

July 2, 1968

D. W. McLEAN ET AL

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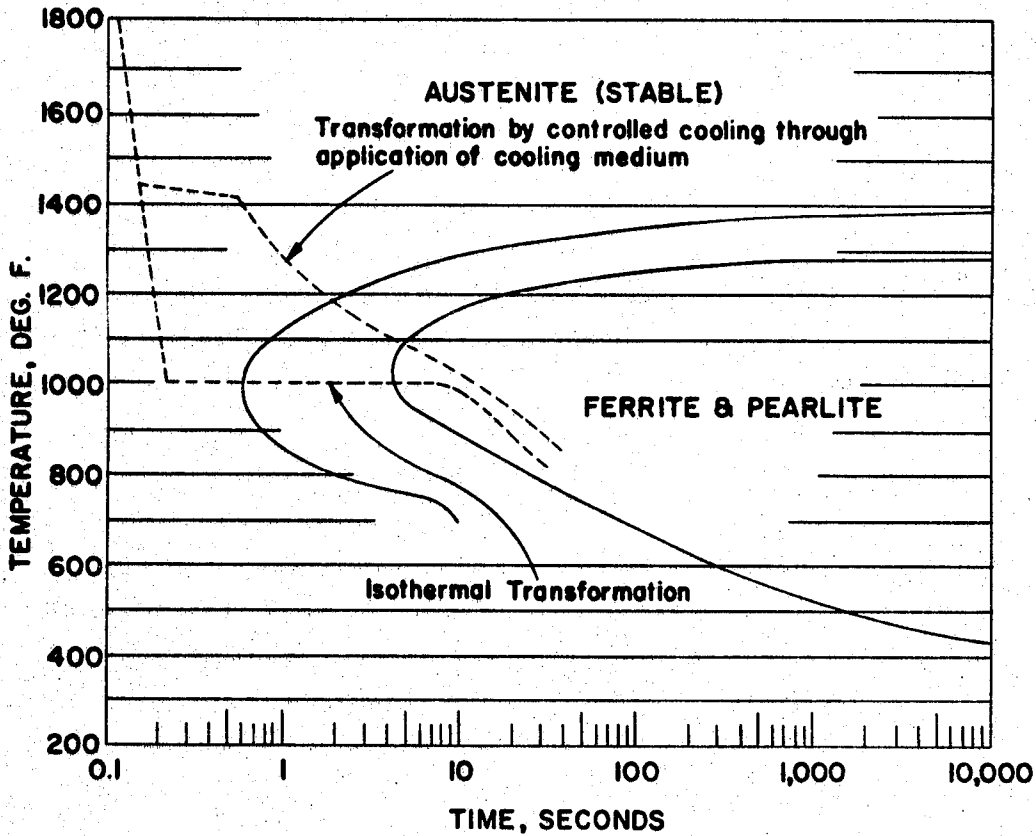
APPARATUS FOR THE CONTROLLED COOLING OF RODS

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FIG. 1

0.50 CARBON STEEL



INVENTORS

DAVID W. McLEAN

BY CHARLES G. EASTER

Russell, Chittick & Pfund
ATTORNEYS

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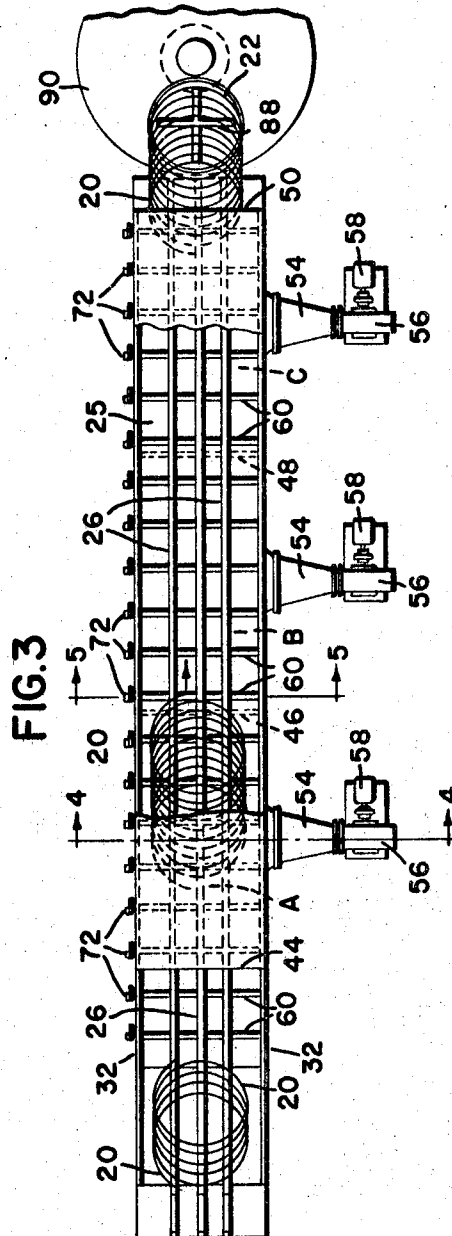
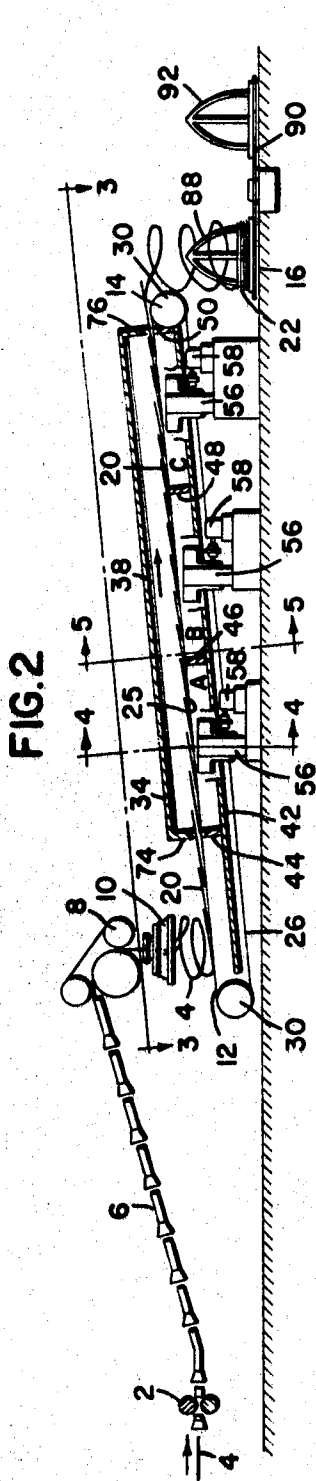
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INVENTORS

DAVID W. McLEAN

BY CHARLES G. EASTER

Russell, Chittick & Pfund

ATTORNEYS

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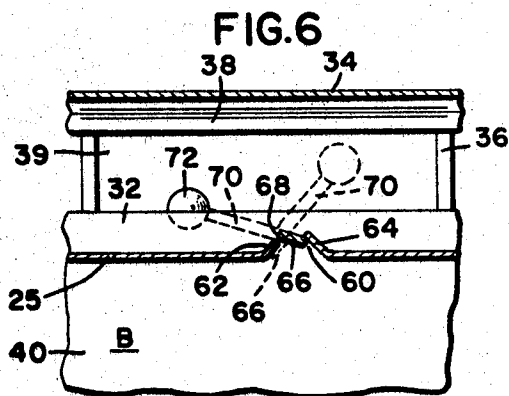
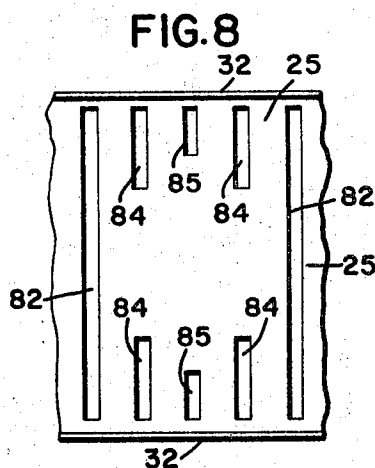
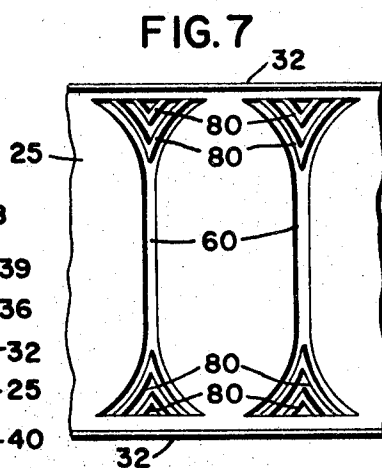
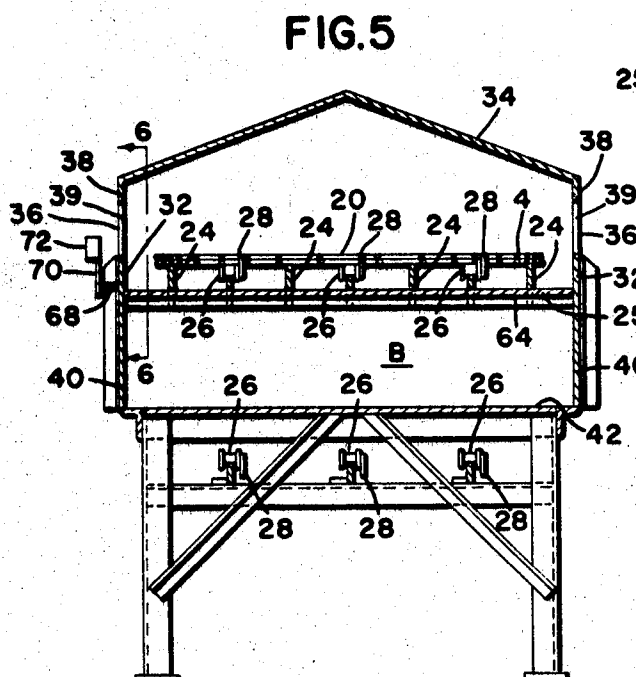
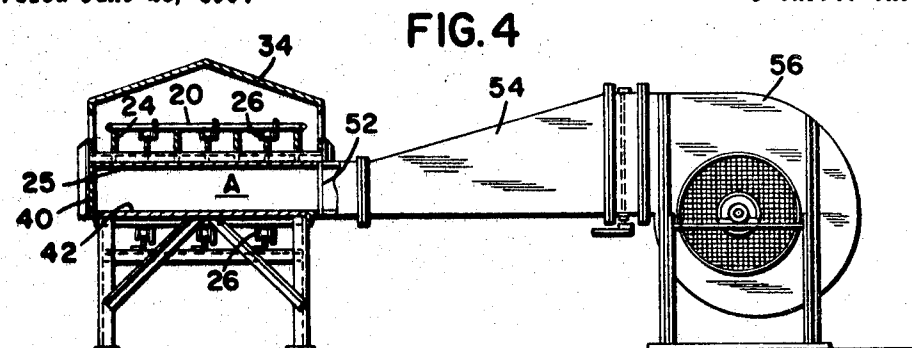
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INVENTORS
DAVID W. McLEAN
BY CHARLES G. EASTER
Russell, Chittick & Hund
ATTORNEYS

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APPARATUS FOR THE CONTROLLED COOLING OF RODS

David W. McLean, Hamilton, Ontario, and Charles G. Easter, Burlington, Ontario, Canada, assignors by mesne assignments, to Morgan Construction Company, Worcester, Mass.

Continuation of application Ser. No. 219,220, Aug. 24, 1962. This application June 29, 1964, Ser. No. 378,812 7 Claims. (Cl. 266—3)

This invention, which is a continuation of U.S. Ser. No. 219,220, filed Aug. 24, 1962, now abandoned, relates to a means for imparting selected micro-structure and mechanical properties to hot rolled metal rods by controlled cooling in direct sequence with a hot rolling mill generally called a rod mill, and more particularly to an apparatus for imparting to rods of various grades of steel different micro-structures and mechanical properties, depending upon the grade of steel, subsequent processing and intended use, by controlled cooling in direct sequence with a rod mill.

In the normal production of steel rods, the rods leave the finishing stand of the rod mill at a temperature of approximately 1800° F. The delivery pipes which carry rods to the laying reels are equipped with water nozzles, and the rods are normally cooled to about 1450° F. as they enter the reels. Here the rods are formed into coils, each coil normally representing the product of a complete billet weighing from 400 to about 1200 pounds. Little cooling occurs during coiling in conventional laying reels because the collected mass of the coil within the enclosed chamber of the reel retards heat loss during the time of approximately one minute required for coiling. After completion of coiling, coils are discharged from the reels to a conveyor on which they travel slowly, cooling slowly in still air. When each coil has cooled sufficiently (to about 1000 to 1200° F.) to permit suspension from a hook without being deformed out of circular shape, it is normally transferred to a hook carrier. This transports the coils in succession toward points of inspection, trimming, tying and shipping, to storage, or to a wire mill. It also provides sufficient time for additional slow cooling to a suitable temperature for inspection, tying and handling. This normal practice leads to a number of detrimental and costly results. The prolonged exposure to air at high temperature produces a layer of scale (iron oxide) on all exposed surfaces, resulting in a direct metal loss amounting to about 1.5%. The slow cooling promotes grain growth, and in grades of steel containing more than .20% carbon leads to metallurgical and mechanical properties which preclude subsequent processing, such as wire drawing, unless further treated. In medium and high carbon grades, steel rod coils produced in this conventional manner must be subjected before drawing into wire to a separate heat treating process generally known as patenting.

Numerous efforts have been made to overcome these objections to the conventional practice. One such effort is disclosed in United States Patent No. 2,756,169 (Corson, Goetz and Lewis) and further amplified in United States Patent No. 2,994,328 (Lewis). This involves providing alternate cooling and heat diffusion zones in the pipes leading from the mill to the laying reels. This process was designed specifically for use with high carbon steel rods and was intended to produce micro-structure

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and mechanical properties equivalent to those expected from subsequent patenting. This has failed to achieve its objective fully because of practical difficulties associated particularly with rod delivery speeds. This process was applied to an early rod mill having a maximum delivery speed of about 4000 feet per minute and even at this relatively low speed required location of the reel 110 feet from the finishing stand of the mill. At modern delivery speeds of 6000 to 7000 feet per minute, the distance required precludes practical use of this process because rods cannot be pushed consistently through pipes of such length without buckling. Another effort in this direction is disclosed in United States Patent No. 2,516,248 (O'Brien). This involves placing a hood on the top of the rod coil after discharge from the laying reel and blowing air from the inside of the coil through the rings comprising the coil. Still another effort is shown in United States Patent No. 2,673,820 (Morgan) where air is blown through the rings comprising the coil while the coil is being formed in the laying reel. This and the method disclosed by O'Brien provided significant improvement over the conventional practice, particularly with regard to the reduction of scale loss. These methods, however, cooled the rod rings at quite different rates, depending upon the location of each rod ring within the coil. In the O'Brien method, the inner and outer rings are cooled quite rapidly, in fact, too rapidly to produce suitable properties for drawing into wire, while rings within the interior of the coil are cooled too slowly. In the Morgan method, the rings comprising the first and final portions of the coil receive relatively little cooling, resulting in variations of properties along the length of the rod. Furthermore, both the O'Brien and Morgan methods, originally applied to rod coils weighing less than 1000 pounds, produce intolerable variations of properties when applied to rod coils weighing 1200 to 1400 pounds.

The objects of this invention will shortly be stated in more detail in the following description, aided by the accompanying drawings in which:

FIG. 1 is a transformation diagram for .50% carbon steel;

FIG. 2 is a side elevation showing an apparatus embodying the concepts of the invention;

FIG. 3 is a plan view of FIG. 2 taken on the line 3—3 of FIG. 2;

FIG. 4 is an enlarged section on the line 4—4 of FIG. 2;

FIG. 5 is an enlarged section on the line 5—5 of FIG. 2;

FIG. 6 is a still further enlarged section on the line 6—6 of FIG. 5;

FIG. 7 shows a modified form of transverse air passage which may be used without a hood over the conveyor; and

FIG. 8 shows still another modified air passage.

The micro-structure and metallurgical and mechanical properties which are desired in rods depend upon the composition of the rod material, the subsequent processing, and the intended use. In the case of steel rods, the desired micro-structure and properties depend principally upon the carbon content of the steel. For steel containing less than about .20% carbon the desired micro-structure is predominantly fine-grained ferrite. The latter is a common metallurgical term applied to grains of steel containing little or no carbon. In steels containing about .25

to .70% carbon, the micro-structure ordinarily desired for wire drawing is fine-grained pearlite interspersed with fine-grained ferrite, the proportions of the two constituents depending upon the carbon content within this range. Pearlite is a metallurgical term applied to grains of steel which contain appreciable amounts of carbon but less than .89%. It is composed of alternate layers of ferrite (Fe) and cementite (iron carbide Fe_3C), having been formed by sufficiently slow cooling to avoid the harder, brittle constituents bainite and martensite. For some purposes, however, steels in this carbon range may be desired to have a micro-structure composed of coarse-grained pearlite interspersed with coarse-grained ferrite. The micro-structure desired in steels containing more than .70% carbon can be defined in terms of similar constituents. The desired micro-structure can be affected by alloying elements, such as nickel, chromium and silicon, if these are present in significant amounts, and in such cases also the requirements can be defined in terms of the constituents found in the micro-structure. The character of the micro-structure produced depends in part upon the composition of the rods, and in part upon the manner in which the rods are cooled. The effect of the manner of cooling can be best understood by reference to FIG. 1 which is a temperature-time-transformation diagram (hereinafter referred to as a "TTT diagram") in conjunction with the following description:

This illustration relates specifically to steel containing .50% carbon and containing no significant alloy additions. It will be understood that similar diagrams for other grades of plain carbon or alloy steels would have different characteristics. This type of chart is known as an isothermal transformation diagram, having temperature as ordinate and time as abscissa. The term "transformation" as used here relates to the allotropic transformation which accompanies the cooling of steel. At rolling temperature, the iron of which steel is principally composed is in the form of gamma iron which has the property of containing up to 2% carbon in solid solution. This solid solution is known as austenite. Upon cooling through a critical temperature, the austenite undergoes a transformation, becoming ferrite, which has much less capacity for holding carbon in solid solution. The carbon rejected from solid solution during transformation, as well as the carbon retained in solid solution, may take one or more of many different forms, depending upon the temperature at which transformation begins and the rate of cooling during transformation. The crescent-shaped curve at the left of FIG. 1 represents for each temperature the time required to initiate the transformation. The second or inner crescent-shaped curve represents for each temperature the time at which the transformation would be completed if the temperature remained constant during transformation. Because the transformation is an exothermic reaction, because there is at most times some temperature gradient within the cross-section of the rods, and because in most cases the transformation does not occur at constant temperature, this diagram is not numerically exact; but it will serve, nevertheless, to illustrate the requirements. To produce the desired micro-structure for drawing into wire, it is essential that transformation be completed fully approximately at or near the "knee" of the inner curve. This can be accomplished in various ways. One way is by isothermal transformation, corresponding to conventional lead patenting of steel rod, in which the rod is cooled rapidly by submerging it in a liquid bath held at constant preselected temperature (in this case approximately 1000° F.) and holding it in this liquid bath at constant temperature until transformation is completed. Another way is to cool the rod rapidly to a temperature of 1200 to 1500° F. and then to impose a cooling rate such that transformation will begin at a temperature sufficiently above the knee of the inner curve to have been completed before the temperature has dropped to that at the knee of the inner curve. These two alternatives are shown diagrammatically in FIG. 1. Both of these as well as other alter-

natives are available within the scope of this invention.

One object of this invention, therefore, is to produce, in hot rolled steel rods delivered from a rod mill, micro-structure and mechanical properties which enable the rods to be drawn into wire without intervening heat treatment.

Another object is to produce, in hot rolled rods delivered from a rod mill in most grades of steel commonly rolled in continuous rod mills, a micro-structure and mechanical properties preselected for the particular grade of steel and for the subsequent processing and end use which will enable the rods to enter subsequent processing without intervening heat treatment.

A further object is to produce, in hot rolled metal rods, micro-structure and mechanical properties which are uniform from end to end of the rods as well as throughout the cross-section.

Still another object is to produce, in steel rods delivered from a rod mill at delivery speeds of 6000 feet per minute or higher, micro-structure and mechanical properties uniform throughout the length of the rods which will enable the rods to be drawn into wire without intervening heat treatment regardless of the weight and size of coils formed from the rods.

An additional object of the invention is to subject rods delivered from a rod mill to rapid but adjustably controlled cooling so that a minimum amount of scale will be formed on the surface of the rods and so that the metallurgical and mechanical properties of the rods can be controlled to suit the composition of the rod material, the subsequent processing, and the intended end use.

The novel mechanism which is used to carry out the above-stated objectives will now be described. Referring first to FIGS. 2 and 3, the last stand of a rolling mill is indicated at 2. The rod 4 passes through pipe 6, in which it may be water-cooled in a manner now known to the industry, to a temperature in the range from 1200 to 1500° F. The rod is then turned downwardly by a chain guide 8 to be fed into a laying head 10. The laying head may be of conventional construction of the same type as that customarily used in laying rod in a laying reel. The rod 4 is deposited on a conveyor, preferably a continuously moving conveyor, 12, which preferably slopes upwardly at a small angle so that the discharge end of the conveyor at 14 is high enough above the floor level to facilitate subsequent collection of the rod rings at the collecting position 16.

Since the conveyor moves the rod in the direction of the arrow 18, the rod as deposited thereon will be in the form of a succession of non-concentric, substantially circular convolutions 20, which are clearly shown in FIG. 3. These non-concentric convolutions are continuously deposited on the conveyor to the extent of the metal present in the original billet fed into the rolling mill. Thus the collected coil 22 will have a weight substantially the same as that of the billet. While a simplified method of collecting the rod in coil 22 has been shown, it will be understood that other means or reassembling the non-concentric rings as they leave the conveyor may be used without in any way affecting the invention herein disclosed and claimed.

The preferred form of the conveyor 12 is shown in more detail in FIGS. 4, 5 and 6. It will be seen to consist of a plurality of parallel longitudinally extending tracks 24 whose upper surfaces reside in a common plane. The tracks are supported by a longitudinally extending upper floor 25. Between these tracks are conveyor chains 26 to which are attached upwardly extending fingers 28 of sufficient length to engage the non-concentric rod rings in a manner effective to move them steadily and without distortion along the tracks 24. The chains travel over driven sprockets 30, the speed of which may be controlled to change the rate of travel of the rings along the conveyor.

In the preferred construction, the conveyor has longitudinally extending side walls 32 which run for the full

length of the conveyor. The top of each of the walls 32 is preferably at about the same level as the rod rings. A longitudinally extending roof or cover 34 is located above most of the conveyor, being supported by a plurality of spaced posts 36 that extend upwardly from the walls 32. The roof 34 terminates on both sides in a short downturned wall 38 which is, however, sufficiently above the walls 32 to provide an adequate space 39 for the discharge of cooling air, or other medium, which, in a manner to be explained, is forced through the traveling rod rings.

The preferred mechanism for forcing cooling air through the moving non-concentric rod rings will now be described. The side walls 32 extend downwardly a substantial distance below the upper surface of the conveyor as indicated at 40, and these walls are connected by a bottom imperforate floor 42. A plurality of vertical walls 44, 46, 48 and 50 divide the space within upper and lower floors 25 and 42 and the walls 40 into a plurality of plenum chambers which are designated A, B and C. Each of these chambers has an opening in its side as shown at 52 in FIG. 4, to which opening is connected a pipe 54 leading from the discharge side of a powerful fan 56. As shown in FIG. 2, there are three fans 56 and each is driven by a suitable motor 58. It will be understood that the number and size of plenum chambers and the size and capacity of the fans may be varied at will to produce the desired volume of air that is to be passed over the moving rod ring 4 as they travel continuously along the conveyor. It will also be understood that cooling media other than air may be used, and that the cooling medium may be delivered from one or more of the plenum chambers at selected temperatures above or below atmospheric temperature to accomplish the objects of the invention. In addition, it will be understood that a liquid cooling medium may be used, in which case the coolant will be delivered through pipes and nozzles rather than through a plenum chamber, and the portion not vaporized will be collected and drained through sumps and pipes.

In order that the air may be directed over and past the rod rings to provide the uniform cooling effect that is required in the practice of this invention, the following mechanisms are utilized:

The floor 25 has a substantial number of transverse openings extending thereacross. These openings are of uniform cross-section, and one such opening is shown in FIG. 6 and indicated at 60. At this opening, the adjacent edges 62 and 64 of the floor 25 have been turned upwardly to direct the air escaping from the plenum chamber through the rod rings. These edges also engage a valve member 66. Valve member 66 is large enough to cover opening 60 and is carried by a shaft 68 which extends laterally beyond the wall 40 as shown in FIG. 5. Shaft 68 has fixed on its end an arm 70 which carries a counterweight 72. It will be seen in FIG. 6 that when the arm 70 has been swung to the left counterweight 72 will hold the valve 66 in closed position, blocking any air flow through opening 60. When the counterweight has been swung to the right, the valve 66 will assume the open dotted line position so that air forced into the plenum chamber B by fan 56 may flow freely upwardly through opening 60 to pass over all parts of the moving rod rings 4 as they move steadily over opening 60.

It is appreciated that the rod is resting on the upper edges of the tracks 24, but these tracks are relatively narrow in transverse dimension so that there is no perceptible diminution of the cooling effect of the upwardly flowing air because of the tracks 24.

By examination of FIG. 5, it will be appreciated that when the rod is laid on the moving conveyor in the form of non-concentric rings, as shown in FIG. 3, there will be a minimum of concentration of metal at the center of the conveyor with increasing concentrations as the sides of the conveyor are approached. That is to say, over any

selected cross-section through the rings there will be an increasing number of crossings as the sides of the rings are approached. Furthermore, the position of that part of each deposited ring at the center of the conveyor extends generally transversely, whereas those parts of each ring at the sides of the conveyor extend generally in the direction of the conveyor. The result of this is that where a transverse slot or an opening of uniform width is utilized through which cooling air is blown upwardly in substantially uniform quantities per unit of time over the entire area of the opening a greater cooling effect will be present at the center portions of the openings than at the edges because there is a smaller mass of metal present over a given cross-sectional area of the opening at the center than at the sides. Since the cooling air is moving upwardly at a uniform rate over the entire area of the transverse opening, it follows that the cooling rate of the rod would, under normal circumstances, be faster at the center than at the sides. Since it is essential in the present method that the rate of cooling of all parts of each ring be substantially uniform, means has been provided for applying in effect more cooling air to the side portions of the ring than at the center. What we have done is to take the air which has come upwardly through the center portions of the transverse openings and which has not been heated to the same extent as the air coming upwardly at the sides of the rings and redirect it laterally so that as it flows toward and out the side openings 39 it will flow over and around all portions of the rod rings on both sides of the center and particularly over the heavy concentrations of metal that are present toward the sides.

Putting it still another way, the hood over the conveyor and transverse openings causes a turbulent re-direction of the air that has come up through the center of the openings where there is a lesser mass of metal to be cooled. This re-directed central air, which is of somewhat lower temperature than the air that has passed up and over the heavy concentration of metal at the sides of the rings, is mingled with hotter side air and passes again over the sides of the rings so that heat is extracted from all parts of all of the rings at substantially the same rate. In this way uniform cooling is achieved.

On referring to FIG. 3, it will be noted that there are shown twenty transverse air passages 60, and each of these passages is controlled by a valve 66. In the roof of each of the plenum chambers A, B and C have been shown six passages, while two passages, normally closed, precede the transverse wall 44. Through the use of these valve passages, the quantity of air passed over the moving rod rings may be controlled in a manner to give the proper rate of cooling for the particular rod then being processed so that the requirements of that rod's transformation curve can be met to produce a rod with the correct metallurgical properties.

It is not essential that the successive curtains of cooling medium be directed vertically. The walls of the passages 60 could be sloped forwardly to rearwardly to cause the air or other medium to flow upwardly at an angle to the vertical without adversely affecting the cooling requirements.

Furthermore, it is to be understood that the invention is not to be limited to means for directing the cooling medium upwardly through the rings. Inverted supply channels could be provided which would direct the cooling medium downwardly through the rings to give the same cooling effect.

It will be noted in FIG. 2 that the roof 34 over the conveyor commences at 74 and terminates at 76. Thus there is an uncovered space on the conveyor between laying head 10 and the start of the roof at 74. In this open area of the conveyor, appreciable cooling of the rod is achieved through radiation. This open area thus provides a zone in which rods can be cooled for a brief period of time at a relatively slow rate without requiring application of a special cooling medium. This period of relatively

slow cooling prior to allotropic transformation permits grain growth to a selected degree, which is desirable for some materials and uses. It is to be understood that the length of the hood 34 and the preceding open area may be varied to meet particular conditions called for by the metallurgical properties of the rod being treated. Likewise, the number and dimensions of ports 60 may be increased or decreased and the volume of coolant passed through the ports that are open may be changed by the operator as needed to meet the requirements of the transformation curve. The basic consideration is that all parts of each of the non-concentric rings be uniformly cooled in a proper time so that the resulting collected rings forming coil 22 will have the required uniform metallurgical properties. It is the rapidity, control and uniformity of cooling which has not heretofore been capable of achievement by other known mechanism that is the outstanding accomplishment of the present invention.

By the time the rings have reached the end of the hood 34, the temperature of the rod will have fallen at a rate sufficient to have passed through the inner curve of the transformation diagram at a point above the inner knee, thus putting the rod in such condition that subsequent cooling at reasonably rapid rates will have no further effect on the metallurgical properties nor will there be any significant scale development thereafter. In fact, by this cooling process there is negligible scale formation after the rod leaves the laying head 10 because the overall cooling is achieved so rapidly.

Other alternative means for achieving the uniform cooling of rod as it is moved along the conveyor from the laying head to the collecting position are shown in FIGS. 7 and 8. In these two structures, the overhead hood may be dispensed with insofar as the cooling requirements are concerned.

In the construction shown in FIG. 7, the rectangular transverse opening shown in FIG. 3 has been changed to a configuration in which the transverse opening is narrow in the center and expands gradually to a maximum dimension at the sides. The curvature of the sides of this opening will be proportioned to the mass of metal present at any given longitudinal section along the overlapping non-concentric rings. In this way, the lesser mass of metal at the center, which will be subjected to the succession of cooling zones for a minimum total time, will be cooled at the same rate as the greater mass of metal at the outer edges, which will be subjected to the succession of cooling zones for a maximum and proportionately longer time. The intermediate portions of the transverse openings will be correspondingly shaped to apply the coolant for such total time as required to achieve the same uniform rate of cooling of the intermediate portions of the rings.

The number of rings of the rod per unit of length of the conveyor may be varied at will without affecting the uniformity of cooling, although for a constant flow of coolant and constant rod size the rate of cooling will decrease as the number of rings is increased. When the concentration of the rings is greater, the volume of coolant forced through the transverse openings may be increased to achieve cooling at the same rate. Conversely, when the concentration of rings is decreased, the volume of coolant per unit time may be suitably decreased, thereby to achieve the same cooling rate.

When air or other gas is used as a coolant, in order to insure that the velocity of the coolant passing through the transverse opening shown in FIG. 7 is uniform over all portions, the passage may be partitioned in the manner indicated by the thin curved vertical walls 80. With a substantially uniform pressure in each of the plenum chambers A, B and C passages of uniform size will give substantially uniform velocities flowing upwardly past the rings as they move thereover.

Another modification of air passage construction which will result in uniform cooling of the non-concentric rings

without the use of a hood is shown in FIG. 8. Here there are a succession of full-width passages 82, which are similar to those shown in FIG. 3. In between these full-width passages are a series of shorter passages 84, and between each pair of passages 84 is a still shorter passage 85. The cumulative effect of this arrangement is to produce the needed greater flow of air over the sides of the overlapping rings and a lesser flow as the center is approached. The number and size of the passages may be readily adjusted to be in agreement with the varying mass of metal of the rings, which is at a minimum at the center and increases at first slowly as the sides are approached and finally rapidly just before the side areas of the rings are reached.

The collecting mechanism 16 is of a simplified form. The rod rings 4 as they leave the end of the conveyor fall over the conical head 88 to be collected in a coil 22. As soon as the last ring of the coil is deposited, the turntable 90 is rotated, bringing a new head 92 to the collecting position to receive the next oncoming succession of rod rings. As this next coil is being assembled, the coil 22 is removed from the core 88.

It is our intention to cover all changes and modifications of the examples of the invention herein chosen for purposes of the disclosure which do not constitute departures from the spirit and scope of the invention.

What is claimed is:

1. Apparatus for producing steel rod comprising in combination: a mechanism for rolling steel to rod diameter at an elevated temperature above transformation temperature; a delivery means for receiving said rod continuously and directly from said mechanism; spaced supports positioned to receive said rod from said delivery means; rod laying means for directing said rod from said delivery means and for continuously depositing said rod on said spaced supports in the form of discretely offset rings while said rod is still at a temperature above transformation, said rod laying means and said supports constructed and arranged to provide an offset of said rings and a dimension of contact between said rod and said supports which allows substantially complete exposure of the surface of said rod to a flowing current of a gaseous cooling medium; means associated with said delivery means for cooling said rod rapidly from rolling temperature above transformation down to a temperature near to but above transformation directly after said rod issues from said rolling mechanism and while the austenitic grains thereof are still small due to the mechanical action of said rolling mechanism, whereby austenitic grain growth following rolling is inhibited; and, means for imparting a substantially uniform fine grained pearlitic structure suitable for extensive cold working to said rod including means associated with said spaced supports for directing a flowing current of said gaseous cooling medium around said spaced supports through said rings and to substantially all exposed surfaces of said rod to cool said rod through transformation substantially uniformly throughout the length of said rod.

2. The apparatus as set forth in claim 1 wherein the cooling means associated with said delivery means includes means for applying a liquid coolant to the surface of rod passing through said delivery means.

3. The apparatus as set forth in claim 1 wherein said gaseous cooling medium is forcibly applied.

4. The apparatus as set forth in claim 3 wherein the flow of said gaseous cooling medium is distributed in proportion to the distributed mass of metal to be cooled.

5. The apparatus as set forth in claim 4 further characterized by means for re-directing the gaseous cooling medium that has passed over the center portion of said offset rings laterally to contact the side portions of said rings where the concentration of metal is the greatest.

6. The apparatus as claimed in claim 3 means for pro-

ducing a succession of cooling zones through which said offset rings are carried along said spaced supports, the application of gaseous coolant to the rings in each said cooling zones being independently variable.

7. The apparatus as claimed in claim 1 wherein said spaced supports are so small in the dimension of contact with said rod rings as to have negligible influence on the cooling rate of said rod by conduction of heat into said supports, and negligible interference with the uniform application of said gaseous coolant to the surfaces of said rod.

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10 J. SPENCER OVERHOLSER, *Primary Examiner*.

J. D. HOBART, E. MAR, *Assistant Examiners*.