This invention relates to the annealing of steel. It is especially directed to apparatus for facilitating the box annealing of stock, coiled, flat-rolled steel products.

In the production of cold reduced, flat-rolled steel products in relatively thin gauge, steel ingots are initially hot rolled into slabs 4"-7" thick. These slabs are further reduced in thickness by additional hot rolling to produce a flat rolled product having a thickness of about \( \frac{1}{2}\)"-\( \frac{1}{8}\)". Depending upon consumer requirements, the hot rolled strip is further reduced in thickness by cold reduction to produce a steel sheet having a smooth dense surface. Cold reduced, flat rolled products have application as the base metal in the production of tin plate, galvanized sheetings, electrical steels, or as a material of construction in the fabricating of a variety of sheet metal products.

In the cold working of the flat-rolled product structural changes occur and it is necessary to process anneal the cold worked material at elevated temperatures to cause recrystallization of the cold worked structure and to soften the steel. Although continuous annealing processes are available, a large proportion of cold rolled strip product is heat treated in a so-called box annealing process wherein the cold rolled sheet steel are stacked in a heating furnace of a suitable design which has facilities for providing a controlled atmosphere for protecting the steel coil from oxidation during heating and cooling, and covered by a light inner cover.

The annealing cycle, which is carried out in the presence of a circulating controlled atmosphere gas such as nitrogen, or various prepared gases containing nitrogen, and marketed under trademarks such as DX, NX, HNX, etc., or other compositions, consists of a heating phase, a soaking phase, and a cooling phase. During the annealing phase the cold rolled steel coils are heated to a temperature within the range of 1100°-1300° F. and held at this temperature. The heating phase is about 24-48 hours and the soaking phase usually takes a total of about 4-24 hours. Thereafter the charge of cold rolled steel in the heating furnace with a continued circulation of the atmosphere gases. The cooling phase takes about 60-80 hours. Considerable time is required to insure the production of sheet steel having the desired softness and ductility with most of the time being consumed in the heating and cooling cycles.

In accordance with this invention there is provided an inner cover for use in box annealing which can be utilized to facilitate the box annealing process and decrease the heating and cooling time of the annealing cycle without deleteriously affecting the quality of the annealed flat rolled product.

Referring to the drawings, FIGURE 1 shows a cross sectional view of a radiant tube-fired bell type furnace employed in heat treating coils of flat-rolled products in which is illustrated the use of the inner cover of this invention for enclosing the coils and in which a controlled atmosphere gas is circulated.

FIGURE 2 is a side elevation view of an illustrative inner cover employing the features of this invention.

FIGURE 3 is a top view of the inner cover shown in FIGURE 2 with a portion of the end wall cut away.

FIGURE 4 is a fragmentary view of an upper corner of the inner cover shown in FIGURE 1 illustrating an illustrative means for reinforcing the outer casing wall of the inner cover and facilitating its handling.

FIGURE 5 is a fragmentary view of a bottom corner of the inner cover shown in FIGURE 2 illustrating the flared open end and adjacent reinforcing means.

FIGURE 6 is a plan view of an illustrative diffuser and separator plate utilized for separating the stacked coils.

FIGURE 7 is a cross sectional view of the diffuser plate shown in FIGURE 6 taken along line 7-7.

FIGURE 8 is a fragmentary view of a portion of the diffuser plate.

In the course of a box annealing operation the effect of the heat treating is influenced not only by the time of heating and the temperature level maintained, but also by the atmosphere surrounding the material. In the annealing of coils of flat rolled metal products in bell type furnaces inner covers are employed to enclose the coil product and permit the circulation of a controlled atmosphere gas within the confined area. In using inner covers, bell type furnaces having a removable shell are employed to cover the hearth of the furnace. The furnace is charged by stacking rows of flat-rolled steel products on the furnace hearth. An inner cover is placed over the stack of coils and sealed with a finely divided refractory material such as sand at the bottom. Then the furnace shell or portable heating unit is lowered over the assembly. Provisions are made for supplying a constant stream of a gas for control of atmosphere into the interior of the inner cover for circulation around the coils. To aid in the distribution of the gas within the inner cover, separators are placed between the coils.

Control atmosphere gas is first introduced into the inner cover to purify the interior. This gas also circulates during the heating, soaking, and cooling phases of the cycle.

In FIGURE 1 there is illustrated a typical bell type furnace 10. This furnace consists of a permanent base or stand 11 which is provided with a peripheral channel 12 and faced with a suitable refractory 13. Refractory 13 is provided with an annular groove 14 in which inner cover 15 is placed. Heating cover 16, suitably lined with refractory materials 17, is indirectly fired by means of radiant tubes 18 resting on suitable brackets 19 mounted on the wall of heating cover 16. A suitable gas-air combustion mixture is supplied to conventional burner means, not shown, for supplying the heat needed for the annealing cycle. Base 20, located in the base of the furnace, is employed for circulating the gas for controlling the atmosphere within the inner cover in connection with the baffled, diffuser element 21 and diffuser plate 22 resting on the face of the base refractory 13. The gas is introduced into the system by suitable inlet and outlet means, not shown. A plurality of flat rolled product coils 25 are stacked on diffuser plate 22 with separators 26 being placed between each coil to aid in the distribution of the controlled atmosphere gas inside the inner cover. Inner cover 15 is placed over the stack of coils with tubular, hollow inner core 27 positioned within the central openings of the coils with the open end of inner cover 15 resting within annular groove 14. Inner cover 15 is sealed to the base 11 by means of a powdered refractory 28 piled about the lower end of inner cover 15. It will also be noted that the open end of heating cover 16 rests within peripheral channel 12 which is packed with a suitable refractory 29 to effect the sealing of the heating cover 16 with stand 11. Heating cover 16 is suitably braced and also provided with lifting lug 30 which permits the heating cover to be removed by a suitable hoisting device and set aside while the furnace is being charged with the coiled products.

As heretofore mentioned, the box annealing cycle requires a considerable amount of time. Because it is
necessary for the heated coils to soak at the selected annealing temperature for a time sufficient to effect the desired modification or improvement in the softness or ductility of the product, the annealing cycle cannot be modified by reducing the time required for this phase. By employing the instant invention, however, it is possible to cut down on the time of the annealing cycle by as much as 25% or more, depending upon the size of the coils and furnace, by reducing the time required for the heating and cooling phases of the annealing cycle. This is provided by employing an inner cover such as illustrated in FIGURE 2 which employs an open ended axial tubular hollow inner core depending within the central areas of the stacked coils. The inner core, when positioned, improves the circulation of the gas within the inner cover and decreases the time required for the stacked coils to be heated throughout to the desired soaking temperature as well as decreases the time required for the coils to cool to a temperature which would permit handling after the soaking phase of the annealing cycle. In FIGURE 2 is illustrated a specific embodiment of an inner cover of the instant invention. Inner cover 15 comprises an open ended outer tubular casing 35. One end of tubular casing 35 is enclosed by means of end wall 36 which is suitably mounted thereon by means of welding or other conventional fastening expedients. To the other end of tubular casing 35 is fitted flared skirt 37 which in use rests within annular grooves 14 provided in base 11 of furnace 10. To facilitate the handling of inner cover 15 suitable reinforcing is provided. In the illustrative inner cover a pair of top and bottom rings 38 and 39 fabricated from rectangular cross sectional bar stock circumscribe casing 35 adjacent either end thereof and are welded in place. End wall 36 is braced by means of gird support 40 which consists of a plurality of bars 41 radially mounted on the inside of end wall 36. Axially depending from end wall 36 is open ended hollow tubular core 42. One end of inner tubular core 42 is enclosed by means of that portion of end wall 36 cooperating therewith. The free end of tubular core 42, however, is open. The tubular core 42, which is preferably cylindrical, depends within casing 35 preferably for a distance such that a restricted gas passage is formed for the extent of the aligned central openings of the stacked coils. To improve the effect of the inner tubular core 42 gas ports 43 and 44 are provided at the end of tubular member 42 affixed to end wall 36. These ports permit the flow of gases within tubular core 42 and preclude the formation of a "dead air" space at the closed end of tubular member 42 which might have a deleterious effect on the heating efficiency of the inner cover of this invention.

In use the inner cover of this invention is placed over the stacked coils to provide an outer and an inner cooperating annular gas channel formed, respectively, (1) between the inner wall of the outer casing and the outer surface of the stacked coils and (2) the outer wall of tubular core 42 and the inner surface of the central openings of the stacked coils. The ratio of the cross sectional dimensions of the respective annular gas channels is selected such that the free flow area in the center openings of the coil stack is greatly reduced by means of the inner tubular core. Accordingly, when a controlled atmosphere gas is circulated within the inner cover a low pressure high velocity area is created in the annular gas channel formed in the central opening. This pressure differential will draw the circulating gas for control of atmosphere through the spacer plates provided between the stacked coils to effect a more rapid heating and cooling of the cooled material, depending upon the temperature within the furnace.

To facilitate the placement of the inner cover it is preferred that the inner tubular member have a diameter with relation to the diameter of the central opening of the coil stack such that there is as much lateral clearance between the outer surface of the coil and the outer casing as there is between the inner core surface of the coil and the wall of the inner tubular member. Using this design the inner cover can be readily positioned without any interference between the inner tubular core and the stack coils by using the outer casing as a guide in placing the inner cover in position.

As an illustration preferred ratios of the cross-sectional areas of the outer and inner gas channels, for a coil of flat-rolled metal product having an outer diameter of 73" with a central opening of 24" the dimensions of the outer cover and inner tubular member are selected such that the ratio of the annular gas channels should be within the range of 2.4:1 to 2.5:1. A suitable inner cover for coils of this size is provided if a lateral spacing of 4" is provided between the casing and core elements of the cover and the coil surfaces adjacent thereto. It is apparent, however, that depending upon the particular designs employed as well as coil sizes, core sizes and other factors, the radial and illustrative lateral spacing can vary and other suitable ratios, as well as spacings, can be used in order to effect the objectives of this invention.

In the illustrative embodiment shown in FIGURE 2, cover plate was designed for use in the box annealing of coiled hot rolled products in which the coils had a maximum diameter of 73" with the central opening of 24". The outer casing was fabricated from a low carbon, rimmed steel having the following analysis. Carbon .......................... 0.07% max. Manganese .......................... 0.32-0.42%. Phosphorus .......................... 0.015% max. Sulphur .......................... 0.30% max.

One half inch thick steel plate was employed in fabricating the outer casing as well as the end wall. The outer casing was 1471/4" long and was circular in cross section having a 69" O.D. The inner tubular hollow core, which had an outer diameter of 12", was fabricated from 1/2" thick enameling iron and depended from the end wall to about 1" from the flared open end of the outer casing. A pair of diametrically opposed gas inlets were provided on the inner tubular member at the end adjacent the end wall. These gas inlet ports were semicircular holes having a 1/2" radius. Suitable reinforcing in the form of 1 1/2" x 4" steel rings was used adjacent the closed and open ends of the outer casing. In assembling the various components by welding in which was taken to insure that gas-tight seams were provided.

In use the inner cover is positioned over the stacked coils and heat supplied to the furnace by a suitable heating system. During heating, heat is radiated from the furnace heating tubes toward the inner cover. Concurrently heat accumulates at the top of the furnace and inner cover. A portion of this heat would be conducted down the core of the inner cover of this invention and as the outer casing and inner tubular core become hot, heat is radiated simultaneously toward both the outer and inner layers of the coiled flat rolled products.

With the tubular core disposed within the central opening, the proper flow of convective currents, which are the principal means for transferring heat from the inner cover to the coils, is effected. The prepared control atmosphere circulates inside the inner cover in a path which forms the outer side of the coiled stack and down the central opening of the stack with the use of the hot atmosphere being distributed through separate openings between each coil. By employing the inner cover design of this invention the pressure and velocity differential of the circulating gas system is increased. The pressure differential is important because it causes the circulating atmosphere to pass through the separate plates heating or cooling the inner layers of the coils, depending upon the phase of the annealing cycle. Increasing the velocity of the hot gas passing any portion of the coiled surfaces
also aids in transferring heat to the coil because with the increased velocity any insulating surface film is removed more efficiently. In cooling the coils the system is very much the same with the flow of heat being in the opposite direction.

In FIGURES 6-8 is shown a typical separator plate 50 which consists of an annular ring 51 having a plurality of involute vanes 52 equally spaced on the outer diameter and inner diameter of annular ring 51. To facilitate the handling of the separator plate in lifting ring 53 of suitable dimensions is positioned within the opening of annular ring 51 and welded thereto. The opening in the lifting ring has about the same area as the transverse cross sectional area of the core opening of a coiled product with which it is used.

In fabricating the inner cover of this invention it is preferred that heat resisting alloys be utilized and that plate thicknesses be sufficient to minimize damage to the inner cover upon handling. Accordingly, the outer casing and inner core should be fabricated from materials preferably having a thickness of 1/2 to 3/4. In order to avoid heat distortion of the inner tubular member an enameling grade steel can be used because these steels can be employed at the annealing temperatures without distortion. Although it is preferred that the outer casing and inner core have substantially circular cross sections, it is apparent that other tubular configurations can be employed. In addition it is not necessary that the component elements of the heating cover be fabricated from flat plate, and other types of surfaces, such as corrugated, can be used.

It is apparent that the instant invention has application in a variety of annealing processes wherein the steel or other material to be annealed is in coiled form and arranged in stacks within a suitable bell-type box annealing furnace. In employing the instant invention to improve the circulation of controlled atmosphere gases within the inner cover by modifying the velocity and pressure differentials within the inner cover, variations in the specifically described inner cover can be made without departing from the scope of the invention. It is therefore intended that the subject invention, which has other equivalents and modifications, be defined by the claims appended hereto.

1. an inner cover for box annealing a stack of flat rolled metal product coils having a central opening, the coils in said stack being separated by separator plates placed between said coils, which comprises an open-ended outer tubular casing, having a solid outer wall, a solid end wall enclosing one end of said casing, an open-ended inner tubular hollow core depending from said end wall and substantially coaxial with said outer casing, said inner core being provided with inlet ports adjacent the terminal end thereof attached to said end wall and with the sidewall portion of said core below the terminal end being free from openings, said cover adapted to cover said coils with said core penetrating said central opening with said outer casing cooperating with the outer surface of said coil to form a first gas passage for the upward flow of a controlled atmosphere gas, and said inner core cooperating with the inner surface of the central opening of said coil to form a second gas passage for the downward flow of a controlled atmosphere gas, first and second passages being interconnected by means of a header space at the top of said inner cover, the ratio of the cross-sectional area of said first passage to the cross-sectional area of the second passage being sufficiently high to provide a low pressure, high velocity area in said second passage with respect to said first passage.

4. an inner cover in accordance with claim 3 in which said inner core has a substantially circular cross sectional area.

5. an inner cover for box annealing a stack of flat rolled metal product coils having a central opening, the coils in said stack being separated by separator plates placed between said coils, which comprises an open-ended outer tubular casing, having a solid outer wall, a solid end wall enclosing one end of said casing, an open-ended inner tubular hollow core having a substantially coaxial with said outer casing, said inner core being provided with inlet ports adjacent the terminal end thereof attached to said end wall and with the sidewall portion of said core below the terminal end being free from openings, said cover adapted to cover said coils with said core penetrating said central opening with said outer casing cooperating with the outer surface of said coil to form a first gas passage for the upward flow of a controlled atmosphere gas, and said inner core cooperating with the inner surface of the central opening of said coil to form a second gas passage for the downward flow of a controlled atmosphere gas, first and second passages being interconnected by means of a header space at the top of said inner cover, the ratio of the cross-sectional area of said first
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passage to the cross-sectional area of the second passage being sufficiently high to provide a low pressure, high velocity area in said second passage with respect to said first passage, said second passage having at least the same lateral width as said first passage.

6. In combination, a bell type box annealing furnace having a hearth and removable heating cover, a stack of a plurality of flat-rolled metal product coils positioned on said hearth and having a central opening coextensive with said stack, separator plates disposed between each coil layer, and an inner cover resting on said hearth and enclosing said stack which comprises an open-ended, outer tubular casing, having a solid outer wall, a solid end wall enclosing one end of said casing, an open-ended inner tubular hollow core depending from said end wall and substantially coaxial with said outer casing, said inner core penetrating said central opening and substantially traversing said stack and being provided with inlet ports adjacent the terminal end thereof attached to said end wall and with the sidewall portion of said core below the terminal end being free from openings, said outer casing cooperating with the outer surface of said coil to form a first gas passage for the upward flow of a controlled atmosphere gas, and said inner core cooperating with the inner surface of the central opening of said coil to form a second gas passage for the downward flow of a controlled atmosphere gas, first and second passages being interconnected by means of said spacer plates and a header space at the top of said inner cover, the ratio of the cross-sectional area of said first passage to the cross-sectional area of the second passage being sufficiently high to provide a low pressure, high velocity area in said second passage with respect to said first passage.

7. In combination, a bell type box annealing furnace having a hearth and removable heating cover, a stack of a plurality of flat-rolled metal product coils positioned on said hearth and having a central opening coextensive with said stack, separator plates disposed between each coil layer, and an inner cover resting on said hearth and enclosing said stack which comprises an open-ended, outer tubular casing, having a solid outer wall, a solid end wall enclosing one end of said casing, an open-ended inner tubular hollow core having a substantially circular cross section depending from said end wall and substantially coaxial with said outer casing, said inner core penetrating said central opening and substantially traversing said stack and being provided with inlet ports adjacent the terminal end thereof attached to said end wall and with the sidewall portion of said core below the terminal end being free from openings, said outer casing cooperating with the outer surface of said coil to form a first gas passage for the upward flow of a controlled atmosphere gas, and said inner core cooperating with the inner surface of the central opening of said coil to form a second gas passage for the downward flow of a controlled atmosphere gas, first and second passages being interconnected by means of said spaced plates and a header space at the top of said inner cover, the ratio of the cross-sectional area of said first passage to the cross-sectional area of the second passage being sufficiently high to provide a low pressure, high velocity area in said second passage with respect to said first passage, said second passage having at least the same lateral width as said first passage.

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