

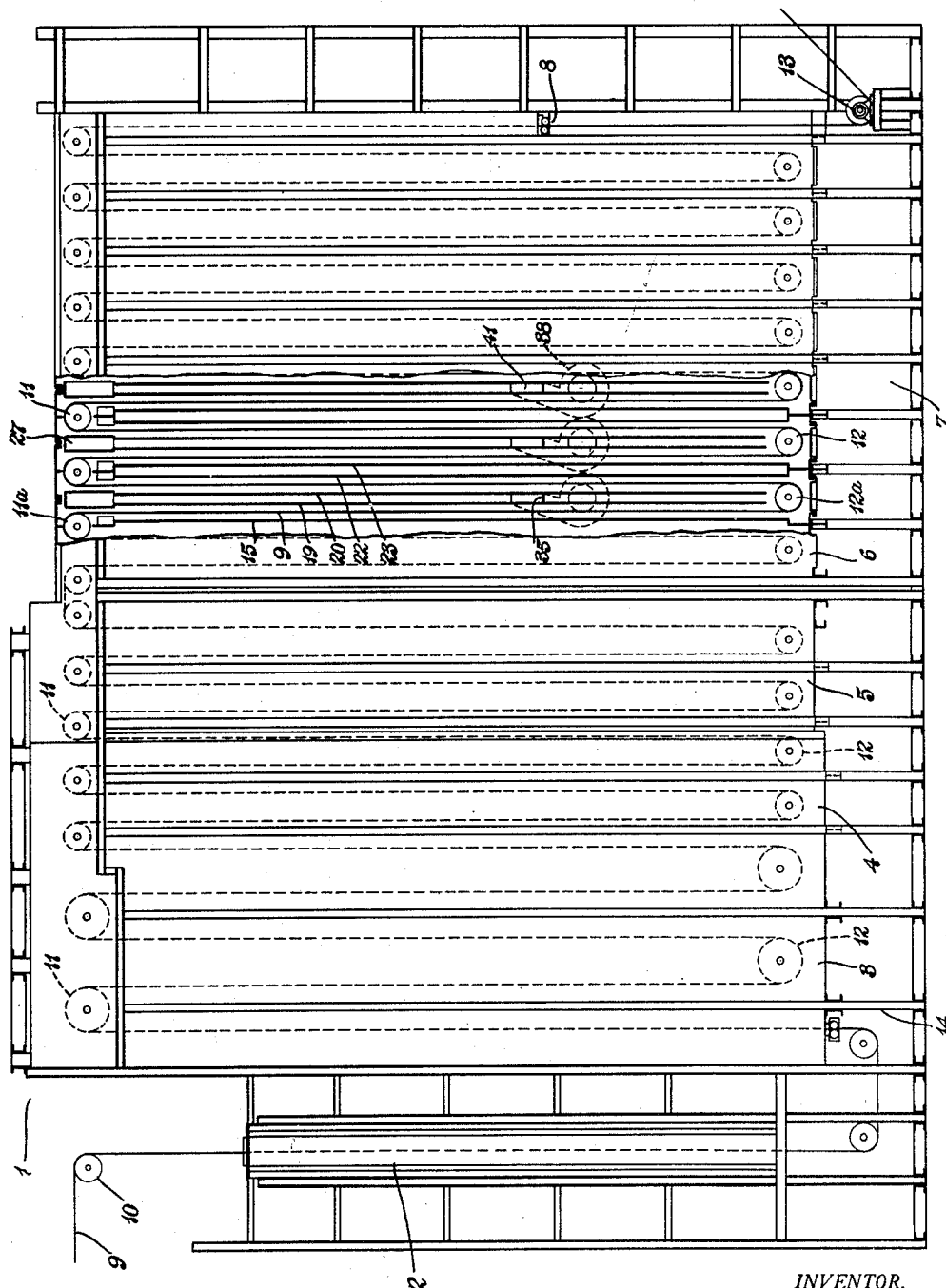
Nov. 2, 1954

A. H. VAUGHAN
FORCED CIRCULATION COOLING APPARATUS
FOR CONTINUOUS STRIP FURNACES

2,693,353

Filed June 6, 1951

5 Sheets-Sheet 1



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5 Sheets-Sheet 2

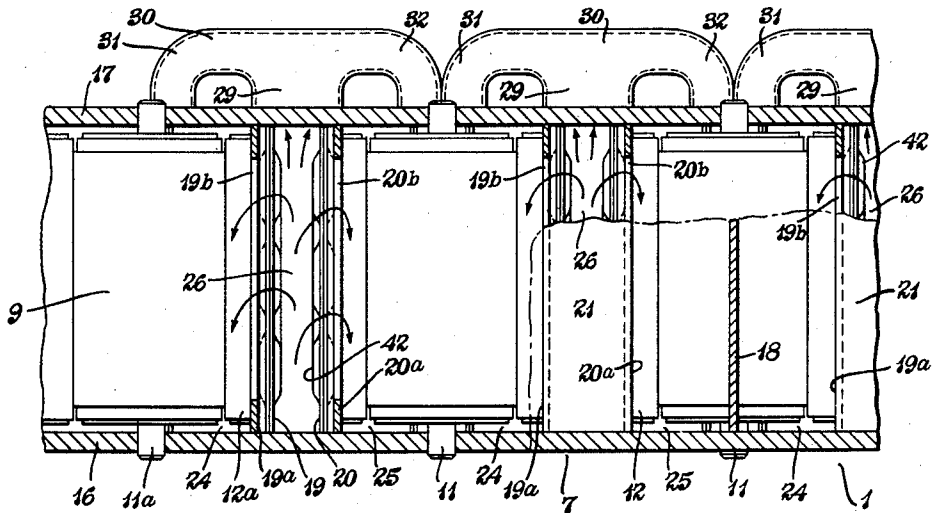


Fig. 3

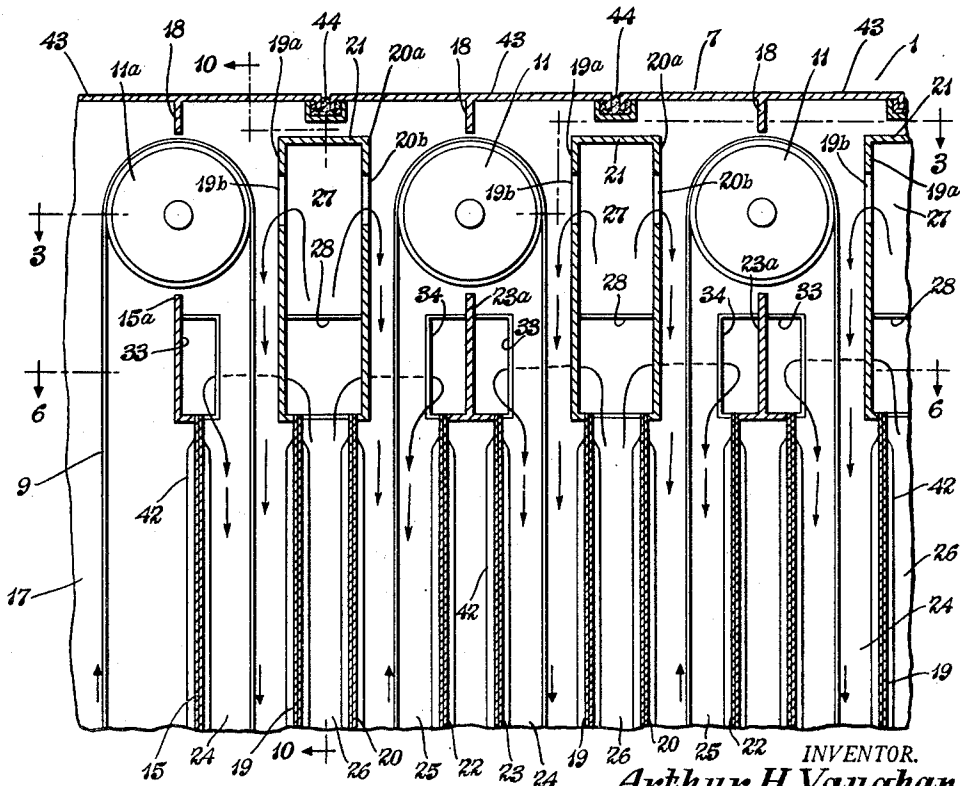


Fig. 2

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5 Sheets-Sheet 3

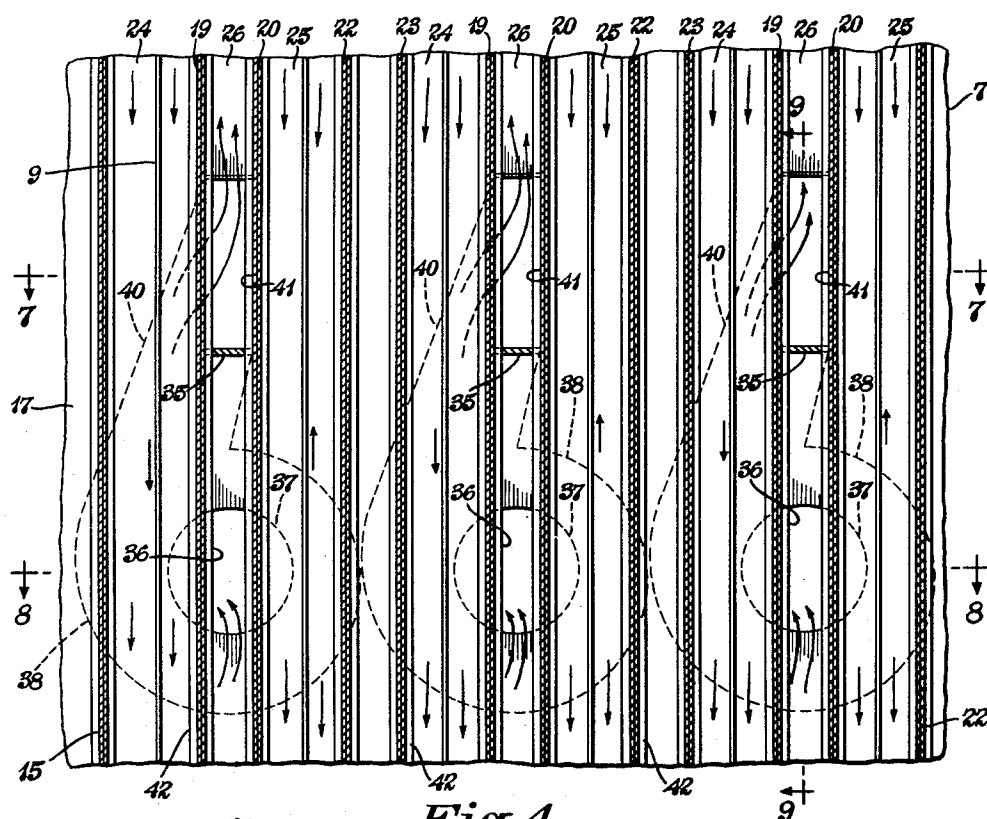


Fig. 4

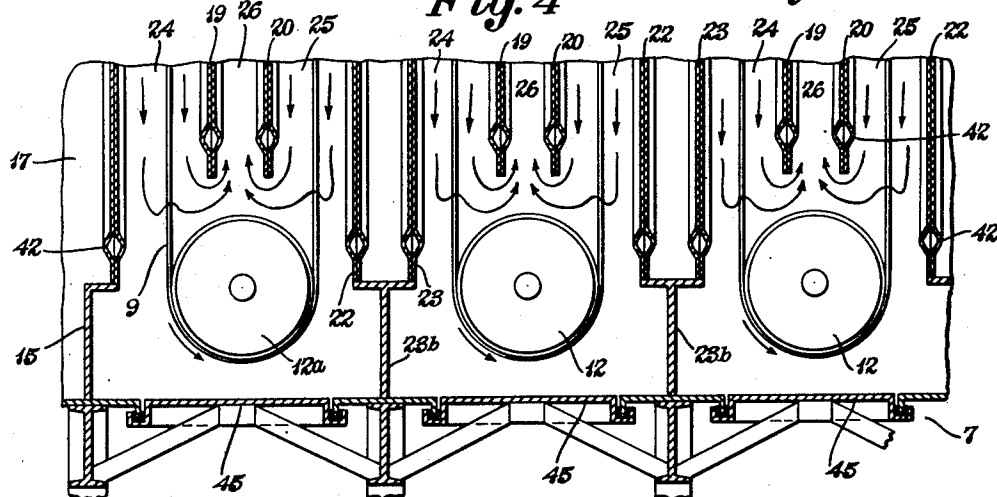


Fig. 5

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5 Sheets-Sheet 4

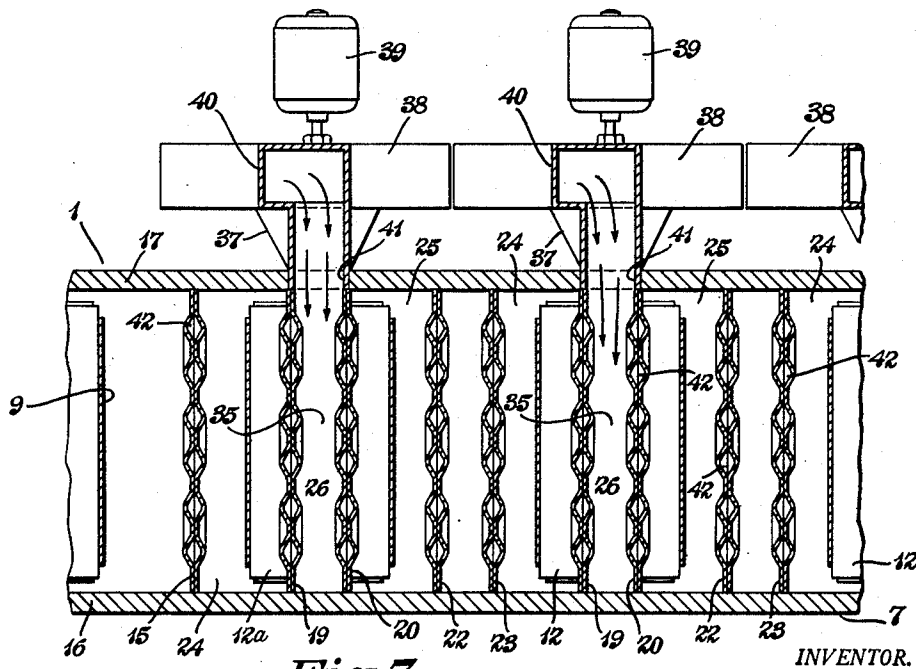
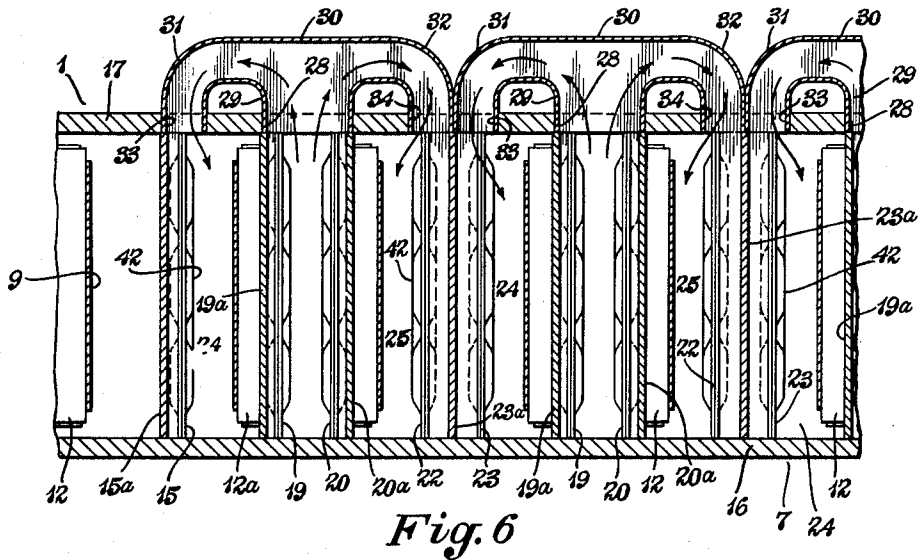


Fig. 7

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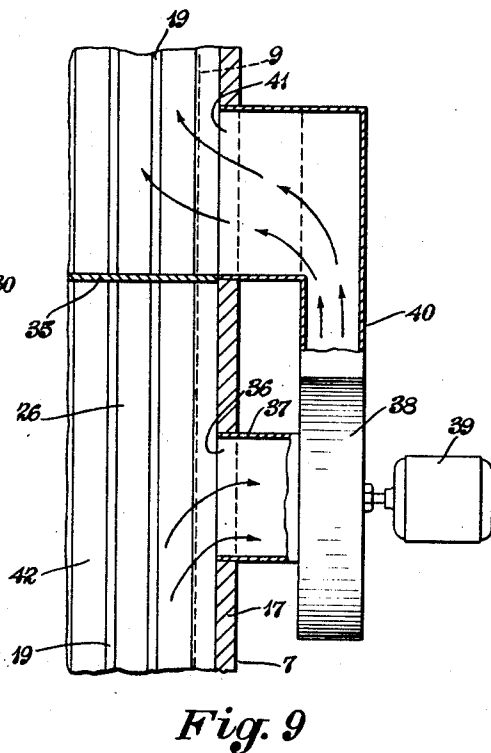
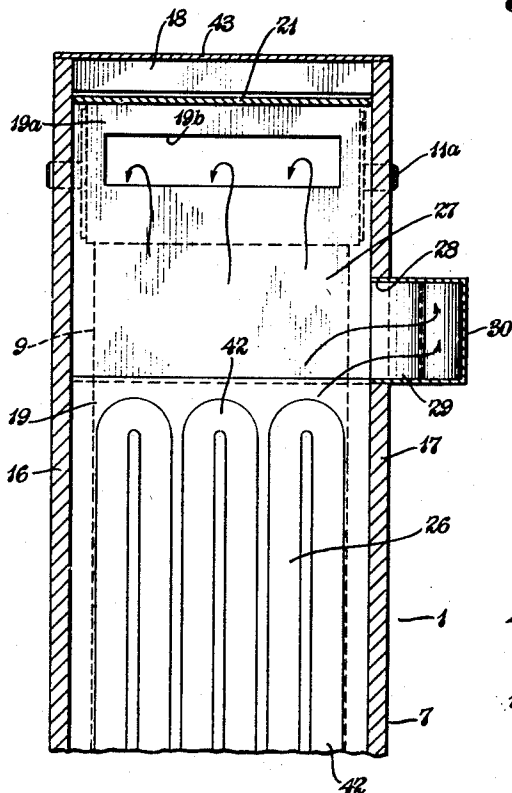
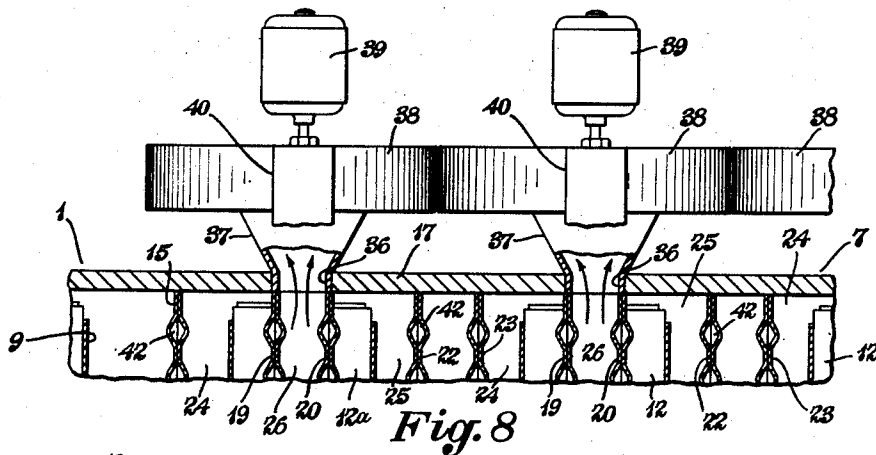
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FORCED CIRCULATION COOLING APPARATUS FOR CONTINUOUS STRIP FURNACES

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Application June 6, 1951, Serial No. 230,237

5 Claims. (Cl. 266—3)

The invention relates generally to a continuous strip bright annealing furnace and more particularly to forced circulation cooling apparatus associated with such a furnace to enable a continuous strip passing at high speed through the furnace to be cooled rapidly to a temperature at which it may be safely exposed to the atmosphere without injury to the strip surfaces in completing the annealing operation.

Present day manufacture of strip steel involves high speed rolling and related operations and it is desirable that necessary annealing operations incident to the production of finished strip likewise be carried out at high speed.

For instance, in the production of tinplate it is desired to provide for the continuous bright annealing of the strip, which may be 0.010" thick and 30" or more wide, at speeds as high as 1000 F. P. M. This means that approximately 30 tons of strip will pass through the furnace every hour.

In performing a desired bright annealing operation at high speed on such material, it is necessary to continuously heat, soak and first slowly cool the material in a controlled atmosphere for suitable periods of time to obtain the desired metallurgical results. Then the material may be rapidly cooled from, say, about 900° F. to a temperature at which oxidation will not result on exposure of the strip to the atmosphere, say about 200° F. However, it is very difficult to rapidly cool a continuously moving strip through such a temperature range when travelling at speeds of the order of 1000 F. P. M. In other words, it is much more difficult to cool a rapidly continuously moving strip at a high cooling rate than it is to heat the strip at a high heating rate. This is particularly so when the temperature of the strip approaches room temperature, because of the relatively low temperature differentials involved between the strip temperature and the temperature of the cooling medium.

Furthermore, space requirements present a problem since under the conditions outlined nearly 1700 feet of strip will be in the heating and cooling chambers of the furnace at any one time, and obviously it would be economically impractical to provide annealing and cooling equipment nearly one-third of a mile long to handle the material in a continuous one direction pass.

Accordingly, it is necessary, from a practical standpoint, to provide for the passage of the continuous strip material to and fro or back and forth in loops between conveyor rolls in the heating and cooling chambers of the equipment in order to reduce the size of the equipment and to conserve space. The back and forth strip travel may be accomplished by threading the strip either vertically or horizontally through the heating and cooling chambers of the equipment. This arrangement is very desirable from certain standpoints, but difficulties are created thereby in connection with rapidly cooling the strip from, say, 900° F. to 200° F.

Cooling of the rapidly moving strip may be accelerated by using forced circulation of a cooling medium. Theoretically, most efficient cooling can be performed by providing for counterflow of the cooling medium with respect to the direction of strip travel. However, it is not practical to provide equipment arranged for complete counterflow of cooling medium throughout the entire length of strip travel in the cooling chamber of an annealing furnace because of unbalanced pressures at the entrance and exit ends of the cooling chamber regardless of the path of strip travel therethrough.

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Further problems are present in cooling or extracting heat from the cooling medium used in such a forced circulation system. This cooling medium, in the case of a continuous bright annealing furnace and in order to avoid oxidation of the strip during cooling, ordinarily must be the same controlled atmosphere that is utilized in the furnace heating chambers to avoid oxidation during heating. Likewise, there is the further problem of avoiding unbalanced pressures in the forced circulation system so as to, on the one hand, avoid loss of the controlled atmosphere, and on the other hand, avoid ingress of air to the cooling chambers. Finally, from an economy standpoint, it is desirable to use water as a means of cooling the cooling medium in the forced circulation system.

I have discovered a solution to these complex and interrelated problems which involves for each to and fro strip pass, the provision in apparatus for rapidly cooling a continuously moving strip passed to and fro over a series of conveyor rolls in a controlled atmosphere chamber, of a duct through which the strip passes in one direction, of a second duct spaced from the first duct through which the strip passes in the opposite direction, and of an intermediate duct preferably between the first and second ducts. I further provide circulating fan means for discharging controlled atmosphere cooling medium from one end of the intermediate duct and for drawing it into the other end of said duct. I further provide passages leading from the discharge end of said intermediate duct to one end of each of the first and second ducts on both sides of the strip conveyed therethrough; and also passages communicating between the intake end of the intermediate duct and the other ends of the first and second ducts on both sides of the strip passing therethrough. Finally, I construct the walls of said ducts preferably as cold plate walls by forming the same either of plate coil material, or as double thickness walls. In each instance water may be circulated through such walls so that the cooling medium in passing along the walls at high velocity is thereby rapidly cooled, and in turn rapidly cools the strip in the first and second ducts.

Accordingly, it is a primary object of the present invention to provide forced circulation cooling apparatus for a continuous strip bright annealing furnace in which a strip moving at high speed may be rapidly cooled, particularly during the latter stages of cooling, to a temperature approximating room temperature.

Furthermore, it is an object of the present invention to provide forced circulation cooling apparatus for a continuous strip bright annealing furnace in which strip moving at high speed may be rapidly and efficiently cooled while passing to and fro over a series of conveyor rolls in a controlled atmosphere chamber.

Likewise, it is an object of the present invention to provide improved forced circulation cooling apparatus for a continuous strip bright annealing furnace in which the strip may be passed through the heating and cooling stages of the annealing operation at speeds as high as 1000 feet per minute in a small sized unit.

Also, it is an object of the present invention to provide forced circulation cooling apparatus for a continuous strip bright annealing furnace in which the continuously moving strip passes to and fro over a series of conveyor rolls and in which the cooling medium is circulated at high velocity in a direction contra to the direction of strip travel in about half of the strip passes.

Moreover, it is an object of the present invention to provide forced circulation cooling apparatus for a continuous strip bright annealing furnace in which cooling medium travelling at high velocity along the strip surfaces is cooled substantially throughout its path of travel at the same time that it in turn is cooling the strip.

Furthermore, it is an object of the present invention to provide improved forced circulation cooling apparatus for a continuous strip bright annealing furnace which eliminates the necessity of conveying the cooling medium out of and reintroducing it into the cooling chamber for cooling the cooling medium.

Likewise, it is an object of the present invention to provide improved forced circulation cooling apparatus

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for a continuous strip bright annealing furnace in which pressure differential problems in the cooling medium circulation system are avoided.

Furthermore, it is an object of the present invention to provide forced circulation cooling apparatus for a continuous strip bright annealing furnace in which water cooled cooling surfaces are located in close proximity to the strip and the cooling medium is passed at high velocity simultaneously in contact with both the strip and the cooling surfaces thereby reducing the over-all size of the apparatus to a minimum and obtaining high cooling efficiency.

Finally, it is an object of the present invention to provide new apparatus for rapidly and efficiently cooling continuous moving strip preferably as a component part of a continuous strip bright annealing furnace which is simple and effective in operation, which overcomes the foregoing difficulties, which solves long standing problems in the art, and which obtains many new results and advantages herein set forth.

These and other objects and advantages apparent to those skilled in the art from the following description and claims may be obtained, the stated results achieved, and the described difficulties overcome, by the discoveries, principles, apparatus, parts, combinations, sub-combinations, elements and methods which comprise the present invention, the nature of which is set forth in the following general statement, a preferred embodiment of which—illustrative of the best mode in which the applicant has contemplated applying the principles—is set forth in the following description, and which are particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

The nature of the improvements in forced circulation continuous strip cooling apparatus of the present invention may be stated in general terms as preferably including a cooling chamber, means for continuously moving strip material to and fro over a series of conveyor rolls in said chamber, said chamber being provided with a controlled atmosphere, duct means through which the strip is passed in one direction, second duct means spaced from the first duct through which the strip is passed in the opposite direction, an intermediate duct between the first and second duct means, circulating fan means for discharging controlled atmosphere cooling medium from one end of the intermediate duct and for drawing it into the other end of said intermediate duct, passage means communicating between said one end of said intermediate duct and one end of each of the first and second duct means on both sides of the strip passing therethrough, passage means communicating between the other end of the intermediate duct and the other end of each of the first and second duct means on both sides of the strip passing therethrough, and cooling surface means on either side of the strip associated with said first and second duct means.

By way of example, a preferred embodiment of improved forced circulation strip cooling apparatus is illustrated in the accompanying drawings forming a part hereof, wherein:

Fig. 1 is a diagrammatic side elevation of a preferred arrangement of improved cooling apparatus with certain parts broken away and in section;

Fig. 2 is an enlarged fragmentary somewhat diagrammatic sectional view of the top ends of said certain of the cooling ducts illustrated in Fig. 1;

Fig. 3 is a section looking in the direction of arrows 3—3, Fig. 2;

Fig. 4 is a view similar to Fig. 2 of an intermediate portion of the ducts, illustrating the connections between the ducts and circulating fans;

Fig. 5 is a view similar to Figs. 2 and 4 showing the bottom ends of certain of the ducts;

Fig. 6 is a view similar to Fig. 3 looking in the direction of the arrows 6—6, Fig. 2;

Fig. 7 is a view similar to Figs. 3 and 6 looking in the direction of the arrows 7—7, Fig. 4;

Fig. 8 is a view similar to Fig. 7 taken on the line 8—8, Fig. 4;

Fig. 9 is a fragmentary vertical section looking in the direction of the arrows 9—9, Fig. 4; and

Fig. 10 is a fragmentary vertical section looking in the direction of the arrows 10—10, Fig. 2.

Similar numerals refer to similar parts throughout the various figures of the drawings.

The improved forced circulation cooling apparatus is

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shown somewhat diagrammatically in Fig. 1 incorporated in a continuous strip bright annealing furnace generally indicated at 1. The furnace 1 may include a flame heating zone generally indicated at 2, a heating zone generally indicated at 3, a soaking zone generally indicated at 4, a controlled cooling zone generally indicated at 5, a pipe coil cooling zone generally indicated at 6, a forced circulation cooling zone generally indicated at 7, and an exit 8.

The continuously moving strip to be treated is indicated at 9 and passes from a roll or other equipment (not shown) over a guide roll 10 to enter the flame heating zone 2. The strip 9 then threads back and forth over upper and lower guide or conveyor rolls 11 and 12 in the various chambers of the furnace so as to pass to and fro through said chambers or compartments. During such travel the strip 9 moves successively through the zones 2, 3, 4, 5, 6 and 7 to the furnace exit 8. It then may pass under guide roll 13 to a coiler (not shown) or other desired handling or treating equipment.

The strip 9 may, for example, be a cold rolled steel strip 0.010" thick and 30" or more wide, used for the manufacture of tinplate; and the bright annealing operation to which the strip is subjected in furnace 1 may be carried out at strip speeds as high as 1000 F. P. M. However, other gauges and widths of strip material may be treated in the furnace 1 at other speeds than indicated.

In subjecting the continuously moving strip 9 to a bright annealing operation the heating, soaking and initial cooling steps are performed at suitable temperatures for suitable periods of time to obtain the desired metallurgical results. Thus, as shown, the strip may make three passes through the heating zone 3, five passes through the soaking zone 4, five passes through the controlled cooling zone 5, two passes through the pipe coil cooling zone 6, and fourteen passes through the forced circulation cooling zone 7 before it emerges through the furnace exit 8 into the atmosphere. It is to be understood that the number and character of zones, and the number of passes in each zone, may be varied in accordance with the character of heat treatment desired and the gauge, width, speed and type of material treated.

The furnace heating and cooling chambers are maintained filled with a suitable special or controlled atmosphere, supplied from any suitable source in a usual manner, to prevent oxidation of the strip surfaces during the annealing or heat treatment.

In the example given, the strip temperature may be approximately 900° F. as it leaves the pipe coil cooling zone 6 and this strip temperature must be reduced to approximately 200° F. before the strip leaves the controlled-atmosphere-filled furnace chamber at exit 8, for otherwise oxidation of the strip surfaces would result on exposure of the strip to the atmosphere.

The furnace 1 may be constructed in any suitable or usual manner with a structural framework generally indicated at 14, and with refractory walls and partitions for the chambers formed in the heating and soaking zones 3 and 4. The walls forming the cooling chambers of zones 5, 6 and 7 may also be mounted on the structural framework 14 and may be built of any usual material such as metal plates. The conveyor rolls 11 and 12 may also be mounted in a usual manner on the framework 14 or journaled in bearings (not shown) mounted in the furnace walls. Some of the rolls 11 and 12 may be driven, if desired, by suitable drive means, power for conveying the strip 9 through furnace 1 also being supplied by the coiler.

The furnace may be equipped with suitable fuel burners (not shown) in all zones thereof where it is necessary to supply heat for carrying out the desired heat treating operation. In the case of a controlled atmosphere furnace for bright annealing where it is necessary to maintain a special atmosphere in the furnace, these burners may be usual radiant tube fuel burners. However, other usual means of supplying heat to the furnace and of maintaining a controlled atmosphere in the furnace may be used where desired.

When strip metal is continuously annealed at speeds as high as 1000 F. P. M., as much as 1700 or more feet of strip must be in the furnace heating and cooling chambers in order to satisfy the required heating and cooling cycle. A compact and space saving furnace arrangement enabling such length of strip to be in the furnace chamber is illustrated in Fig. 1 in which the strip passes vertically up and down or to and fro within

using water as the ultimate cooling means and without requiring special refrigeration or other similar equipment for cooling the cooling medium circulated in the forced circulation system.

Another important feature of the present invention is the provision for longitudinal flow of the circulating cooling medium which enables the cross sectional area of the stream to be kept small whereby a large strip area is served by relatively small cubic feet per minute flow of cooling medium. This in turn means that the blowers may be relatively small and the power requirements for the blowers correspondingly small.

Still another important feature of the present invention is that because of the closed circulation system character of the means for circulating cooling medium and the 50% parallel flow and 50% counterflow of the cooling medium with respect to strip travel, the pressures at the entrance and exit ends of the forced circulation cooling zone 7 are inherently balanced so that flow of air into the cooling chamber or loss of special atmosphere from the cooling chamber are avoided. This is frequently a problem in the provision of forced circulation for either heating or cooling a furnace structure because usually, since pressure difference is necessary to produce flow, there are pressure differences between the entrance and exit ends of a chamber in which forced circulation is provided.

It is usual practice in cooling by forced circulation to pass a stream of gas first in contact with the surfaces to be cooled and then through cooling coils. In contrast, another important feature of the present invention is that the circulating gas stream passes simultaneously in contact both with the surfaces to be cooled and with the cold plate surfaces which in turn cool the cooling medium. In this manner no additional space is needed for coil chambers and the over-all size of the apparatus is greatly reduced.

Referring to Figs. 2 and 5, in order to gain access to the conveyor rolls and for threading the furnace, the top wall of the cooling zone may be formed by a series of plates 43 having partition walls 18 integral therewith, and the plates 43 may be flanged for providing a liquid seal 44 between adjacent plates. Similarly, the bottom wall of the cooling zone 7 may have removable liquid sealed plates 45 for permitting access to the lower conveyor rolls 12 and 12a.

Accordingly, the present invention provides a new and different forced circulation cooling apparatus for a continuous strip furnace which incorporates the new and advantageous features described, overcomes prior art difficulties, and solves long standing problems in the art.

In the foregoing description certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art because such terms are utilized for descriptive purposes herein and not for the purpose of limitation and are intended to be broadly construed.

Moreover, the description of the improvements is by way of example, and the scope of the invention is not limited to the exact details illustrated and described.

Having now described the various features, discoveries and principles of the invention, the construction and the operation of a preferred apparatus arrangement, and the advantageous, new and useful results obtained thereby; the new and useful discoveries, principles, apparatus, combinations, parts, sub-combinations and elements, and mechanical equivalents obvious to those skilled in the art, are set forth in the appended claims.

I claim:

1 Apparatus for cooling continuously moving strip passing to and fro over a series of conveyor rolls in a controlled atmosphere chamber including, a first duct through which the strip travels, a return duct adjacent and parallel with the first duct, circulating fan means connected with said ducts for circulating gaseous cooling medium at high velocity in a closed circuit through said first duct and then through the return duct back to the first duct, the walls of the first duct on each side of the strip being formed with water cooled surfaces closely adjacent the strip, the first and return ducts having a common wall, and the return duct walls also being formed with water cooled surfaces.

2. Apparatus for cooling continuously moving strip passing to and fro over a series of conveyor rolls in a

controlled atmosphere chamber including walls forming a first duct through which the strip passes, another wall spaced from and parallel with one of said first duct walls forming a return duct, a partition wall transverse the return duct walls and located intermediate the ends of said first and return duct walls, circulating fan means having an inlet communicating with the return duct at one side of said partition wall and having an outlet communicating with the return duct at the other side of said partition wall, said circulating fan means discharging controlled atmosphere into said return duct through said inlet and withdrawing controlled atmosphere from said return duct through said outlet; manifold means connected with one end of the first and return ducts, said manifold means including walls forming an opening between the return duct and the first duct on one side of the strip, said manifold means also including walls forming a communication between said return duct and the first duct on the other side of the strip; means communicating between the other end of the return duct and the other end of the first duct on both sides of the strip, and cooling surface means associated with walls of the first duct on either side of the strip throughout the length of strip travel in the first duct.

3. Apparatus for cooling continuously moving strip passing to and fro over a series of conveyor rolls in a controlled atmosphere chamber including walls forming a first duct through which the strip passes, other walls spaced from and parallel with said first duct walls forming a second duct in which the strip passes in the opposite direction, certain of said first and second duct walls forming a return duct between and parallel with said first and second ducts, a partition wall transverse the return duct and located intermediate the ends of said return duct walls, circulating fan means having an inlet communicating with the return duct at one side of said partition wall and having an outlet communicating with the return duct at the other side of said partition wall, said circulating fan means discharging controlled atmosphere into said return duct through said inlet and withdrawing the atmosphere from said return duct through said outlet; manifold means connecting one end of the return duct with one end of the first and second ducts, said manifold means including walls forming openings between the return duct and the first and second ducts on one side of the strip, said manifold means also including walls forming a communication between the said return duct and the first and second ducts on the other side of said strip; means communicating between the other end of the return duct and the other end of the first and second ducts on both sides of the strip, and cooling surface means associated with the walls of the first and second ducts on either side of the strip throughout the length of strip travel in said first and second ducts.

4. Apparatus for cooling continuously moving strip passing to and fro over a series of conveyor rolls in a controlled atmosphere chamber including walls forming a first duct through which the strip passes, other walls spaced from and parallel with said first duct walls forming a second duct in which the strip passes in the opposite direction, certain of said first and second duct walls forming a return duct between and parallel with said first and second ducts, a partition wall transverse the return duct and located intermediate the ends of said return duct walls, circulating fan means having an inlet communicating with the return duct at one side of said partition wall and having an outlet communicating with the return duct at the other side of said partition wall, said circulating fan means discharging controlled atmosphere into said return duct through said inlet and withdrawing the atmosphere from said return duct through said outlet; manifold means connecting one end of the return duct with one end of the first and second ducts, said manifold means including walls forming openings between the return duct and the first and second ducts on one side of the strip, said manifold means also including walls forming a communication between said return duct and the first and second ducts on the other side of said strip; said fan means connected with the ducts for circulating controlled atmosphere at high velocity in a closed circuit through one of said ducts on both sides of the strip in the direction of strip travel and through the other duct on both sides of the strip in a direction opposite that of the strip travel, means communicating between the other end of the return duct and

the furnace chambers and zones. However, it is to be understood that the path of travel or passes of strip back and forth through the furnace chambers may be arranged to be horizontal rather than vertical. The vertical pass arrangement, however, is preferable since it avoids any necessity for supporting sagging portions of the strip between conveyor rolls at the ends of passes.

In accordance with the present invention improved forced circulation cooling means are provided in the zone 7 for rapidly cooling the strip from approximately 900° F. to approximately 200° F. in such zone. In order to provide for such forced circulation cooling of the strip as it passes to and fro over the upper conveyor rolls 11 and under the lower conveyor rolls 12 in zone 7, a series of ducts are formed in the cooling chamber, one duct for each strip pass either up or down. These ducts are formed by providing a series of partition walls laterally across the furnace chamber.

Referring particularly to Figs. 2, 3, 4 and 5, the first partition wall at the left-hand side of zone 7 is indicated at 15 and extends from the bottom of the furnace chamber (Fig. 5) to just beneath the conveyor roll 11a which is the entry conveyor roll for zone 7. Partition wall 15 also extends cross-wise of the furnace chamber between side walls 16 and 17. Immediately above conveyor roll 11a, a baffle plate or wall 18 extends downward from the roof of the furnace and between side walls 16 and 17 to reduce to a minimum any communication between the cooling zones 6 and 7. Thus there is only sufficient space between the top end 15a of partition wall 15 and the bottom of baffle wall 18 to accommodate roll 11a and permit the strip 9 to pass over roll 11a into zone 7.

Spaced to the right of partition wall 15 is another partition wall 19 which extends upward from just above the first lower conveyor roll 12a in zone 7 nearly to the top of the cooling chamber as indicated at 19a. The partition wall 19 likewise extends laterally between furnace side walls 16 and 17. Another partition wall 20, similar to partition wall 19 but spaced to the right thereof (Fig. 2), extends upward from just above lower conveyor roll 12a to near the roof of the cooling chamber as indicated at 20a. Partition walls 19 and 20 are joined at the top by wall member 21 extending from the top ends 19a and 20a thereof.

Another partition wall 22 spaced to the right of partition wall 20 extends upward from the bottom of the cooling chamber and between chamber side walls 16 and 17. Still another partition wall 23 similar to partition wall 22 is provided spaced to the right of partition wall 22; and walls 22 and 23 are joined at the top by wall portion 23a and at the bottom by wall portion 23b. Partition wall portion 23a is similar to partition wall portion 15a and partition wall 23b is similar to the lower end of partition wall 15.

The foregoing arrangement of partition walls is repeated throughout the remainder of the forced circulation cooling zone 7, as shown.

Referring to Figs. 2, 4 and 5, a down-duct 24 is formed between partition walls 15 and 19 through which the strip 9 passes in downward travel, and an up-duct 25 is formed between partition walls 20 and 22 through which the strip passes in upward travel. Intermediate to and parallel with the ducts 24 and 25, a return duct 26 is formed between walls 19 and 20. As shown in Fig. 5, both of the ducts 24 and 25 communicate at their bottom ends directly with the bottom end of return duct 26.

The upper ends 19a and 20a of partition walls 19 and 20, along with connecting top wall member 21, form a manifold 27 for the upper end of return duct 26. A slotted opening 19b is formed in wall portion 19a which establishes communication between manifold 27 and down-duct 24 on the right-hand side of the strip portion 9 passing downward through duct 24. A similar slotted opening 20b is formed in wall portion 20a establishing communication between manifold 27 and up-duct 25 on the left-hand side of the strip portion 9 passing upward through duct 25.

An opening 28 is formed in the side wall 17 connected with the central stem 29 of secondary manifold 30 located on the outer side of side wall 17. Manifold 30 is provided with two end stems 31 and 32, the stem 31 communicating through opening 33 in side wall 17 with the upper end of down-duct 24 on the left-hand side of strip 9 passing downward through duct 24; and stem 32 similarly communicates through opening 34 formed in

side wall 17 with the upper end of up-duct 25 on the right-hand side of strip 9 passing upward in duct 25. In this manner, the upper end of return duct 26 communicates with the upper ends of ducts 24 and 25 on both sides of the strip passing therethrough.

As shown in Figs. 4 and 9, a cross partition member 35 is provided intermediate the ends of duct 26 extending between partition walls 19 and 20 and side walls 16 and 17. An opening 36 is formed in side wall 17 below cross partition wall 35 communicating with return duct 26. A fan or blower intake duct 37 communicates with opening 36 and leads to the intake of centrifugal blower 38 driven by motor 39 (Fig. 9). The blower outlet communicates by duct 40 with an opening 41 formed in side wall 17 communicating with return duct 26 above cross partition wall 35.

By these means, when the blower is operating, there is forced circulation of the controlled atmosphere filling the chambers of the furnace, the gases circulated acting as a cooling medium for the strip passing through ducts 24 and 25. Thus, as shown by the arrows in the drawings, the cooling medium discharged from blower 38 passes through duct 40 into return duct 26 above partition wall 35, thence upward in duct 26 to manifold 27 where the gas flow divides into four streams through openings 19b and 20b and secondary manifold 30. These four streams are delivered to the top ends of ducts 24 and 25 on both sides of the strip. The cooling medium then circulates downwardly in both ducts 24 and 25 to the lower ends thereof where the flow merges and is drawn into the lower end of duct 26 (Fig. 5) from whence the cooling medium flows upwardly in return duct 26 to the intake duct 37 of blower 38.

The blowers 38 are operated to circulate the cooling medium at high velocity so that the latter effectively and efficiently cools the strip by convection. It will be appreciated that while the greatest cooling effect can be obtained if the cooling medium is circulated at all times in the direction opposite to the direction of strip travel, nevertheless it would be difficult to provide for such cooling medium flow along the strip travelling to and fro in the cooling chamber shown.

The structure of the present invention provides a compromise in which the circulated cooling medium flows in a direction opposite to the direction of strip travel in the up-ducts 25 and in the same direction as the direction of strip travel in the down-ducts 24.

The cooling arrangement of the present invention further involves the provision of means for cooling the cooling medium that is circulated in a closed system by each blower 38. For this purpose, the partition walls 15, 19, 20, 22 and 23 are each formed as cold plate surfaces. Preferably such a cold plate surface is provided by using plate coil material which comprises two metal sheets having matched corrugations formed therein providing an internal passageway through which water may be circulated. These water circulation passages are indicated generally in the drawings at 42 and may be connected in any desired or usual manner with a source of cold water supply and with a warm water outlet.

Alternatively, the cold plate surfaces may be formed by spaced sheets forming a water jacket through which water may be circulated. As another alternative, the partition walls may be formed of single thickness sheet metal and usual pipe coils through which water is circulated may be mounted thereon in ducts 24 and 25 on both sides of the strip and along the inside of the walls of ducts 26.

By forming the partition walls as cold plate surfaces in any of the manners indicated, the cooling medium being circulated at high velocity through the ducts 24, 25 and 26 passes along the cold plate surfaces at high velocity and is cooled by convection by the cold plate surfaces not only at the same time that the circulating cooling medium is cooling the strip in ducts 24 and 25 but also in its travel through return duct 26.

The cold plate surfaces provided by the partition walls in addition to extracting heat from the circulating cooling medium, which in turn cools the strip, also have some direct cooling effect upon the strip because of the close proximity of the cold plate surfaces to the strip in each pass.

By these means, very rapid, efficient and effective cooling of the strip is obtained so that the strip may be quickly cooled in the cooling zone 7 from say 900° F. to 200° F.

the other end of the first and second ducts on both sides of the strip, and cooling surface means associated with the walls of the first and second ducts on either side of the strip throughout the length of strip travel in said first and second ducts.

5 5. Apparatus for cooling continuously moving strip including walls forming a cooling chamber, conveyor rolls for continuously moving the strip to and fro through said chamber, there being strip entrance and exit openings for said chamber, a first duct in said chamber 10 through which the strip travels in one direction from one conveyor roll to a second conveyor roll, a second duct in said chamber through which the strip travels in the opposite direction from said second conveyor roll to a third conveyor roll, a return duct between and parallel 15 with the first and second ducts and including manifold means at one end for making communication between the return duct and one end of said first and second ducts on both sides of the strip, a partition wall transverse of the return duct, the return duct having an inlet on one 20 side of the partition wall and having an outlet on the other side thereof; fan means connected with the inlet and outlet for circulating controlled atmosphere cooling medium at high velocity in a closed circuit from said inlet through the return duct, then through one of said 25 first and second ducts on both sides of the strip in the direction of strip travel and through the other of said

first and second ducts on both sides of the strip in a direction opposite that of strip travel, and then from the first and second ducts in a common closed path through said return duct to said outlet; means associated with the first and second ducts closely adjacent each side of the strip throughout the length of the ducts for simultaneously cooling said strip and said cooling medium as the strip travels through said first and second ducts and as the cooling medium circulates through said ducts in said closed circuit and cools the strip traveling there-through; and said first and second ducts and said return duct and the fan means therefor which form said closed circuit being repeated in said cooling chamber to form a plurality of closed cooling medium circulation circuits along the path of strip travel as the strip moves continuously to and fro over the conveyor rolls through said cooling chamber.

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