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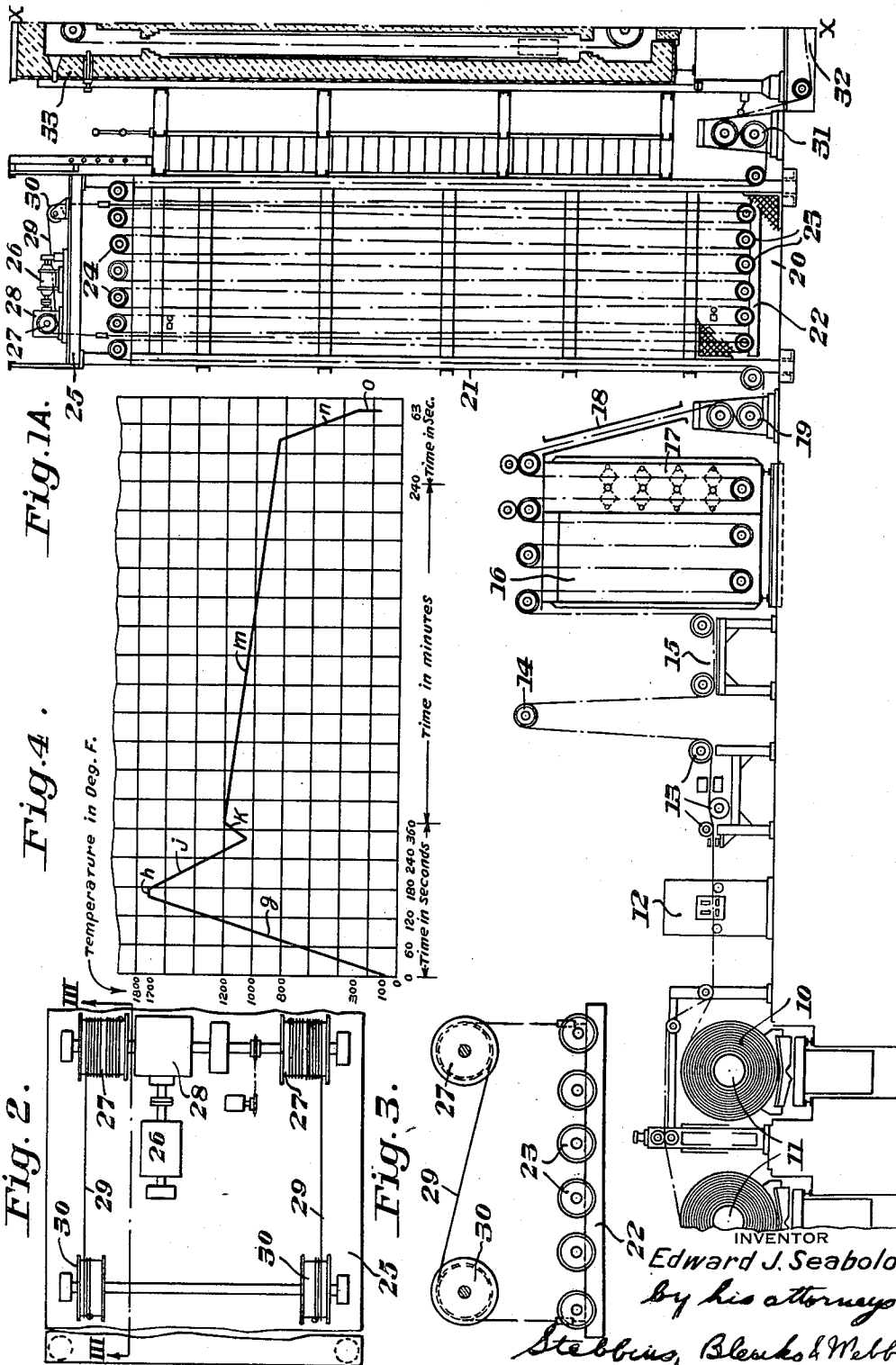
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2,585,277

APPARATUS FOR ANNEALING STRIP

Filed June 27, 1946

5 Sheets-Sheet 1



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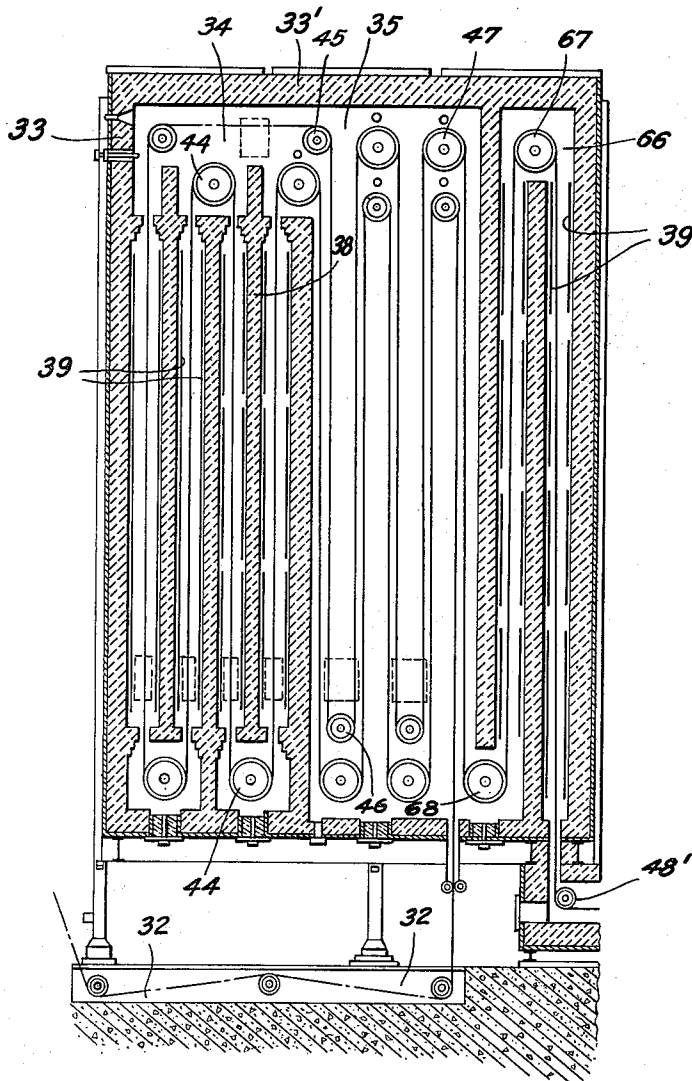
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Fig. 1B.



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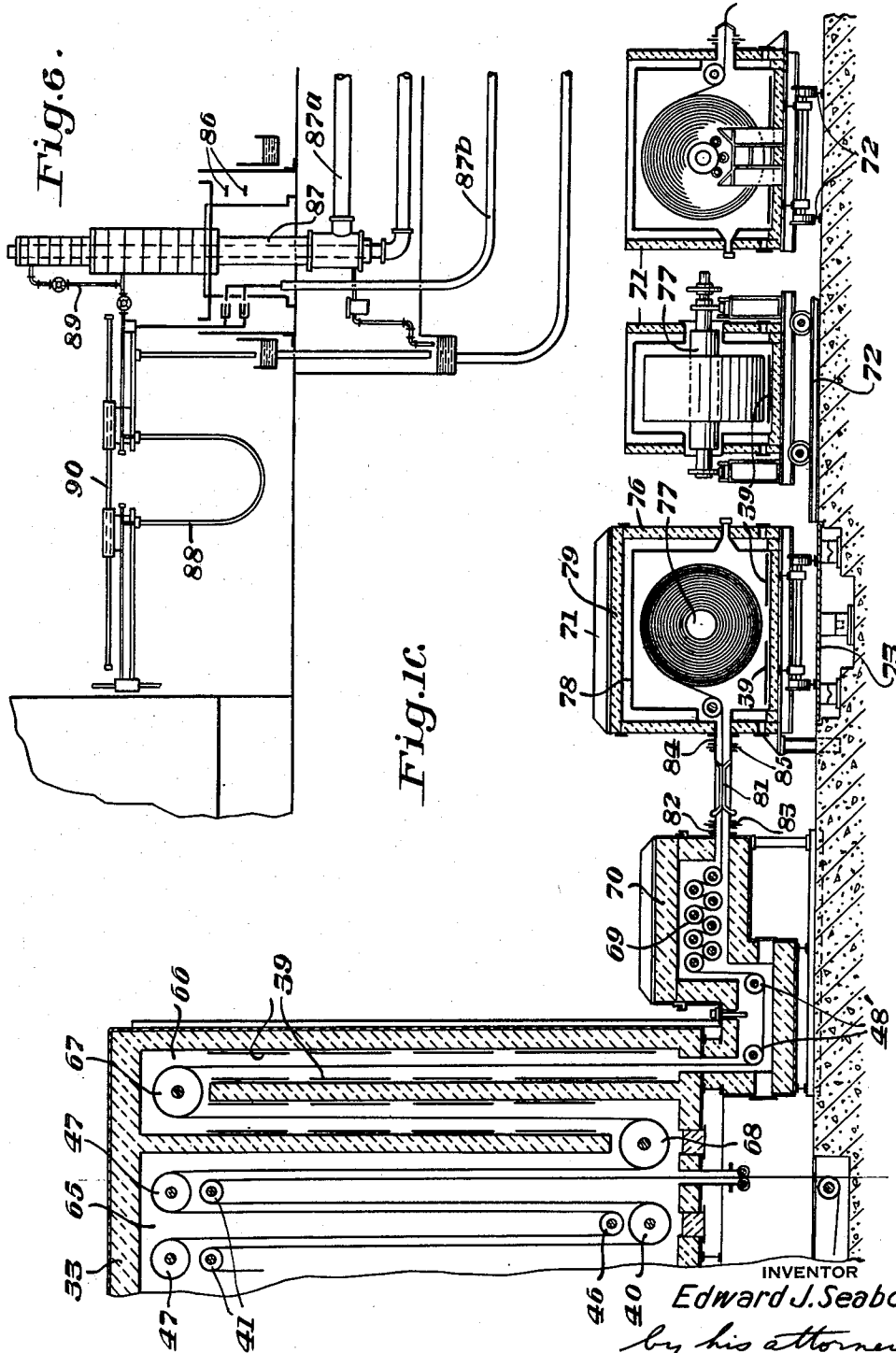
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APPARATUS FOR ANNEALING STRIP

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5 Sheets-Sheet 3



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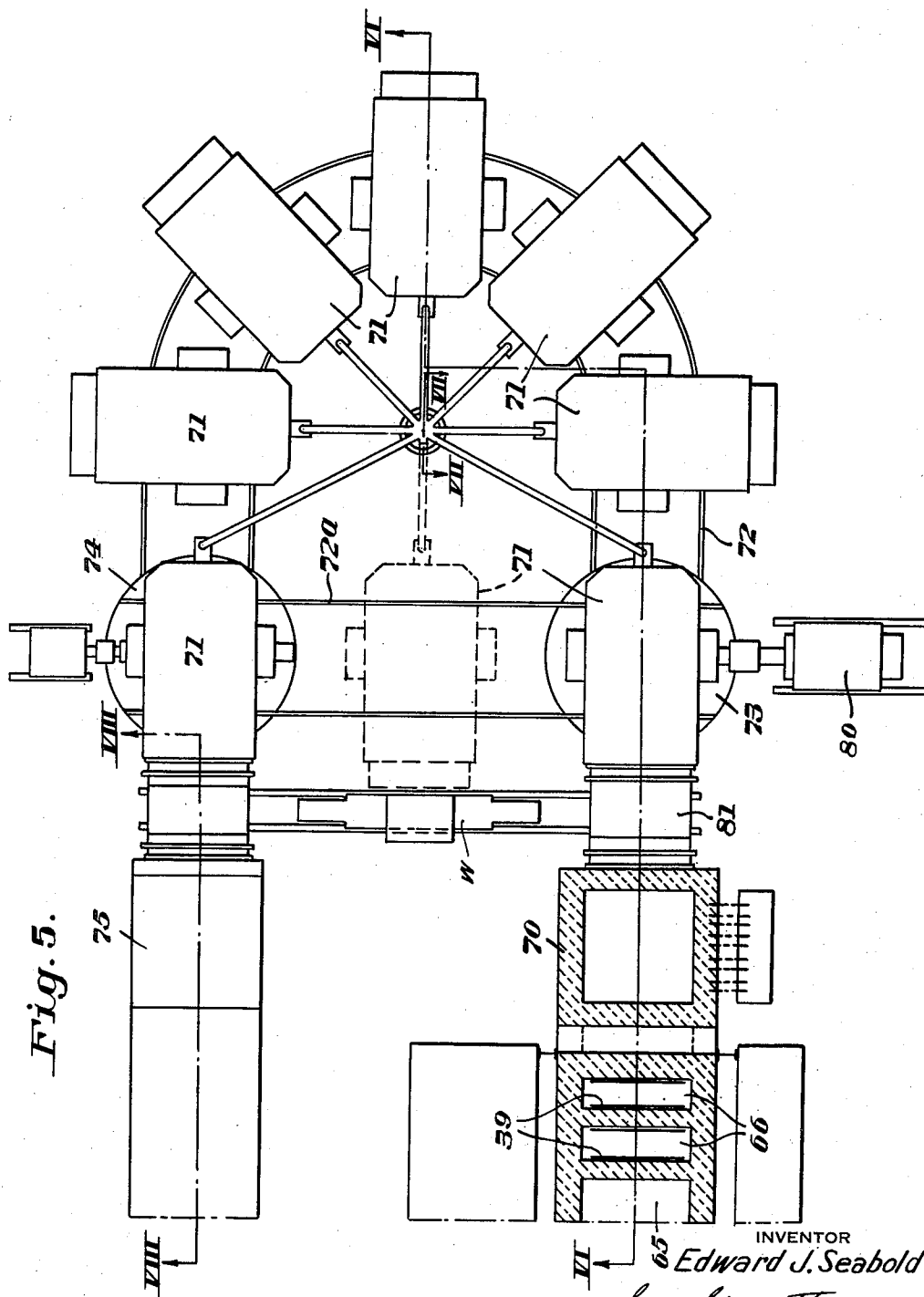
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APPARATUS FOR ANNEALING STRIP

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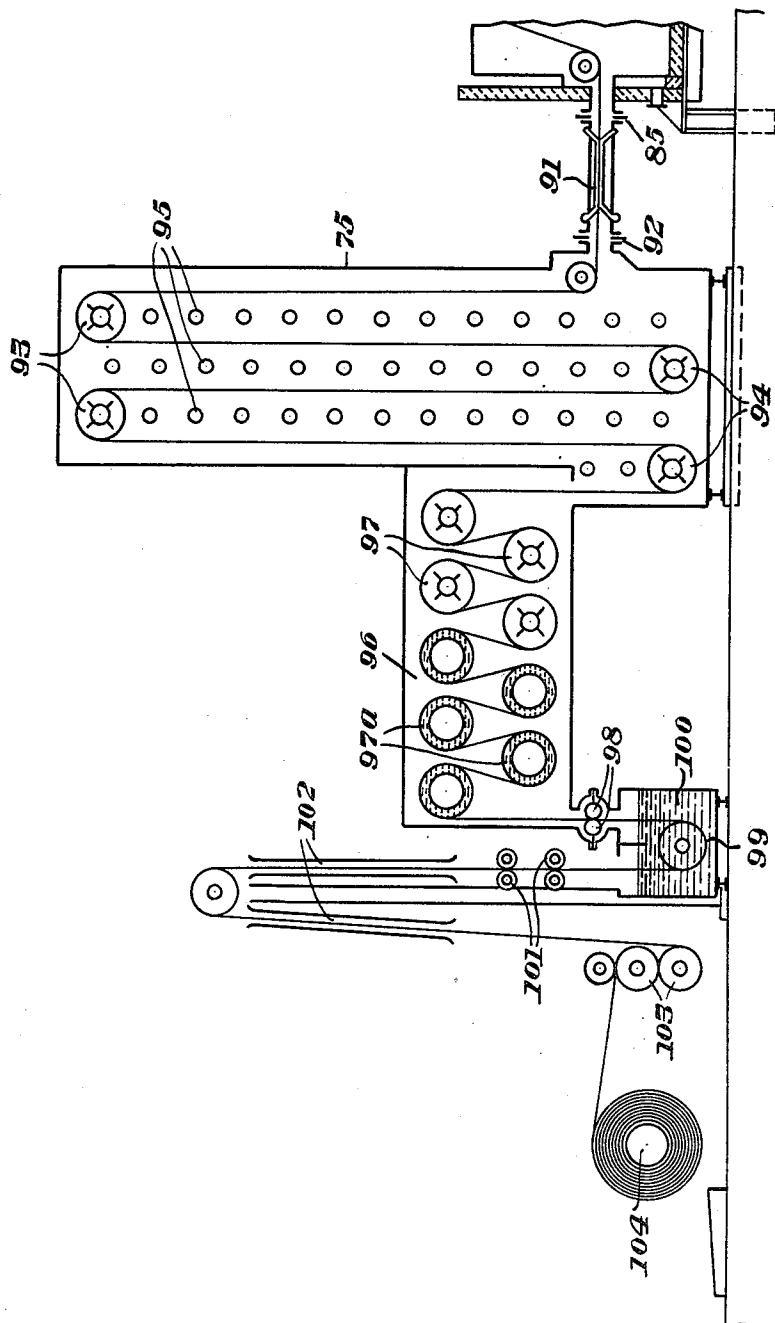
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APPARATUS FOR ANNEALING STRIP

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Fig. 7.



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APPARATUS FOR ANNEALING STRIP

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7 Claims. (Cl. 266—3)

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This invention relates to the processing of metal strip and particularly to an apparatus for annealing ferrous strip.

Since the advent of continuous cold mills for reducing strip to final gauge, the product has been annealed in coil form in cover- or hood-type furnaces. Several proposals have been made, however, to anneal strip in strand form in order to obviate the long heating and cooling periods which are unavoidable when annealing coils, and a few such installations have been made. Electric heating has usually been contemplated by such proposals and incorporated in the actual installations. The cost of electric heating is naturally greater than that of heating produced by the combustion of fuel and this has limited the utilization of continuous annealing. Accordingly, it has been proposed heretofore to increase the thermal efficiency by causing the strip leaving a furnace after being heated to the desired maximum temperature, to give up heat to the entering strip which is at atmospheric temperature. The known arrangements for this procedure, however, are not capable of achieving a very large recovery of heat.

I have invented a novel method and apparatus for annealing strip in strand form characterized by several advantages not realized before. In a preferred embodiment and practice, I provide a furnace with a heating section and a heat-exchange section and guide strip therethrough successively in strand form, in a plurality of vertical, up-and-down loops. The strip first enters the heat-exchange section and after passing through the heating section, it returns to the heat-exchange section and is brought into close proximity to the entering strip for a substantial period of time. Specifically, the entering strip passes through several up-and-down loops which extend between adjacent runs of the loops through which the outgoing, heated strip travels. My method thus comprises heating the entering strip first at a relatively low rate, then at a higher rate, and cooling the strip initially at a relatively low rate. I subsequently cool the strip more rapidly. In one embodiment and practice, I provide the furnace with a reheating chamber adapted to raise the temperature of the strip appreciably above the point to which it is initially cooled. I then coil the strip for further cooling in an insulated enclosure after which I uncoil the strip and cool it quickly to final temperature in strand form.

My invention also includes a novel loop for

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accumulating surplus strip and means for permitting the strip to be coiled after heating while in a protective atmosphere, with provision for cutting the strip after a coil has been completed and rejoining coils into a continuous strand for final cooling while still under a protective atmosphere. I also provide coiler cars traveling around a closed path including stations at the discharge end of the furnace and the entry end of the apparatus for cooling the strip rapidly in strand form.

A complete understanding of the invention may be obtained from the following detailed description and explanation which refer to the accompanying drawings illustrating a preferred embodiment and practice thereof. In the drawings,

Figures 1A, 1B and 1C together constitute a largely diagrammatic view, partly in side elevation and partly in longitudinal section showing one form of the apparatus;

Figure 2 is a plan view of the entry loop;

Figure 3 is a section on the plane of line III—III of Figure 2;

Figure 4 is a curve illustrating the variation in the temperature of the strip at various points in its travel through the apparatus;

Figure 5 is a view partly in plan and partly in horizontal section of the portion of the apparatus illustrated in Figure 1C which is a section taken along the plane of line VI—VI of Figure 5;

Figure 6 is a partial section, largely diagrammatic, taken along the plane of line VII—VII of Figure 5;

Figure 7 is a partial section taken along the plane of line VIII—VIII of Figure 5.

Referring now in detail to the drawings and, for the present, to Figures 1A, 1B and 1C, a coil of strip 10 is fed from one of two uncoilers 11 through a welder 12 adapted to join the ends of successive coils into a continuous length. The strip then passes around a series of guide rolls 13, up over a looping roll 14 and thence to a cut-out table having guide rolls at the ends thereof. The strip then passes through a cleaning tank 16 and a rinse tank 17 passing about a plurality of vertically spaced guide rolls forming one or more loops. From the rinse tank, the strip passes through a drier 18 and around a pair of pulling pinch rolls 19.

The strip then passes to the entry loop 20. The loop comprises an open frame 21 having a carriage 22 suspended therein for vertical movement. The carriage 22 is provided with guide rolls 23 and cooperating guide rolls 24 are jour-

naled in the frame near the top. The strip passes successively around the rolls 23 and 24 and is thus formed into a plurality of vertical loops. The accumulated surplus strip permits continued travel through the heating furnace, to be later described, while the trailing end of a coil is detained at the welder 12 for attachment to the leading end of a succeeding coil. As the surplus strip is taken up, the carriage 22 is raised. The carriage is partially counterbalanced by hoisting mechanism mounted on a platform 25 at the top of the tower and including a torque motor 26 driving hoisting drums 27 through a reduction gear 28. Cables 29 trained around the drums 27 and sheaves 30 extend downwardly to the carriage.

The motor 26 is constantly energized and thus exerts a controllable upward force on the carriage. This force acts to partially counterbalance the weight of the carriage and its rolls but is not sufficient to raise the carriage. This is effected only by the tensioning of the strip sufficiently to take up the surplus accumulated in the looper. Whenever the carriage is raised as a result, the hoisting mechanism immediately overhauls the cables 29.

From the entry looper 20, the strip passes around a pair of master pinch rolls 31 and over guide rolls in a trench 32 and into a furnace indicated generally at 33. The furnace comprises a heating section 34 and a heat-exchange section 35 subdivided by a cross wall or baffle 37 terminating short of the bottom of the furnace. The heating section has baffle walls 38 terminating short of the top and bottom of the furnace. Electric resistance heaters 39 are mounted on the walls of the heating section and on the baffle walls 38. The strip enters the furnace through an opening 42 in the bottom thereof after passing between sealing rolls 43.

Vertically spaced guide rolls 40 and 41 in the heat-exchange section 35 guide the entering strip through a plurality of up-and-down vertical passes. These passes, as will be explained shortly, are parallel to a plurality of passes for the strip which has passed through the heating section and is on its way out of the furnace. The entering strip is thereby heated at a relatively low rate, by radiation from the previously heated portions of the strip. Guide rolls 44 adjacent the top and bottom of the heating section 34 guide the preheated strip through a plurality of up-and-down passes between the baffle walls 38. In this portion of its travel, the strip is further heated by direct radiation from the heaters 39. The heaters in the last pass, however, are adjusted merely to supply the heat losses through the walls without raising the temperature of the strip, thereby affording an opportunity for the heat to soak through the material so that all portions of the latter will be at a uniform temperature.

From the last pass in the heating section, the strip passes over spaced guide rolls 45 above the upper guide rolls 44 and then travels over vertically spaced guide rolls 46 and 47 so disposed in the heat-exchange sections that the outgoing strip, as previously stated, will closely parallel the several runs of the incoming strip between the guide rolls 40 and 41. It will be evident from the drawings that the guide rolls 40 and 41 for the entering strip and the guide rolls 46 and 47 for the strip leaving the furnace cause the strip to pass through mutually interfitting up-and-down loops whereby a good opportunity is afforded for absorption of heat by the entering strip from that

which has already passed through the heating section. This effects a relatively slow cooling of the strip leaving the furnace, concurrently with the relatively slow heating of the entering strip.

I am able to produce material having greater ductility by heating it slightly and coiling it under a protective atmosphere for further cooling at a very low rate in coiled form. The strip is then uncoiled and finally cooled at a higher rate in strand form, under a protective atmosphere.

On leaving the heat-exchange section, the strip enters a reheating section 66 provided, like the heating section 34, with radiant heaters 39. The section 66 has upper and lower guide rolls 67 and 68 and includes two vertical passes. After traversing both these passes, the strip passes over exit guide rolls 48' and thence around a series of staggered flexing and drag rolls 69 enclosed within a thermally insulated chamber 70.

A plurality of coiler cars 71 are adapted to travel around a closed track 72 including turntables 73 and 74. The turntable 73 is located adjacent the chamber 70 and the turntable 74 adjacent a cooling tower 75. Each coiler car includes a thermally insulated enclosure 76 mounted on wheels and having a coiling mandrel 77 journaled therein. An inner cover 78 is provided for maintaining an atmosphere of protective gas around a coil of strip on the mandrel 77. A removable cover 79 is disposed on the enclosure 76 while coiling strip on the mandrel. A drive mechanism indicated at 80 adjacent the turntable 73 is adapted to be coupled to the mandrel 77 when it is desired to coil strip thereon.

An access gate 81 is provided in a neck 82 extending outwardly from the chamber 70 and having a seal 83 therein. A similar neck 84 extending from the enclosure 70 is adapted to engage the gate 81 and has a seal 85 therein. The gate is preferably water-cooled. The mandrel 77 has a length of strip permanently secured thereto to which the end of the strip emerging from the chamber 70 is adapted to be welded by a welder 45 W on opening of the access gate 81 after the seals 83 and 85 have been closed. When the connection has been made, the gate is reclosed and the seals opened, whereupon the strip which has been through the furnace may be coiled by driving the mandrel 77, the strip being fully protected against atmospheric oxidation at all times. When a full coil has been wound on the mandrel 77, the seals 83 and 85 are again closed. The portion of strip within the gate 81 may then be quickly cooled by special connections for circulating protective gas therethrough. The gate 81 is then opened and the completed coil is severed from the succeeding portion of the continuous length of strip. Preferably the severance is effected at the welded joints between successive lengths made by the welder 12. After a coil has been wound on the mandrel, the cover 79 is removed from the enclosure 76 and the car 71 is advanced counterclockwise along the track 72 and an empty car is brought into coiling position.

If desired, radiant heaters 39 may be mounted adjacent the bottom of the coiler cars to provide controlled cooling of the coils. The current for these heaters and the protective atmosphere for the inner cover are supplied by radial connections from slip rings indicated diagrammatically at 86 and a central supply pipe 87. A connection 87a extends from the pipe 87 to a source of gas suitable for the atmosphere surrounding

the coils. A connection 87b extends from the slip rings to a suitable source of current. The radial connection for the current leads includes a flexible loop 88 and the connection for supplying gas to the inner cover includes piping 89 and a telescoping connection 90.

As shown in Figures 5 and 1C, a plurality of coiler cars are employed and they advance slowly around the track 72 in succession after having coils wound thereon. The number of cars and the length of the track, of course, will be such as to provide the desired period of furnace cooling for the coils so that, by the time a car has reached the turntable 74, its coil will have cooled to a temperature of around 900° after which more rapid cooling may be effected in the tower 75. The latter, as shown in Figure 7, is provided with an access gate 91 and a seal 92 similar to those of the chamber 70. Thus, when a car has been properly positioned, relative to the tower 75, the end of the coil projecting through the seal 85 may be connected as by welding to the end of a length of strip already started through the tower 75 after which the gate 91 may be closed and the seals 92 and 85 opened so that the strip may be uncoiled and passed through the tower in strand form. When the coil has been unwound and severed from the connection length secured to the mandrel, the car is returned to a position adjacent the chamber 70 by a connecting track 72a.

The tower 75 is provided with upper and lower rolls 93 and 94 around which the strip passes in a plurality of up-and-down loops. Banks of cooling coils 95 are disposed between the loops and have water circulated therethrough in order to cool the strip rapidly. An extension 96 from the tower is provided with a plurality of air-cooled rolls 97 and water-cooled rolls 97a around which the strip passes for further cooling. On leaving the extension 96, the strip passes between sealing rolls 98 and around a guide roll 99 in a quench tank 100. The strip then passes upwardly between wringer rolls 101, through drying chutes 102 and finally around a stand of coiler pinch rolls 103 and onto a coiler 104.

Figure 4 illustrates graphically the variation in the temperature of a point on strip from .340" to .075" thick being processed in accordance with a typical example of the modified practice of the invention, although the exact values of temperature are merely for illustration and may vary materially. The strip is first heated from atmospheric temperature to a maximum of about 1700° as indicated by portion g of the curve of Figure 4. This heating is actually accomplished in two steps, at different rates, but this is not shown in Figure 4 because of the small scale employed on the horizontal axis. The material is heated from room temperature in passing through the heat-exchange section and as the strip passes through the heating section of the furnace, its temperature rises more rapidly. The strip is then held at the maximum temperature for a short time as indicated at h and is next cooled at a relatively slow rate to a temperature of between 1000 and 1100° as it passes through the heat-exchange section of the furnace. This is indicated by portion j of the curve. Next the strip passes through the reheating section 66 and its temperature is raised to about 1200° as indicated by portion k of the curve. After being coiled, a very slow or furnace cooling of the strip occurs as indicated by the portion m of the curve to a temperature of between 800 and 900°. It will be noted that in this portion of the curve, the hori-

zontal scale has been compressed. After traveling around the track 72 on one of the coiler cars, and being entered into the cooling tower 75, the strip has its temperature reduced rapidly to about 300° as shown by portion n of the curve of Figure 4 and is finally quenched as indicated by portion o of the curve.

If it is desired to produce bright-annealed strip, the furnace chamber and cooling towers must be supplied with an atmosphere of non-oxidizing gas. A suitable atmosphere may be obtained by burning any clean fuel gas with an insufficient supply of air, cooling and dehydrating it. The gas is preferably introduced into the furnace in the heating section and flows under a slight positive pressure toward the cooling towers. The gas, however, may be first passed through the quench tank above the surface of the water to remove any vapor therefrom.

It will be apparent that the method and apparatus described above are characterized by numerous advantages. Among these are the speed of processing which enables finished material to be shipped soon after it is cold rolled as is now being demanded increasingly by consumers, the production of material having good physical properties and micro-structure in substantial amounts, i. e., up to 15 tons per hour, at an overall cost no greater than that of the conventional batch annealing. In respect to cost, a special advantage is the saving resulting from the fact that the cleaning step is combined with the annealing. It will be appreciated that this avoids the extra handling necessary when the cleaning operation is conducted separately, as well as the cost of a separate cleaning line. By heating the material in single strand, more accurate control of the time-temperature cycle is obtained as well as a greater flexibility in the heat treatment. The desired relief of strain and refinement of grain can readily be accomplished. The maximum temperature is easily controlled as well as the soaking stage and successive cooling stages. Processing in strand form also produces material which is more nearly uniform in annealing characteristics throughout the length of the strip. One factor in the economy achieved by the invention is the fact that it permits the recovery of about 50% of the heat imparted thereto. The flexibility results from various combinations of time and temperature which may be obtained by changes in the speed of travel of the strip and the ease with which the heat energy delivered to the strip may be controlled.

The procedure described hereinabove provides an improved annealing cycle because of the relatively slow heating and cooling which occurs at the beginning of the heating and cooling stages, respectively. Slow initial cooling of the material from its maximum temperature to about 900° F. is particularly desirable. Below that temperature, the strip may be cooled more rapidly for efficient operation. The final cooling by a water quench permits the strip to be temper-rolled immediately.

In addition, the practice has the advantage of very slow cooling characteristic of batch annealing without the limitation to slow heating which is also characteristic thereof as well as wide variations in the time at which various portions of the coil are held at the maximum temperature. The very slow cooling thus obtained promotes complete spheroidization giving a product having extremely good ductility. The reheating step relieves any internal strain produced by the initial

cooling but does not cause grain growth, thereby preserving the small grain size produced by the initial cooling.

It will be evident that the invention is well adapted to automatic control. The details thereof are not shown, however, since they may be varied to suit the needs of particular installations.

Although I have illustrated and described but a preferred embodiment and practice of the invention, it will be recognized that changes in the procedure and apparatus disclosed may be made without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. In strip annealing apparatus, in combination, a heating furnace for heating strip in strand form, said furnace having an outlet for said strand, a movable enclosure adapted to be moved into registry with said outlet, means for coiling said strand within said enclosure, a cooling tower adapted to cool strip in strand form having an inlet for said strand, means for moving said movable enclosure along a closed track circuit after a strand has been coiled therein out of registry with said furnace outlet and into registry with said tower inlet, means for uncoiling said coil in said enclosure and passing it through said inlet to cool said strand and means for returning said movable closure into registry with said furnace outlet, whereby rapid heating, temperature holding and relatively rapid cooling are obtained.

2. In strip annealing apparatus, in combination, a loop heating furnace for heating strip in strand form, said furnace having an outlet for said strand, a movable enclosure adapted to be moved into registry with said outlet, means for coiling said strand within said enclosure, a loop cooling tower adapted to cool strip in strand form having an inlet for said strand, means for moving said movable enclosure along a closed track circuit after a strand has been coiled therein out of registry with said furnace outlet and into registry with said tower inlet, means for uncoiling said coil in said enclosure and passing it through said inlet to cool said strand, means for supplying protective gas to said furnace, enclosure and tower, sealing means for the respective passages between said furnace and said enclosure and between said enclosure and said tower during movement of strip therebetween, and means for returning said movable closure into registry with said furnace outlet, whereby rapid heating, temperature holding and relatively rapid cooling are obtained in a continuously protected atmosphere.

3. In strip annealing apparatus, in combination, a heating furnace for heating strip in strand form, said furnace having an outlet for said strand, a plurality of insulated coiler cars adapted to be moved successively into registry with said outlet, means for successively pulling strands from said furnace and coiling them respectively within said coiler cars, a cooling tower adapted to cool a strip in strand form having an inlet for said strand, means for moving said coiler cars successively into registry with said tower inlet, a closed circuit track extending between said furnace and said tower and adapted to accommodate a predetermined number of said coiler cars, said track extending along one path from said furnace to said tower and along another return path from said tower to said furnace, and means for uncoiling said coil in each of said coiler cars when said cars are respectively

in registry with said tower inlet to pass the strip therein in strand form through said inlet to cool said strand, whereby rapid heating with predetermined temperature holding and relatively rapid cooling are obtained in a flexible annealing operation.

4. In strip annealing apparatus, in combination, a heating furnace for heating strip in strand form, said furnace having an outlet for said heated strand, at least one insulated coiler car having a neck communicating with the inside of said coiler car, said car being adapted to be moved to bring said neck into registry with said outlet, strip sealing means respectively on said outlet and said neck, an access gate extending between said strip sealing means when in said registry, common means for pulling said strand from said furnace and coiling it within said coiler car, a welder adapted to weld the leading end of said strand to said coiling strip when said access gate is open and said strip sealing means are closed, said access gate being adapted to be closed after said welder is withdrawn, said strip sealing means being adapted to be opened when said access gate is closed to permit coiling of said strand in said coiler car, a cooling tower adapted to cool a strip in strand form having an inlet for said strand, means for moving said loaded coiler car to bring said neck into registry with said inlet, strip sealing means on said inlet, an access gate extending between said respective strip sealing means when in said last-mentioned registry, said welder being adapted to weld the outer end of said coiler strand in said coiler car to the following end of a strand passing through said tower when said last-mentioned access gate is open and said respective strip sealing means are closed, and means for uncoiling said strand when said welder is withdrawn to cool said strand, whereby strand heating and cooling take place in continuous strip processing with intermediate coil temperature holding in an annealing operation.

5. In strip sealing apparatus, in combination, a loop heating furnace for heating strip in strand form, said furnace having an outlet for said strand, strip sealing means at said outlet, at least two closed coiler cars adapted to coil said strand therein and transport the same, each said car having a neck adapted to be moved into registry with said outlet, strip sealing means at said neck, a loop cooling tower adapted to cool a strip in strand form having an inlet for said strand, strip sealing means at said inlet, means for moving each of said cars to move the neck thereof out of registry with said outlet and into registry with said inlet, access gates adjacent said outlet and inlet adapted to bridge the space between said respective strip sealing means when they are in respective registry, welding means for said strand adapted to be introduced through said respective access gates when said respective strip sealing means are closed, a substantially closed track circuit extending between said furnace and said tower along which said cars are moved, and centrally positioned means for supplying protective gas to said cars during movement, whereby strand heating and cooling takes place in substantially continuous strip processing with intermediate coil temperature holding in an annealing operation with a continuously protective atmosphere.

6. In strip annealing apparatus, in combination, a strand heating furnace having an outlet, a gas seal adjacent said outlet, an access gate

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adjacent said seal, a coiler car having a common inlet and outlet thereto, a gas seal on said coiler car adjacent said common inlet and outlet, said coiler car movable into and out of position with said seals and said access gate in registry to provide a short direct passage for said strand into said coiler car, a mandrel within said coiler car, and means for turning said mandrel to pull said strand from said furnace and coil it within said coiler car before opening said access gate to sever said strand and move said car out of registry with said furnace outlet.

7. In strip annealing apparatus, in combination, a strand heating furnace having an outlet, a gas seal adjacent said outlet, an access gate adjacent said seal, a coiler car having a common inlet and outlet thereto, a gas seal on said coiler car adjacent said common inlet and outlet, said coiler car movable into and out of position with said seals and said access gate in registry to provide a short direct passage for said strand into said coiler car, a mandrel within said coiler car, means for turning said mandrel to pull said strand from said furnace and coil it within said coiler car before opening said access gate to sever said strand and move said car out of registry with said furnace outlet, a strand cooling enclosure having an inlet, a gas seal adjacent said inlet, an access gate adjacent said last-mentioned

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seal, a track extending between said furnace and said cooling enclosure, means for turning said coiler car to present said common inlet and outlet both to said furnace and to said cooling enclosure, said gas seal adjacent said inlet and access gate adjacent thereto providing with said seal on said coiler car a short direct passage for said strand into said cooling enclosure, and means for returning said coiler car to said furnace.

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