Nov. 13, 1962 L. WILSON 3,063,878

METHOD OF AND APPARATUS FOR ANNEALING

Filed May 7, 1958

4 Sheets-Sheet 1

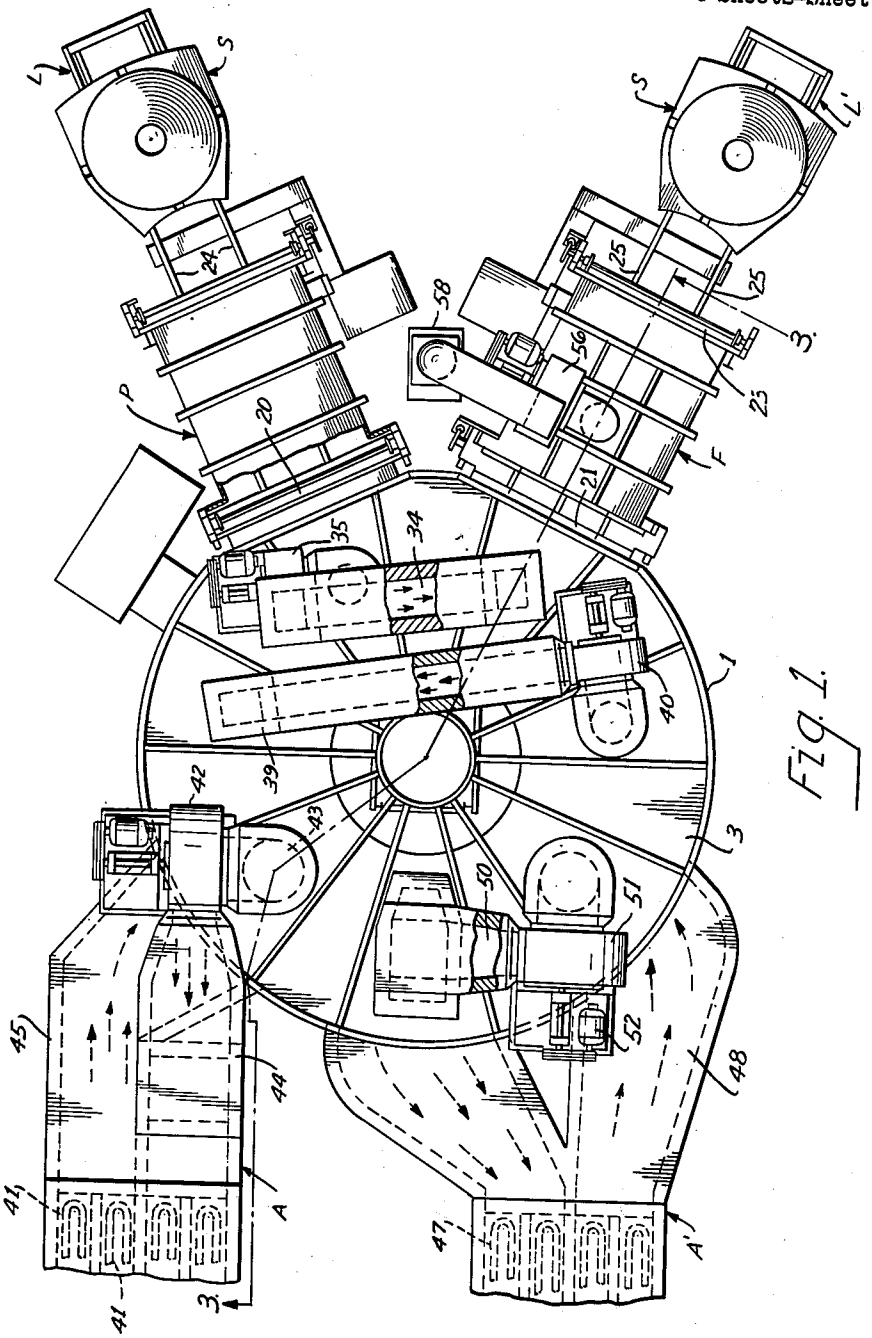


Fig. 1.

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Filed May 7, 1958 4 Sheets-Sheet 2

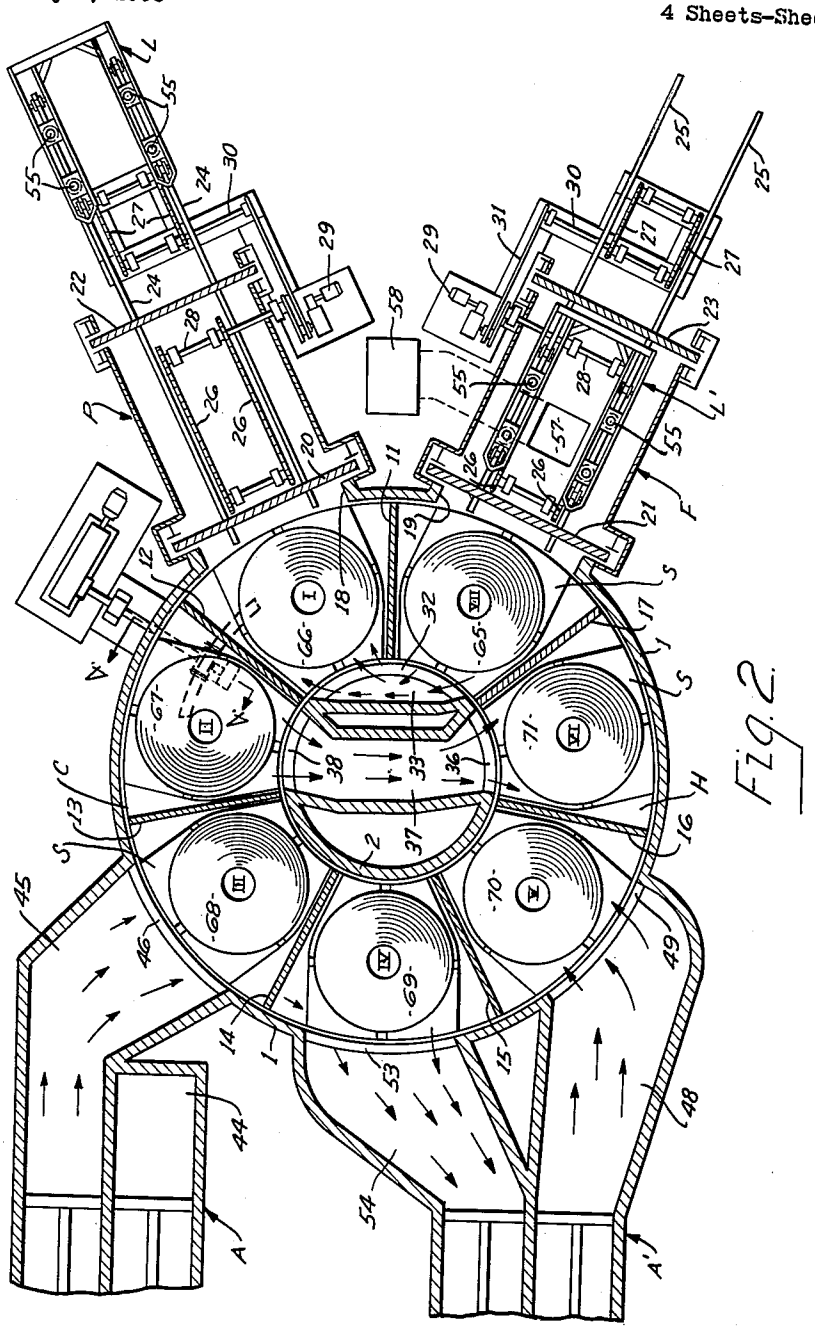


FIG. 2.

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METHOD OF AND APPARATUS FOR ANNEALING

Filed May 7, 1958 4 Sheets-Sheet 3

Fig. 4

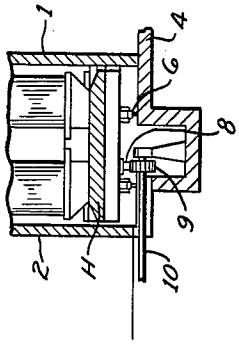
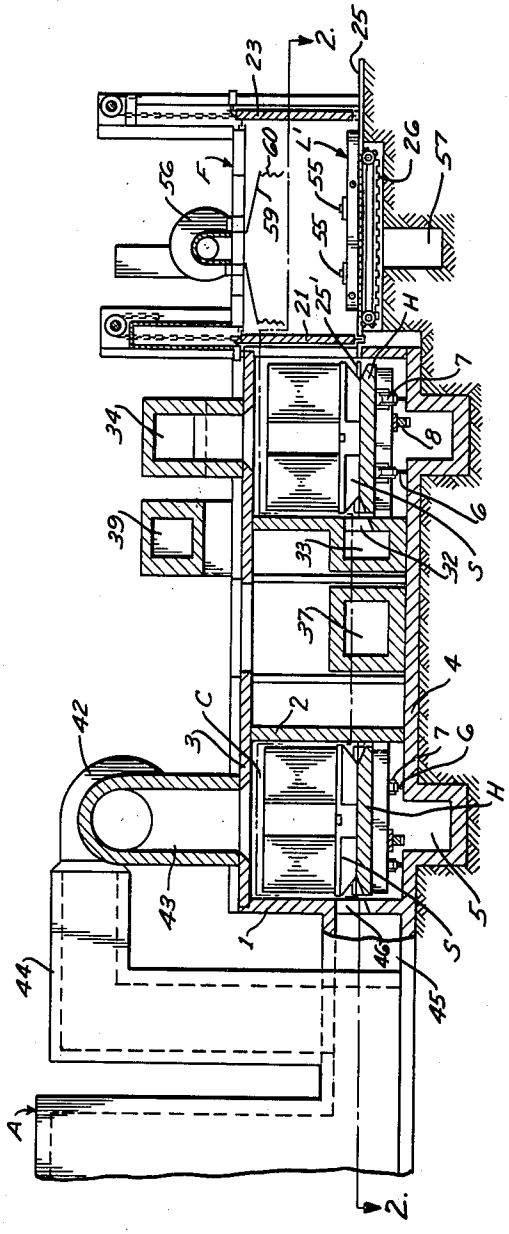


Fig. 3



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METHOD OF AND APPARATUS FOR ANNEALING

Filed May 7, 1958 4 Sheets-Sheet 4

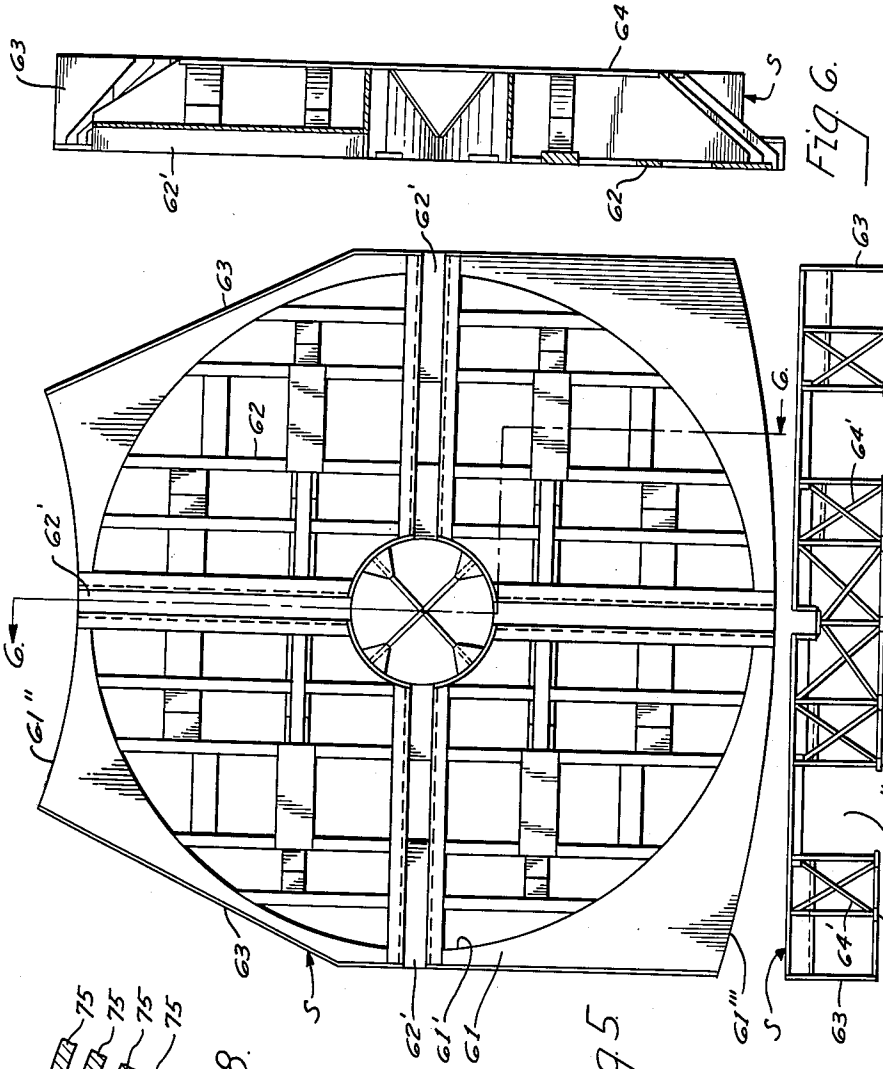


Fig. 6.

Fig. 7.

Fig. 5

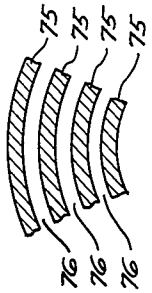


Fig. 8.

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3,063,878

METHOD OF AND APPARATUS FOR ANNEALING

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Filed May 7, 1958, Ser. No. 733,762
14 Claims. (Cl. 148—13)

This invention relates to the annealing of metals and more particularly to an improved method of and apparatus for annealing coils of metal strip. Specifically, my invention involves certain novel procedures and apparatus whereby the time required for and cost of annealing coils of strip metal is greatly reduced from prior commerical practices.

In the copending Lee Wilson and Edwin A. Corns United States patent application Serial No. 639,939, filed February 13, 1957, there is disclosed a method of and apparatus for annealing coils of strip metal, with particular reference to cold roll steel strip, wherein a tight wound coil of strip metal is "opened" into a coil having its laps or convolutions spaced apart from each other by a distance from about one-half to about three times the thickness of the strip. The thus opened coil is maintained with its axis vertical and heated by forcing a heated gaseous atmosphere at high velocity through the spaces between the laps of the opened coil. As is fully explained in said copending patent application, the opened coil annealing of strip steel by convection heating from high velocity gaseous atmosphere enables a coil to be brought up to annealing temperature in a small fraction of the time required by previous annealing systems in which the tightly wound coil was heated by the application of heat to the external ends and side walls thereof. Depending on the dimensions of the coil being handled, the surface area of an opened coil available for direct heat transfer to the strip is from about two hundred to about one thousand times the surface area available for heat transfer with a tight coil.

As is also pointed out in said copending patent application, the heating of an opened coil for annealing purposes may be effected in a bell type furnace. A single opened coil is shown as being heated within an inner cover in a bell type furnace in the said Wilson and Corns patent application, and apparatus for annealing a plurality of opened coils stacked one upon another is described and claimed in the copending patent application of Calvin C. Blackman and Robert J. Beemer Serial No. 703,905, filed December 19, 1957 and owned by the applicant herein.

Although the annealing of opened coils in a bell type furnace is a great improvement over the annealing of tight wound coils in such furnaces, the full possibilities of opened coil annealing are not achieved in bell furnace installations.

Accordingly it is an object of the present invention to provide a method of and apparatus for annealing opened coils of strip metal whereby great savings are effected in first cost of the apparatus required to produce a given output, operating costs are greatly reduced as compared to previous procedures, a better and more uniform product is obtained, control of the annealing operation is facilitated, the time required for annealing a coil of a given size and weight is greatly reduced, and the inventory of coils in process is much less than that required where tight wound coils are annealed in bell type furnaces.

Other objects of my invention include the provision of an improved traveling hearth recuperative type annealing furnace whereby a substantial portion of the heat applied to the strip to anneal same is recuperated or recovered and transferred to preheat other coils that have not been

brought up to annealing temperature; the provision of a traveling hearth annealing furnace wherein an atmosphere of inert gas may be mantained to preserve the finish of the metal strip and prevent oxidation thereof during annealing; and the provision of means for supporting the opened coils for loading into the furnace, treatment in the furnace, and withdrawal from the furnace which facilitates the desired flow of atmosphere through the opened coils during annealing and greatly simplifies the coil handling problem.

The above and other objects of my invention will appear from the following description of my recuperative traveling hearth furnace and my improved procedure for utilizing same. As illustrated in the drawings attached hereto, and described more in detail later in this specification, my novel apparatus includes a furnace having a traveling hearth and a furnace chamber through which the opened coils to be annealed pass in step-by-step fashion. The traveling hearth carries a series of spaced dividing walls which separate the furnace chamber into a plurality of charge compartments. As the hearth is advanced in successive steps, the charge compartments progressively move to and are indexed at a series of charge treating stations where the various heating and/or cooling steps are performed. Between each indexing movement of the hearth each compartment remains at its particular station for a predetermined period of time, and when the proper time has elapsed, the hearth advances one step to index each charge compartment at the next treating station. At a certain station or stations heat is applied to the coil from an external source by forcing heated atmosphere vertically through the opened laps of the coils while at another station or stations the coils that have been heated to annealing temperature and soaked for the proper time are cooled by a circulating body of gaseous atmosphere which is forced through the hot coil and then through suitable ducts to another coil in a charge compartment disposed at a preheating station in advance of the heating station so that the incoming coils are preheated by heat derived from the cooling of the coils which have been subjected to annealing temperatures. Thus a recuperative system is provided which results in a substantial reduction in fuel costs, my novel structure being such that the preheating, final heating and soaking, and cooling operations may be carried out in a unit requiring a minimum of floor space and of low first cost as compared to other coil annealing apparatus of equal output capacity.

The furnace illustrated in the drawings and specifically described herein is of the rotary hearth type in which the coils under treatment move in a circular path. It will be understood, however, that my invention may be incorporated in straight-through or linear furnaces in which the coils travel in a straight line, in so-called U-type furnaces, or other arrangements wherein the path of travel of the coils is not circular.

Referring now to the drawings:

FIGURE 1 is a plan view of a rotary type traveling hearth furnace according to my invention;

FIGURE 2 is a horizontal cross-sectional view of the furnace installation shown in FIGURE 1, taken substantially on line 2—2 of FIGURE 3;

FIGURE 3 is a vertical cross-sectional view through the furnace structure shown in FIGURE 1, taken substantially on line 3—3 of FIGURE 1;

FIGURE 4 is a fragmentary vertical cross-sectional view, taken substantially on line 4—4 of FIGURE 2 and illustrating the rotary hearth drive means;

FIGURE 5 is an enlarged detached plan view of one of the coil support units used in annealing opened coils in the furnace shown in FIGURES 1–4;

FIGURE 6 is a vertical cross-sectional view taken substantially on line 6—6 of FIGURE 5.

FIGURE 7 is an end elevation of the coil support unit of FIGURE 5 looking at the large or outer end thereof; and

FIGURE 8 is an enlarged fragmentary plan view of a part of an opened coil illustrating the spacing between the laps.

The rotary hearth furnace illustrated in the accompanying drawings and which embodies the present invention includes an annular furnace chamber C defined by an outer wall **1**, an inner wall **2**, and a top wall or cover **3**. These walls are supported on a foundation or base **4** having an annular pit **5** projecting below the bottom of the annular furnace chamber C.

Supported on circular tracks **6**, which rest on the base **4**, is the rotary hearth H. This hearth is annular in form and is supported on tracks **6** by a plurality of circumferentially spaced wheels **7**. The inner and outer edges of the hearth H extend into close proximity to the inner and outer chamber walls **1** and **2**, and suitable sealing means may be provided to maintain the desired seal between the moving edges of the hearth and the stationary walls of the furnace chamber.

A circumferential rack **8** is mounted on the underside of hearth H and, as seen in FIGURE 4, is engaged by a drive pinion **9** carried on shaft **10**. Shaft **10** may be driven by any suitable power means (not shown) such as an electrical motor, and, to effect rotation of the hearth H in the desired step-by-step manner as will be more fully referred to later, timing and control means of any suitable and well-known type may be employed.

A plurality of radially extending, circumferentially spaced, vertical dividing walls **11–17** inclusive are carried by and move with the rotary hearth H. The edges of these walls are disposed in close proximity to the outer, inner and top walls **1**, **2** and **3** of the furnace chamber C and, in effect, divide the furnace chamber C into a series of charge compartments equal in number to the number of dividing walls. As the hearth H and the dividing walls **11—17** have close fits within the annular furnace chamber, each of the charge compartments formed by the dividing walls may be maintained at different atmospheric or heating conditions from that of the adjacent charge compartments. Furthermore, as the hearth H is rotated (as shown in the drawings in counter-clockwise direction) in indexed step-by-step travel, the several charge compartments will be moved successively between a series of charge treating stations which are indicated on FIGURE 2 of the drawings by the reference characters I–VII inclusive. It will be understood that when the hearth H is advanced a step, it will move a distance such that any given dividing wall will be moved into the previous position of the next dividing wall ahead in the direction of rotation of the hearth. In other words, referring to FIGURE 2, when the hearth is advanced one step, the dividing wall **11** will move into the position of wall **12**, wall **12** will move into the position of wall **13**, etc. For reference purposes, the several charge compartments carried on the rotary hearth H will be identified by the dividing walls at their ends. Thus, as seen in FIGURE 2, the charge compartment disposed at station I is identified as charge compartment **11—12**, the charge compartment station disposed at station V is identified as compartment **15—16**, etc.

As best seen in FIGURE 2, a charge loading opening **18** is formed in the outer furnace chamber wall **1** at station I, and a charge discharge or unloading opening **19** is located at station VII. Suitable vertically movable doors **20** and **21** respectively are adapted to close and open said openings **18** and **19**. Outside of the main furnace chamber C at the charging or loading opening **18** is an atmosphere lock and purge chamber P, and an atmosphere lock and cooling chamber F is similarly disposed outside of the unloading opening **19**. These chambers P and F have gas tight connections with the exterior housing of the furnace and are provided with outer vertically movable doors **22** and **23** respectively.

Tracks **24** support a charge loading carriage L for movement into and out of the purge chamber P and the furnace chamber C, and tracks **25** similarly support unloading carriage L'. Each charge compartment on hearth H also has a pair of tracks which align with and form extensions of tracks **24** and **25** when the hearth is in its stationary indexed positions. These hearth tracks are seen at **25'** in FIGURE 2.

In order to advance and retract the carriages L and L', drive means are provided adjacent each pair of tracks **24** and **25**. Referring to FIGURES 2 and 3, the drive means for unloading carriage L' includes an inner pair of drive chains **26** and an outer pair of drive chains **27**. These chains are supported on suitable spaced sprockets and have their upper reaches extending generally at or slightly below the level of tracks **25**. They are driven by the shaft **28** which in turn is connected through suitable gearing, etc. to a drive motor **29**. Shaft **30** which drives the sprockets which support outer drive chains **27** is also driven by motor **29** through a belt or chain connection **31**.

Interengaging dog or clutch means are provided on the underside of the carriage L' and on the drive chains **26** and **27** so that when these chains are rotated in one direction the carriage will be advanced toward and into the furnace chamber and, when they are moved in the opposite direction, the carriage will be withdrawn. Two sets of drive chains **26** and **27** are provided so that the outer door **23** may be closed behind the carriage when it is in the cooling lock or chamber F and the carriage then advanced into the furnace chamber by action of the drive chains **26**. The outer set of drive chains **27** will engage the pick-up devices on the carriage L' during outer movement thereof before the carriage is released from its driving connection to the chains **26**, and thus drive chains **27** will effect movement of the carriage through the outer door **23** of the chamber F. Similar reference characters have been applied to the corresponding drive chains, etc. which are disposed at the purge lock or chamber P for moving the carriage L, the two installations substantially alike in arrangement and function.

In order to provide the desired circulation of furnace atmosphere, as will be fully explained later, the inner wall **2** of the furnace chamber C is slotted just above the top surface of the hearth H at treating stations VII and I. This slot is seen at **32** in FIGURES 2 and 3 and connects the furnace chamber with an atmosphere conduit on passage **33** which connects the lower portions of stations I and VII. Another atmosphere conducting pipe or conduit **34** extends from the top of station I to the top of station VII, and a fan or blower **35** (see FIGURE 1) in conduit **34** is adapted to effect a circulation of atmosphere through the slot **32** from the bottom of station VII, through conduit **33**, through slot **32** to the lower part of station I, up through the coil in station I, out through the top wall **3** of the furnace into conduit **34** and back into the top of station VII. The atmosphere then passes downwardly through the coil at station VII, and this circulation is continued by the blower **35** for purposes to be explained later.

In like manner a slot **36** through wall **2** at the lower part of station VI provides a gas passage into the conduit **37** which extends across the furnace and connects to another slot **38** at the lower part of station II. An atmosphere conducting pipe **39** extends over the top of the furnace from the top of station II to the top of station VI, and a fan or blower **40** (FIGURE 1) is adapted to create and maintain a circulation of atmosphere through and between the charge compartments that are disposed at stations II and VI. In this instance the blower **40** is operated so that the circulation is downwardly through the coil in the compartment which is disposed at station II, across through lower conduit **37**,

upwardly through the coil in the compartment at station VI, and back across over the top of the furnace through conduit 39 and into the top of the compartment at station II.

In order to supply heat to bring the opened coils being treated to annealing temperature, an outside heater unit A is disposed adjacent station III of the furnace chamber. This heater unit includes a suitable source of heat such as radiant combustion tubes 41, and a fan or blower 42 is adapted to withdraw atmosphere upwardly from the charge compartment at station III through a conduit 43, move this atmosphere through conduit 44 into the heater unit A where it is heated by passing over the hot combustion tubes 41 (or other source of heat such as electrical heating units or the like). After passing through the heater A, the atmosphere travels through a bottom conduit 45 and a slot 46 in the outer wall 1 of the furnace into the charge compartment indexed at station III. The circulating atmosphere which is moved through the charge compartment at station III transfers heat rapidly and most efficiently to the opened coil supported at this station.

A secondary atmosphere heater unit A' is also disposed outside of the main furnace chamber adjacent stations IV and V. This unit is also heated by radiant tubes 47 or other suitable means. A gas conducting conduit 48 extends from the lower part of the heater unit A' through a slot 49 in furnace wall 1 into station V just above the hearth H. The upper part of station V is connected to the upper part of station IV by conduit means 50 (see FIGURE 1) in which is interposed a blower 51 driven by a suitable motor 52. The lower part of station IV is connected back to the heater unit through a slot 53 in outer wall 1 of the furnace chamber and conduit 54. In operation the blower 51 is driven in a direction which will effect circulation downwardly through the coil in the charge compartment at station IV, through lower conduit 54 into the heater A', through the heater in contact with the radiant heating tubes 47, out through lower conduit 48 and slot 49 into the lower part of the charge compartment at station V, upwardly through the coil at station V and out through the top thereof to blower 51 and back down through the coil in station IV. The purpose of this application of heat, as will appear later, is to bring the coils up to final annealing temperature and maintain them thereat for the desired soaking time.

In order to permit the opened coils to be charged into and removed from the furnace and properly to support the coils in the furnace so that circulation of atmosphere will be channeled directly through the coils, and substantial flow other than through the coils be prevented, I provide coil support units that are seen at S in FIGURES 2 and 3 and are illustrated in detail in FIGURES 5, 6 and 7. Each of the support units S includes a top baffle plate 61 having a circular central opening 61' therein across which extends a perforate grid-like structure 62 whereby an opened coil may be supported thereon with a minimum interference with the flow of atmosphere through the opened laps of the coil. The forward edge of the support unit S is arcuate as seen at 61'' to conform to and be disposed in close proximity to the inner wall 2 of furnace chamber C when the unit is in one of the hearth charge chambers. The side walls 63 of the units S converge at their inner portions to conform to and closely fit the inner portions of the adjacent divider walls which define the several charge compartments on the hearth H. In order properly to support the upper face of the grids 62 in spaced relation above the top of the hearth H, a plurality of bottom members 64 are supported by a suitable reinforced truss-like structure 64'. These bottom members 64, however, are omitted in spaced parallel channels 64'' so that the units S may fit over the carriages L and L' and be supported on the hydraulic lifters 55 thereof so that they may be moved into and out of the furnace chamber.

When lifted by the lifters 55, the bottom members 64 of the supports S will clear the top of the hearth H, and when a unit S is positioned in one of the charge chambers on the hearth H, as seen in FIGURES 2 and 3, the lifters 55 may be lowered to permit the bottom members 64 to rest on the top of the hearth H and to allow the carriages L or L' to be withdrawn. The open channels 64'' also straddle or overlie the portions 25' of the tracks 24 and 25 which extend into each of the charge chambers on the hearth.

The outer edge 61''' of the baffle plate 61 is curved to conform to the curvature of the outer wall 1 of the furnace chamber C. Thus when a support S is positioned in a charge chamber on the furnace hearth, the inner edge 61'' of the top baffle plate is in close proximity to the inner wall 2 of the furnace chamber, and the outer edge is in close proximity to the outer wall 1 of the furnace chamber. The vertical side walls of the unit S are imperforate, and the coils that are disposed on the units S have outer diameters substantially equal to the diameter of the circular opening 61' in the plate 61. Thus the units S not only act to support the coils above the furnace hearth but also positively to prevent any substantial flow of atmosphere through a charge chamber except through the opened laps of the coil.

This is an important feature of my annealing system as, in order to obtain my improved heating efficiency, the flow of atmosphere must be controlled so that substantially all movement thereof is through the coils, and little or no flow occurs around the outside of the coil or down through the center thereof. Center flow is prevented by closing the central portion of the coil supporting grid surface 62 or by putting a plate over the top of the central opening in the coils before they are charged into the furnace.

A plurality of slots or channels 62' extend radially of the top face of the units S to facilitate the insertion and removal of coil lifting bars below a coil supported on a unit S. Although it is preferred that all coils being handled have an outside diameter substantially equal to the diameter of the circular opening 61' in the baffle plate 61, if a coil is smaller than this circular opening, bypassing of atmosphere may be prevented by wrapping a wire cable around on top of the grid or by other gap closure means.

In FIGURE 1 a coil support unit S is shown supported on the carriage L' on the hydraulic lifters 55 thereof. These lifters are adapted to raise the unit S and the coil support thereon above the floor level so that unit S and its coil may be moved along the tracks 25. In like manner another unit S is shown supported on the carriage L outside of the purge chamber P and is adapted to be lifted and moved by the carriage L into the purge chamber P.

Before a coil to be annealed is charged into the furnace chamber, it is moved into the purge chamber P, the outer door 22 thereof being opened. While in the purge chamber P, and with both the inner and outer doors 20 and 22 closed, a suitable gaseous atmosphere, for instance an inert or somewhat de-oxidizing gas, is caused to enter the chamber P and pass through the open laps of the coil and then to be exhausted from the chamber until all air has been purged from the chamber and the coil. The coil and chamber P are now completely filled with the desired inert or other gaseous atmospher and, when the gate 20 is opened to permit the coil to be charged into the furnace, there will be no escape or dilution of the gaseous atmosphere in the furnace proper.

When a coil is completely annealed, it is disposed at the last station VII. As it is supported on its coil support unit S, the carriage L' may be run under the units S when the door 21 is opened, the hydraulic lifters 55, or other suitable elevating means, operated to lift the unit S and coil from the furnace hearth, and the coil and support unit then withdrawn into the cooling lock chamber F. At

this time the outer door 23 is closed and chamber F is preferably filled with the protective atmosphere so that the atmosphere in furnace chamber C will not be diluted by outside air while door 21 is open. The door 21 is then closed, and the coil 1, which in the example given later, is in the neighborhood of 450° F., may be subjected to forced cooling by operation of a blower 56 mounted on top of the chamber F and adapted to circulate the atmosphere in chamber F through a bottom conduit 57 (FIGURE 3), the coil, and then down through an atmosphere cooling unit 58 and back into chamber F. As seen in FIGURE 3, a hood 59 and flexible sleeve or curtain 60 are adapted to fit over the top of the coil being cooled to channel the circulating cooling atmosphere through the opened laps of the coil. When the desired cooling action has been completed, the door 23 may be opened and the carriage L' moved out together with the coil support S and the annealed and cooled coil supported thereon. The lock arrangement provided by the double doors 21 and 23 prevents the entry of outside air into the furnace chamber C while a coil is being discharged from station VII.

An example of the annealing of opened coils in the illustrated apparatus will now be given, it being understood that the times and temperatures mentioned may be varied to suit the size and type of coils being handled.

An enlarged fragmentary plan view of a portion of an opened coil is illustrated in FIGURE 8. It will be observed that each of the laps or convolutions 75 are spaced apart by gaps or passages 76. As illustrated, these passages are approximately equal in width to the gauge of the metal of the laps 75 but this spacing may be varied, preferably within a range from about one-third to about three times the strip gauge.

It may be assumed that the furnace hearth is in the position illustrated in FIGURE 2 and that one of the timed operating steps of the complete cycle has just been completed. At this point in the cycle, the opened coil in charge compartment 17—11, which is now located at station VII, is ready to be withdrawn from the furnace. Accordingly, the door 21 is opened, the carriage L' is advanced until it is disposed below the coil support unit S on which the coil at station VII is held, the hydraulic lifters 55 on carriage L' are raised to lift the coil support unit S and coil from the hearth H, carriage L' is withdrawn into the coling chamber F, the outer door 23 being closed, and the inner door 21 is then closed.

The charge compartment 17—11 is now empty and opened coils are disposed respectively in charge compartments 11—12, 12—13, 13—14, 14—15, 15—16, and 16—17. Immediately after the annealed coil has been removed from compartment 17—11, the hearth H is advanced or indexted one step whereupon the now empty compartment 17—11 moves to station I, compartment 11—12 with coil 66 therein moves to station II, etc. As soon as this movement of the hearth has been completed, the charging door 20 is opened and carriage L, together with a coil support S and a new coil thereon, is moved into the empty charge compartment. This coil, of course, has ben purged of all air in purge chamber P as previously explained and, when it is disposed in position at station I and carriage L withdrawn, the charging door 20 is closed.

An opened coil is now disposed in the charge compartment at each of stations I–VII inclusive. The coil 66 at station I is substantially at room temperature, and it will be subjected to recuperative heating by transfer of heat from the coil 65 which has just been moved into station VII. In a typical operation this 65 has been reduced to a temperature of approximately 900° F. By circulating furnace atmosphere downwardly through the 900° coil 65 at station VII, through conduit 33, up through coil 66 at station I, and then through blower 35, conduit 34 and again down through coil 65, the temperatures of the two coils may be substantially equalized, i.e., the temperature of coil 66 at station I may be brought up to about 450° F. and the coil 65 at station VII may be brought down to about 450° F.

In the typical operation being described the time of dwell of the hearth H at each treatment station is set at about one hour in order to produce, for example, about twenty tons of uniformly annealed product per hour. However this time may be varied to suit the type and size of coils being annealed, or for other reasons.

While coil 66 at station I is being preheated, the coil 67 at station II (which has previously been given a first preheat at station I) is being given an additional preheating by circulating furnace atmosphere up through coil 71 at station VI, across over the top of the furnace through the conduit 39, down through coil 67 at station II and back across the furnace through lower conduit 37. Coil 71 enters station VI from station V at approximately annealing temperature, for example 1320° F., and during the one hour treatment period its temperature will be reduced to approximately 900° F. while the temperature of the coil 67 at station II will be raised from about 450° F. to approximately 900° F. Thus at stations I and II each coil is raised in temperature from room temperature to approximately 900° F. by heat recuperated from coils which are being cooled to the temperature they are removed from the main furnace chamber.

During the same time period that the above preheating operations have been taking place, the coil 68 has been disposed in compartment 13—14 at station III. This coil enters station III from station II at approximately 900° F. and, by circulating heated gas from the heater A at high velocity vertically through the opened coil 68, its temperature may be raised during said time period approximately to annealing temperature, for example about 1300° F.

As the coil at station III may be heated to a slightly higher temperature at the bottom than at the top because the hot gas from heater A enters the coil at the bottom, the temperature is equalized at station IV where the further coil is heated by atmosphere from another gas heater A' moving in the opposite direction downwardly through the coil (69) at station IV. As the temperature of the coil is approximately 1300° F. when it enters station IV, its temperature is equalized and brought to the desired annealing temperature, for example 1320° F., in a few minutes. The circulation of heated atmosphere at stations IV and V is a series flow through the coils at these two stations, and the output of the heater A' and the rate of flow of atmosphere through blower 51 is so regulated that the coils are maintained at annealing temperature for practically the entire two time periods during which they remain at these stations. Thus each coil is soaked for a total of about two hours at the proper temperature (1320° F. in this example) at the stations IV and V.

As previously explained, when a coil enters station VI, it is at annealing temperature, but while it remains at station VI, heat is withdrawn and transferred to preheat the coil at station II so that a coil 71 at station VI is brought down from about 1320° F. to about 900° F. As also previously explained, the coil 65 at station VII arrived at this point from station VI at about 900° F. and, during its one hour time period at station VII, it is reduced in temperature to about 450° F. while the new coil which has been charged into station I is preheated up to about 450° F.

Upon completion of the seven one hour treating periods described above, the room temperature coil which entered station I has progressed through all seven stations and has been completely annealed and cooled down to about 450° F. in a total elapsed time of between seven and eight hours, some time being required, of course, to effect the hearth movements between the one hour periods and to unload a coil from station VII, advance the empty compartment to station I, and load a new coil therein between each one hour period.

It has been pointed out above that the flow of atmos-

phere through the coil at station VII is downwardly and that through the coil at station I the circulation is upwardly. As has also been pointed out, the circulation at station II is downwardly, at station III upwardly, at station IV downwardly, and at stations V and VI upwardly. Because of this reversal of flow of atmosphere through the coils at successive treating stations, the heating and cooling action of the gas vertically of the coils is substantially equalized. Thus at station I the heated atmosphere passes upwardly through the coil and, as it is at its highest temperature at the bottom of the coil, the temperature of the lower part of the coil at station I at the end of the treatment period at said station may be slightly greater than at the top of the coil. However, when the coil moves to station II, the flow of preheating atmosphere is downwardly through the coil and the atmosphere from station VI is at its highest temperature at the top portion of the coil. Thus differences in temperature between the top and bottom of the coil are minimized. In like manner the reversal of flow at the succeeding stations equalizes the temperature vertically of the coil during heating and soaking periods.

Although I have illustrated and described a rotary hearth furnace having seven charge treating stations, the number of stations may be varied depending upon the type of treatment to be given to the charge. Thus, in some cases, only one pair of cooling and preheating stations may be employed, or soaking may be effected in a single station rather than in two as illustrated herein.

It will also be understood that in addition to a great reduction in the time required for annealing a given quantity of material, the building space required for an equivalent tonnage output is much less with my improved apparatus and procedure than with previously used bell type coil annealing furnace installations. Furthermore fuel costs are substantially reduced by my system because of the recuperative heating of the incoming coils by the coils being cooled, a minimum of labor is required because the coils are handled a minimum number of times and for extremely short distances, the inner covers and coil spacers or convectors commonly employed in tight coil annealing in bell type furnaces are completely eliminated together with their relatively high cost and maintenance problems, and a better annealed product is obtained because of the very uniform heating that can be accomplished throughout the coil. Sticking of the coils at the edges is completely eliminated because the laps are spaced apart during the entire coil heating and cooling operation. Furthermore, because of the small number of coils in process at any given time, as compared to the number of coils in process to produce the same output by prior procedures, my system greatly reduces the number of coils in inventory, thus increasing the working capital available for other purposes.

Although I have described the illustrated embodiments of my improved annealing apparatus and have explained a particular procedure which may be practiced therein, it will be understood that variations and modifications may be made both in my apparatus and method without departing from the spirit of my invention. I do not, therefore, wish to be limited to the exact embodiments herein illustrated and described but claim as my invention all forms thereof coming within the scope of the appended claims.

I claim:

1. A rotary hearth annealing furnace for annealing opened coils of strip metal having spaced apart laps including stationary walls defining a generally annular continuous furnace chamber, a rotary hearth disposed at the lower part of said furnace chamber, a plurality of radially extending dividing walls carried by said rotary hearth and movable therewith, said dividing walls extending in close proximity to said furnace walls whereby said furnace chamber is divided into a plurality of charge compartments, means for supporting an opened coil of strip metal in each of said charge compartments above said hearth and with its axis vertical, means for rotating said rotary hearth and charge compartments in step-by-step movement and indexing said compartments at a series of charge treating stations in said furnace chamber, said furnace walls having charging and discharging openings at the first and last of said stations respectively, door means for closing said openings, means for loading a charge into the charge compartment disposed at said first of said stations, means for withdrawing a charge from the charge compartment disposed at said last of said charge treating stations, means for maintaining an artificial gaseous atmosphere within said furnace chamber, means for circulating between a pair of charge compartments indexed at a particular pair of said work treating stations the atmosphere contained therein whereby heat exchange is effetced between the charges in said pair of charge compartments, gas heating means disposed outside of said furnace chamber, and means for repeatedly circulating a body of said artificial gaseous atmosphere vertically through another of said charge compartments disposed at another of said charge treating stations and said gas heating means whereby the charge in said last named charge compartment is heated, each of said means for supporting an opened coil of strip metal including a baffle plate disposed to direct substantially all of the atmosphere being circulated through the charge compartments vertically through the spaced apart laps of opened coils disposed on said supporting means.

2. An annealing furnace for annealing opened coils of strip metal having spaced apart laps including a traveling hearth having a plurality of charge support means spaced thereon and a plurality of dividing walls supported thereby and defining the ends of a series of charge compartments in each of which is one of said charge support means, stationary walls defining a continuous furnace chamber overlying said hearth and having a series of charge treating stations, means for traveling said hearth through said furnace chamber in step-by-step intermittent movement whereby each of said charge compartments is moved to and from each of said series of charge treating stations, said series of stations including a first charge loading station, a last charge discharge station and intermediate stations therebetween, atmosphere heating means disposed outside of said furnace chamber, means for circulating atmosphere in a closed path through said heater and vertically through the charge compartment at one of said intermediate stations whereby the charge in said charge compartment will be heated, and means for circulating atmosphere vertically through a pair of charge compartments disposed respectively at stations preceding and following, in the direction of hearth travel, said one of said intermediate stations whereby heat from the charge in the compartment at said following station will be transferred to the charge in the compartment at said preceding station, each of said charge support means including a baffle plate disposed to direct substantially all of the atmosphere being circulated through the charge compartments vertically through the spaced apart laps of opened coils on said charge support means.

3. A rotary hearth annealing furnace including stationary walls defining a generally annular furnace chamber, a rotary hearth disposed at the lower part of said furnace chamber, seven substantially equally circumferentially spaced radially extending dividing walls carried by said rotary hearth and movable therewith, said dividing walls extending in close fitting proximity to said furnace walls whereby said furnace chamber is divided into seven substantially identical, circumferentially disposed charge compartments, means for rotating said rotary hearth and charge compartments in step-by-step movement and indexing said compartments successively at seven equally spaced charge treating stations, a charge opening in the furnace wall at the first charge treating station, means for loading a charge into the charge compartment disposed at

said first station, a charge discharge opening in said furnace wall at charge station seven, counting from said first station in the direction of rotation of said hearth, means for withdrawing a charge from the charge compartment disposed at said station seven, atmosphere conducting means adapted to connect the lower portion of the charge compartment at the first station with the lower portion of the charge compartment at station seven, atmosphere conducting means adapted to connect the upper portion of the charge compartment at the first station with the charge compartment at station seven, fan means for creating a circulation of atmosphere through the charge compartments disposed at said first station and station seven and the charges supported therein, atmosphere conducting means between the lower portion of station two and the lower portion of station six, atmosphere conducting means between the upper portion of the station two and the upper portion of station six, means for creating a circulation of atmosphere through the charge compartments at said stations two and six and the charges therein, means outside of said furnace chamber for heating a portion of the furnace atmosphere, atmosphere conducting means between the lower part of station three and said atmosphere heating means and between said atmosphere heating means and the upper part of station three, means for creating and maintaining circulation of atmosphere through said atmosphere heating means and through the charge compartment disposed at station three whereby the charge therein is heated while at station three, a second atmosphere heating means disposed outside of said furnace chamber, atmosphere conducting means between the lower portions of stations four and five and said second atmosphere heating means and between said second atmosphere heating means and the upper portions of stations four and five, and means for circulating atmosphere between said second atmosphere heating means and the charge compartments disposed at stations four and five whereby the charges disposed therein may be supplied with heat.

4. A rotary hearth annealing furnace including stationary walls defining a generally annular furnace chamber, a rotary hearth disposed at the lower part of said furnace chamber, seven substantially equally circumferentially spaced radially extending dividing walls carried by said rotary hearth and movable therewith, said dividing walls extending in close fitting proximity to said furnace walls whereby said furnace chamber is divided into seven substantially identical, circumferentially disposed charge compartments, means for rotating said rotary hearth and charge compartments in step-by-step movement and indexing said compartments successively at seven equally spaced charge treating stations, a charge opening in the furnace wall at the first charge treating station, means for loading a charge into the charge compartment disposed at said first station, a charge discharge opening in said furnace wall at charge station seven, counting from said first station in the direction of rotation of said hearth, means for withdrawing a charge from the charge compartment disposed at said station seven, atmosphere conducting means adapted to connect the lower portion of the charge compartment at the first station with the lower portion of the charge compartment at station seven, atmosphere conducting means adapted to connect the upper portion of the charge compartment at the first station with the charge compartment at station seven, fan means for creating a circulation of atmosphere through the charge compartments disposed at said first station and station seven and the charges supported therein, atmosphere conducting means between the lower portion of station two and the lower portion of station six, atmosphere conducting means between the upper portion of the station two and the upper portion of station six, means for creating a circulation of atmosphere through the charge compartments at said stations two and six and the charges therein, said last named atmosphere circulating means causing the atmosphere circulation in station two to be in a direction opposite to that in the first station and the circulation in station six to be opposite that in station seven, means ouside of said furnace chamber for heating a portion of the furnace atmosphere, atmosphere conducting means between the lower part of station three and said atmosphere heating means and between said atmosphere heating means and the upper part of station three, means for creating and maintaining circulation of atmosphere through said atmosphere heating means and through the charge compartment disposed at station three whereby the charge therein is heated while at station three, a second atmosphere heating means disposed outside of said furnace chamber, atmosphere conducting means between the lower portions of stations four and five and said second atmosphere heating means and between said second atmosphere heating means and the upper portions of stations four and five, and means for circulating atmosphere between said second atmosphere heating means and the charge compartments disposed at stations four and five whereby the charges disposed therein may be supplied with heat, the direction of flow of heated atmosphere from said second atmosphere heating means through the charge compartments at stations four and five being opposite to the flow of heated atmosphere through the charge compartment disposed at station three.

5. The method of annealing opened coils of strip metal which includes the steps of moving a series of opened coils with their axes vertical through a series of treating stations in a furnace, removing annealed coils at one of said stations and adding new coils at another station, heating said coils by forcing heated atmosphere vertically through the opened laps of the coils at a station spaced intermediate said stations where coils are removed and added, circulating atmosphere vertically through a pair of coils, one of which has been heated to annealing temperature and is ready for cooling and the other of which has not yet been heated to annealing temperature, whereby said one coil is cooled and said other coil is preheated, alternating the direction of vertical flow of atmosphere through the laps of the coils at succeeding stations of said series whereby the temperature of said coils is equalized, and moving said coils in step-by-step manner whereby each coil of the series is successively preheated, heated to annealing temperature, and cooled by circulation of atmosphere vertically through the opened laps of the coils.

6. A coil support unit for supporting an opened coil of strip metal in a rotary hearth furnace during annealing including a baffle plate portion having a circular opening therein, a perforate grid structure extending across said circular opening and adapted to support an opened coil thereon, side walls depending from said baffle plate member and defining opposite sides of said unit, and bottom support members spaced from the coil engaging surface of said grid structure and lying substantially in the plane of the lower edges of said side walls, said bottom support members being spaced to provide open channels extending generally in the same direction as said side walls and adapted to receive means for elevating and conveying said coil support unit and a coil thereon, the inner end of said baffle plate member being concavely contoured substantially on the radius of the inner wall of the furnace with which the unit is to be used and the outer end of said baffle plate being convexly contoured substantially on the radius of the outer wall of said furnace.

7. In a rotary hearth furnace for annealing opened coils of strip metal having spaced apart laps, stationary walls defining a generally annular continuous furnace chamber, a rotary hearth carrying walls, dividing said furnace chamber into a plurality of movable charge compartments, means for moving said hearth and charge compartments between a series of charge treating stations, said furnace walls having charging and discharging openings therein, baffle members in said charge compartments and having perforate coil supporting and engaging areas and

imperforate baffle areas spaced above said rotary hearth, means for circulating a body of atmosphere vertically through and horizontally between the charge compartments disposed at a spaced apart pair of said stations, atmosphere heating means disposed outside of said furnace chamber, and means for circulating a separate body of atmosphere in a continuous flow through said atmosphere heating means and vertically through a charge compartment disposed at a station intermediate said pair of stations, said imperforate baffle areas of said baffle plate members being disposed to direct substantially all of said circulating atmosphere through said perforate coil engaging and supporting areas whereby said circulating bodies of atmosphere will be forced through the spaced apart laps of opened coils supported on said perforate coil supporting areas.

8. In a movable hearth furnace for annealing opened coils of strip metal having spaced apart laps, stationary walls defining a continuous furnace chamber, a movable hearth having walls extending into and dividing said furnace chamber into a series of movable charge compartments, means for moving said hearth and charge compartments in step-by-step travel between a series of charge treating stations in said furnace chamber, said furnace walls having charging and discharging openings at the first and last of said stations respectively, door means for closing said openings, baffle plate members in said charge compartments and having perforate coil supporting and engaging areas and imperforate baffle areas spaced above said movable hearth, atmosphere conducting means between said first station and another of said stations that is spaced from said first station by one or more intermediate stations, fan means for circulating atmosphere between said first and said other of said stations, atmosphere conducting means between the station next ahead of said first station and the station next behind said other station, fan means for circulating atmosphere through and between said last two named stations in a direction opposite to the direction of circulating between said first and said other stations, atmosphere heating means outside of said furnace chamber, and means for circulating a separate body of atmosphere in a continuous flow through said atmosphere heating means and vertically through a charge compartment disposed at one of said intermediate stations, said imperforate baffle areas of said baffle plate members being disposed to direct substantially all of said circulating atmosphere through said perforate coil engaging and supporting areas whereby said circulating bodies of atmosphere will be forced through the spaced apart laps of opened coils supported on said coil supporting areas.

9. In a rotary hearth furnace for annealing opened coils of strip metal, stationary walls defining a generally annular continuous furnace chamber, a rotary hearth at the bottom of said furnace chamber, radially extending dividing walls carried by said rotary hearth and separating said furnace chamber into a plurality of circumferentially arranged similar charge compartments, means for rotating said rotary hearth and dividing walls in intermittent step-by-step movement whereby said compartments each progressively move to a series of work stations, a charging door in said furnace wall at a first or charging station, a discharging door in said furnace wall at the last or discharging station, said last station being circumferentially spaced from said first station in the direction of rotation of said hearth by one or more intermediate stations, opened coil support units having circular perforate coil engaging areas, means for supporting said coil support units for radial movement toward and away from said hearth and into and out of said charge compartments through said charging and discharging doors when said compartments are indexed respectively at said charging and discharging stations, said coil support units when in said charge compartments being disposed with their circular perforate coil engaging areas spaced above said rotary hearth whereby atmosphere may be moved vertically through opened coils carried on said areas, said coil support units including baffle portions disposed to substantially block the vertical flow of atmosphere in said charge compartments except through said circular perforate coil engaging areas, means for conducting atmosphere between the lower part of one of said stations and the lower part of another of said stations that is spaced from one station by at least one intermediate station, means for conducting atmosphere between the upper part of said one station and the upper part of said other station, fan means for causing the atmosphere in said one and said other of said stations to circulate therethrough and pass vertically through opened coils in the charge compartments disposed at said stations, means for moving heated atmosphere vertically through a charge compartment and opened coil supported therein when indexed at a heating station between said one and said other of said stations whereby the opened coil may be heated, and means disposed outside of said stationary walls for supplying heat to the atmosphere being circulated at said heating station.

10. A rotary hearth annealing furnace for annealing opened coils of strip metal having spaced apart laps including stationary walls defining a generally annular continuous furnace chamber, a rotary hearth disposed at the lower part of said furnace chamber, a plurality of radially extending dividing walls carried by said rotary hearth and movable therewith, said dividing walls extending in close proximity to said furnace walls whereby said furnace chamber is divided into a plurality of charge compartments, means for supporting an opened coil of strip metal in each of said charge compartments above said hearth and with its axis vertical, means for rotating said rotary hearth and charge compartments in step-by-step movement and indexing said compartments at a series of charge treating stations in said furnace chamber, means for loading a charge into the charge compartment disposed at one of said stations, means for withdrawing a charge from the charge compartment disposed at another of said charge treating stations, means for maintaining an artificial gaseous atmosphere within said furnace chamber, means for circulating between a pair of charge compartments indexed at a particular pair of said work treating stations the atmosphere contained therein whereby heat exchange is effected between the charges in said pair of charge compartments, gas heating means disposed outside of said furnace chamber, means for repeatedly circulating a body of said artificial gaseous atmosphere vertically through another of said charge compartments disposed at another of said charge treating stations and said gas heating means whereby the charge in said last named charge compartment is heated, each of said means for supporting an opened coil of strip metal including a baffle plate disposed to direct substantially all of the atmosphere being circulated through the charge compartments vertically through the spaced apart laps of opened coils disposed on said supporting means, a second gas heating means disposed outside of said furnace chamber, and means for circulating a second body of artificial gaseous atmosphere through said second heating means and vertically through another of said charge compartments indexed at still another of said charge treating stations.

11. A rotary hearth furnace as defined in claim 10 in which said means for loading a charge into the furnace includes a charge loading opening in said furnace wall at said one of said charge treating stations, door means for closing said loading opening, a purge chamber connected to said furnace chamber at said charge loading opening, said purge chamber having an outer door adapted to be opened to permit the entry of a charge into said chamber and to be closed thereafter, and means for directing an artificial gas atmosphere into said purge chamber and the charge therein and permitting air to be urged therefrom.

12. A rotary hearth furnace as defined in claim 10 hav-

ing a charge discharge opening in said furnace wall at said another of said charge treating stations, door means for closing said discharge opening, a final cooling chamber connected to said furnace at said discharge opening and adapted to receive a charge withdrawn from the furnace, said cooling chamber having an outer door adapted to be opened to permit removal of the charge and closed during the cooling operation, and means for forcing a cooling atmosphere through the charge in said cooling chamber.

13. A rotary hearth furnace as defined in claim 11 having a charge discharge opening in said furnace wall at said another of said charge treating stations, door means for closing said discharge opening, a final cooling chamber connected to said furnace at said discharge opening and adapted to receive a charge withdrawn from the furnace, said cooling chamber having an outer door adapted to be opened to permit removal of the charge and closed during the cooling operation, and means for forcing a cooling atmosphere through the charge in said cooling chamber.

14. In a rotary hearth annealing furnace for annealing opened coils of strip metal, stationary walls defining a generally annular continuous furnace chamber, a rotary hearth disposed at the lower part of said furnace chamber and forming the bottom wall thereof, a plurality of radially extending dividing walls carried by said rotary hearth and movable therewith, said dividing walls extending in close proximity to said furnace walls whereby said furnace chamber is divided into a plurality of charge compartments, means for rotating said rotary hearth and charge compartments in step-by-step movement and indexing said compartments at a series of charge treating stations, a charge loading opening in said furnace wall at one of said charge treating stations, a charge loading carriage supported for movement into and out of the charge compartment indexed at said charge loading opening, a coil support unit adapted to be carried by said charge loading carriage and to support an opened coil thereon, said charge loading carriage including means for lifting said coil support unit and the coil thereon above the level of said rotary hearth and lowering said unit and coil into position on said rotary hearth after said carriage is moved into said charge compartment whereby said charge loading carriage may be freely withdrawn from the charge compartment, said coil support unit including a baffle portion, the baffle portion having a circular opening, and a perforate coil engaging area extending across said circular opening, said coil support unit fitting within the walls of the furnace charge compartment, having an atmosphere opening aligned with an atmosphere opening in the furnace wall, and being adapted to channel substantially all of the atmosphere that passes into the charge compartment through the opened coil supported on the perforate coil engaging area.

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