develop controlled cooling processes by blowing air through the reels during the forming of the coils. The amount of the thus formed scale was lower on the average, but it was more adherent and not uniformly distributed throughout the length of the coiled wire rod. The end result was that it was very costly to remove.

In addition, the mechanical properties widely varied throughout the thus obtained wire.

Controlled cooling processes have been used in an attempt to overcome some of these drawbacks. These processes do not act on the whole coil but on each individual turn of wire rod(U.S. Pat. Nos. 1,232,014, 1,295,139, 3,231,432 and French Pat. No. 1,409,716). In these controlled cooling processes, wire rod is either placed immediately in coplanar non-concentric turns on a conveyor, or first conveyed as separate turns with a common horizontal axis and then laid down in non-concentric coplanar turns on a conveyor, or even cooled in separate turns having a common vertical axis. In these controlled cooling processes, during the conveying of the turns before their assembly into coils, the wire rod is subject:

1. either to a pulsed air cooling, the turns being in the horizontal coplanar non-concentric position or in a position with a common vertical axis;

2. or to a cooling by radiation in still air, this type of cooling being accelerated or slowed down depending on the position of the turns which can be placed in a position with a common horizontal axis, or in a coplanar non-concentric horizontal position.

These modern controlled cooling processes allow the wire to be cooled in a uniform and controlled manner. The wire rod obtained with these processes presents only a very slight layer of non-adhering oxide, a good homogeneity of mechanical properties, and drawing properties which can be satisfactory for hard steels



(medium and high-carbon) but not for mild steels (low carbon steels). These must be subjected to several intermediate annealing treatments during their fine drawing. These intermediate annealing treatments clearly increase the costs of the wire processing for the wire-drawer.

The aim of this invention is to confer high fine drafting properties to steel wire rods containing less than 0.15 percent of carbon in such a manner as to allow very fine wire to be drawn without the necessity of any subsequent and intermediate heat treatment of the wire rod and of the process wire.

The principal object of the present invention is to provide a heat treating process carried out in line with the rod rolling mill for steel wire rod with less than 0.15 percent of carbon, in which, after a controlled cooling of the wire rod by a known process, the steel wire rod is subjected to an isothermal holding treatment at a temperature between 200° C and 400° C, and preferably between 280° C and 350° C for a period of at least 30 seconds and preferably at least 1 minute.

The process of this invention provides the treated hot-rolled steel wire rod with a micro-structure allowing it to be drawn into very fine wire without any intermediate annealing. The wire rod is further characterized by having a low amount of non-adherent scale, by lower tensile strength and 0.2 percent off set yield strength all of which are better than those obtained with the known controlled cooling processes and with a very low dispersion of the same properties. Correlatively, that elongation presents on the average higher values than those obtained with the known controlled cooling processes. All these aforementioned advantages taken together allow a mild steel wire rod to be directly drawn without intermediate annealing to obtain a wire with a final sectional area three or four times smaller than the final sectional area of a wire drawn from a wire rod treated by known controlled cooling processes only.

The invention will be better understood in referring to the following description, and the accompanying drawings, relating to several preferred embodiments of methods according to the invention.

FIG. 1 diagrammatically shows one embodiment of an apparatus to carry out the invention.

FIGS. 2 to 6 illustrate different variations of the apparatus to carry out the invention.

FIG. 7 is a diagrammatical side elevation showing a known controlled cooling line for wire rod fitted with a treatment device of the present invention and showing the treatment of a wire rod with less than 0.15 percent carbon.

FIG. 8 is a diagrammatical side elevation showing the installation of FIG. 7 after its immediate conversion for the treatment of a hard-steel wire rod.

FIG. 9 is a diagrammatical side elevation of the device for the simultaneous operation of the shutters.

FIG. 10 is a diagrammatical side elevation of a section of the treatment apparatus in FIG. 7.

FIG. 11 is a cross-section along the line A—A of FIG. 10.

FIGS. 12 to 18 show, by way of an unlimited example, one embodiment and in detail:

FIG. 12 is a diagrammatical side elevation of the operating device of one shutter.

FIG. 13 shows one possible embodiment of an adjusting device, placed at the end of the arm which is integral with the shutter.

FIG. 14 shows the detail of the attachment of the actuating rod to the operating bar of the simultaneous shutter operating device.

FIG. 15 is a section of the part of the mechanism shown in FIG. 6 showing the attachment of the actuating rod on a shutter axle.

FIG. 16 is a section of the attachment of the actuating rod on a shutter axle.

FIG. 17 shows the detail of the riveted attachment of the insulation on the shutter, between two latticed or perforated metal sheets or wire-netting.

FIG. 18 is three X-ray photographs taken of three selection layers of calamine showing increasing degrees of decomposition, from top to bottom.

FIGS. 19, 20 and 21 respectively show the micrographic structures of the three layers of calamine shown in FIG. 18, enlarged to 500 : 1.

FIG. 19 shows the partially decomposed layer which corresponds to the upper spectrum in FIG. 18.

FIG. 20 shows the partially decomposed layer which corresponds to the upper spectrum in FIG. 18.

FIG. 21 shows the layer with a greater degree of decomposition which corresponds to the lower spectrum of FIG. 18.

FIG. 22 shows the sticking of the dislodged particles with an enlargement of 12,650 : 1.

FIG. 23 shows the fine precipitation of iron carbide with an enlargement of 12,650 : 1.

FIG. 24 shows a condition of solid precipitation of carbides only slightly detrimental to fine wire drawing.

FIG. 25 covers two fields; No. 1 in the carbide precipitation but not dangerous, No. 2 is the decomposition of the wustite.

The wire rod obtained with this process is covered with a slight layer of non-adhering oxide or scale and therefore is excellently suited to fine drawing.

This scale adherence phenomenon appears only when the scale thickness is inferior to a certain level and it depends on the decomposition of the layer of wustite close to the surface of the wire rod. The ease of decomposition of the wustite depends on the composition of that phase in the forming conditions of the oxide layer and on the thermal cycle to which the oxide layer is subjected, namely, for a given wustite composition of $FeO_{1-x}$, the speed of decomposition shall depend on the stoichiometry deviation $x$, and on the cooling thermal cycle of the wustite. For a given value $x$, the maximum decomposition rate is found about 400° C and decreases rapidly to become very small around 280° C.

FIG. 18 shows the spectrum of three selected layers of calamine with increasing degrees of decomposition. The layer of calamine which is not decomposed in the top spectrum of FIG. 18 is shown in FIG. 19 with an enlargement of 500 : 1. FIG. 20, with the same enlargement, shows the partially decomposed layer which corresponds to the middle spectrum in FIG. 18 and FIG. 21 shows a layer of calamine with a higher degree of decomposition corresponding to the bottom spectrum in FIG. 18.

The applicant found that the deterioration of the ability for fine drawing was partly related to a phenomenon of anchoring of the dislocations and/or to a very fine carbide-type precipitation in the ferrite crystals. This anchoring or this precipitation can be avoided by holding the wire rod at a temperature between 200° C and 400° C and preferably between 280° C and 350° C for a period of at least 30 seconds and preferably for at least 1 minute. The interstitial atoms placed in a supersaturated solution which, during a rapid cooling gather together either on the dislocations or in the form of very fine precipitates in the ferrite crystals, gather together in the form of massive carbides which are only slightly detrimental to fine drawing. This phenomenon allows a high draft and makes possible a direct drawing to a very small size. The invention can thus be summarized according to the diagram in FIG. 25. For a given wire, there exist two fields, 1 and 2. The non-dangerous precipitation of carbide happening in the first and the decomposition of the wustite in the second. Thus, a more or less very wide field exists according to the cooling conditions in which the equivalent carbide precipitation appears without the decomposition of the wustite occuring to a remarkable extent. The following description relates to the embodiments of some devices to carry out the method of the present invention.

As seen in FIG. 1, the wire rod 1 is in a coil 2 after leaving the turn laying device 3. Between the laying device 3 and the coil 2, the wire rod in the form of flat, coplanar turns 5, and is transported by a motor-driven conveyor 6, such as a chain-conveyor. Before leaving the conveyor, the wire passes through a thermal enclosure 7 heated at 8 by a burner and the burnt gases are evacuated at 9.

The speed of conveyor 6 is so regulated that an element of wire 1 passes through and remains in the enclosure 7 for at least 30 seconds and preferably for at least 1 minute. From a thermal point of view, the burner being designed and regulated to provide in the enclosure 7 a temperature somewhere between 200° C and 400° C, and preferably between 280° C and 350° C.

Referring to FIG. 2, an embodiment is shown wherein the coil 2 is formed on a plate 10 which forms a cover for the thermal chamber 11 heated at 12 and the burnt gases are evacuated at 13.

FIG. 3 shows the stage wherein the finished coil 2 is directly placed in the thermal chamber 11. The heat is applied through the axis of the coil at 12 and the gases are evacuated at 13. An evacuating system for the coil 2 can be envisaged, for example, of the belt type 16.

The apparatus in FIG. 4 differs from that of FIG. 1 by the fact that the enclosure 7 is not directly heated by the burnt gases but by a heated flow of air or gas (a non-oxidizing atmosphere, for example). This flow is heated in a heat exchanger 17 itself heated at 18 and the burnt gases are exhausted at 19. The heat exchanger includes a heat exchanging coil 20 and coil 20 is included in a closed circuit comprising a feeding tube 21, a blower or fan 22 for the warm gas circulation, a return tube 23 and a gas make-up valve 24 of the closed circuit.

The heat exchanger 17 should be designed in such a way that the gas entering the enclosure 7 provide the required thermal conditions to carry out the process.

FIG. 5 shows a part of the apparatus in FIG. 4. A cooling air feeding is provided at 25 in order to regulate the temperature of the gas circulating in the piping 21 to the desired degree.

FIG. 6 shows another variation of the apparatus in FIG. 1. In the embodiment the heat treatment of the wire rod is produced by heat radiated from a heating jacket **26**. This jacket **26** can be heated by a circulation of hot water or of any other heating fluid and the circulation is regulated to provide a temperature within the required range in the area **27**, namely, between 200° C and 400° C.

Another device for the carrying out of the process fundamentally consists of an isothermal holding enclosure for the treatment of turns of steel wire rod containing less than 0.15 percent carbon and which has already undergone a first rapid water cooling treatment after the rolling mill and a second controlled air-cooling. The first and second cooling treatments are carried out by controlled cooling installations of a known type. These use a first water cooling line, followed by a device for laying or forming horizontal or vertical turns placing the wire rod turns flat or vertical onto a conveyor where the wire rod cooling is effected by heat radiation. The duration of this cooling is regulated by varying the distance separating the turn forming or laying device from the beginning of the cooling zone, by the variation of the speed of the conveyor, by the regulation of the rate of flow of the blown air or by some combination of these regulating means.

FIG. 7 is a diagrammatical side elevation showing a known type of a controlled cooling line for wire rod situated directly behind a wire rod rolling mill. This line is equipped with a device to carry out the present invention. It is in the position for the treatment of a steel wire rod with less than 0.15 percent carbon according to the process of this invention, the shutters being in the lowered position to form an isothermal holding enclosure.

It is evident that this device can be mounted after or in the final part of any other type of controlled cooling line for wire rod.

In FIG. 7 showing the treatment of a mild steel wire rod with less than 0.15 percent carbon according to the process, the steel wire rod **101** leaving the first water cooling stage (not shown) is laid down flat by means of apparatus **102** in the form of successive over-lapping non-concentric turns **103** on a conveyor **104**. The turns of wire rod are air cooled by radiation and heat convection in the zone **105** and this cooling is regulated in such a manner that the temperature of the wire rod is at a maximum of 400° C at the end of this zone.

The turns of wire rod next enter the isothermal holding enclosure **106**, placed above the conveyor, comprising an upper part of wall formed by the shutters **107** which can be raised, shown here in the lowered position, the lateral walls **108** (see also FIG. **11**). The bottom part **109** of this enclosure is formed of expanded metal sheets **110** and chain-conveyors **111** of the known type of cooling line.

The turns of wire rod are subjected in the enclosure **106** to the treatment of the present invention throughout the zone **112**. After that the turns of wire rod are water spray cooled in the zone **113**. This water cooling does not affect the structure of mild wire rods composed of less than 0.15 percent carbon. In that part, the turns of wire rod are carried by a roller conveyor **114**. The sprayed water from the sprinklers **115** is collected at **116** (FIG. **8**) in order to be channelled to a collecting tank **117** then sent back under pressure into an intermediate reservoir **117** by a pump **118** after passing through a cooler, not shown, if required.

A turn collector **120** of a known type next collects the turns of wire in the form of coils which are removed on a conveyor of a known type, not shown.

In referring to FIG. **8**, which is a diagrammatical side elevation of the installation in FIG. **7**, shown here in the position for the treatment of hard steel wire rod, the shutters of the isothermal holding enclosure can be seen in the raised position which eliminates the isothermal holding, the wire rod being cooled here in the usual manner for this type of installation.

The wire rod is formed here in vertical turns **121** held apart for rapid cooling by radiation and carried a certain distance by lateral rack conveyors **112** of a known type. The turns of wire rod next fall so that they can be carried flat with a view to less rapid cooling, according to the known process. The turns of wire rod the move into the shutter device relating to the present invention but in this mode of operation the device does not form an isothermal holding enclosure anymore as the shutters **107** are raised to allow the free passage of air over the turns of wire.

FIG. **9** is a diagrammatical side elevation of the simultaneous shutter operating device. The operation of opening or closing the individual shutters is initiated by an operating device **123** which can be a hydraulic jack, an electric motor or any other similarly functioning device. The shutters are held in the open or closed position by an adjustable counterbalance **125**.

This device **123** actuates an operating bar **124** connected to all of the shutters in the direction of the horizontal arrow in FIG. **9** for the simultaneous opening of the shutters **107** or in the opposite direction of the horizontal arrow for the simultaneous closing of the shutters. The operating device **123** is assisted by the action of the adjustable counterbalance **125** in the opening movement of the shutters.

As already mentioned, FIG. **10** is a diagrammatical side elevation of a part of the device relating to the present invention, showing in dotted lines, the open position of the shutters, as well as the corresponding position of the opening arms which are integral with the shutters. FIG. **11** is a section along the line A—A in FIG. **10**, the shutters being shown here in the lowered position. The shutters form here an enclosure with the side walls, this enclosure being open in its bottom part.

The actuating system for each shutter **107** consists of a cranked actuating rod **126** (see FIG. **15**) attached at its lower end to the operating bar **124** as shown in FIG. **14**, this cranked actuating rod **126** being driven with some amount of clearance on the axle **127** of the shutter, as shown in FIG. **16**.

An opening arm **128** is integral with the axle **127** of the shutter and includes an adjustable stop member **129** at its lower end, the details of which are shown in FIG. **13**. The stop member **29** allows the gap **130** between the actuating rod **126** and the opening arm **128** to be altered for each shutter in such a manner as to allow the complete closure of each shutter by its own weight.

In order to open the shutters **107**, the simultaneous shutter operating-device **123** moves the operating bar **124** in the direction of the horizontal arrow in FIG. **9**. The actuating rod **126** presses against the stop member

129 of the opening arm 128 integral with the axle 127 of shutter 107 which begins to open. The counterbalance 126 tilts to assist the operating device 123 and to maintain the shutter 107 in a permanent open position without the intervention of the device 123.

For closing, the operating device 123 moves the operating bar 124 in the direction opposite to the horizontal arrow in FIG. 9, the actuating rods 126 move away from the stop member 129 and the shutters 107 fall back again, closing under their own weight. A stop member, not shown, limits the clearance of the counterbalance 125.

If necessary, the duration of the isothermal holding of the wire rod at a given temperature can be reduced, in keeping one or more shutters in the open position.

Although only some particular embodiments relating to the invention have been described, it is understood that the invention is in no way limited to this and that different modifications, such as those employing different shapes and materials, can be incorporated without departing from the scope and the spirit of the invention, as it is clear that the wire rod undergoing the treatment relating to the present invention can either be treated in separate vertical, horizontal or oblique turns or be treated in formed or in being formed coils.

What is claimed is:

1. A process for heat treating steel wire rod exiting from a rolling mill comprising: exiting a steel wire rod containing less than 0.15 percent carbon from a rolling mill; successively cooling said rod in two stages first to a temperature of about 800° C and then to a temperature of about 400° C thereby positioning interstitial atoms within said rod in a supersaturated solution and effecting the formation of wustite on the rod surface; and then isothermally holding said rod for at least 30 seconds at a temperature between 200° C and 400° C to effect gathering of the interstitial atoms at sites other than dislocation sites and preventing substantial decomposition of the wustite into an oxide which strongly adheres to the rod surface and thus is difficult to remove; whereby the resulting steel wire rod may be directly drawn into a fine wire without undergoing any further heat treatment.

2. A process according to claim 1; wherein said isothermal holding step comprises isothermally holding said rod at a temperature between 280° C and 350° C for a period of at least 1 minute.

3. A process according to claim 1; wherein said successive cooling step comprises first water-cooling said rod to a temperature of about 800° C and then air-cooling the rod to a temperature of about 400° C.

4. A process according to claim 1; including directly drawing said rod immediately after said isothermal holding step into a fine wire without subjecting the rod to any further heat treatment.

5. Wire rod obtained by the process of claim 1 characterized by the fact that it has been subjected to an isothermal holding at a temperature comprised between 200° C and 400° C so that the intersticial atoms placed in a supersaturated solution during a known controlled cooling, gather together on sites other than the dislocations which allows the direct drawing of said wire rod without subsequent heat treatment, to a very small final diameter. and to avoid the decomposition of the thin layer of non-adherent wustite, formed on the surface of the wire during the controlled cooling treatment, into an adherent layer of superior oxide, difficult to remove before the drawing of the wire rod.

* * * * *