Dec. 13, 1955 A. H. VAUGHAN 2,726,458

FORCED CIRCULATION HORIZONTAL COOLING APPARATUS FOR CONTINUOUS STRIP FURNACE

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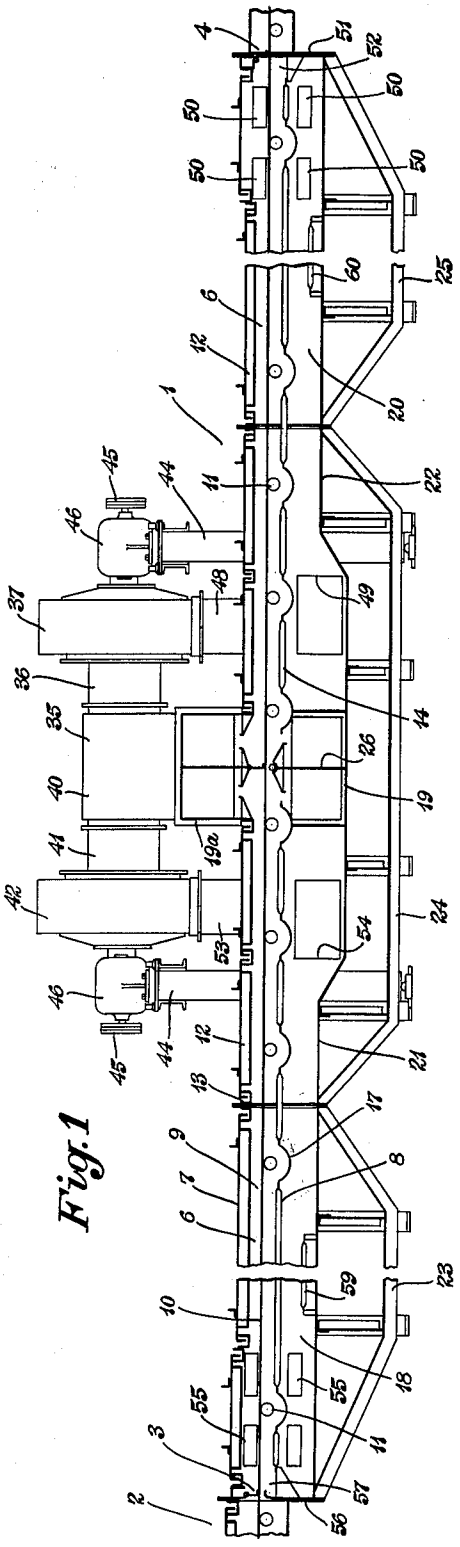


Fig. 1

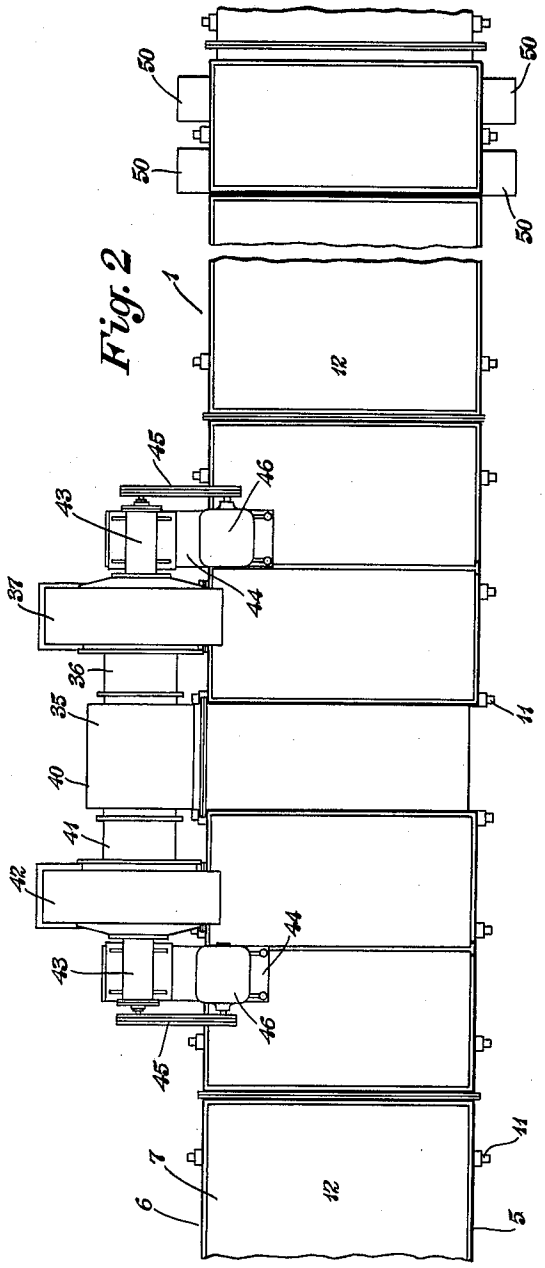


Fig. 2

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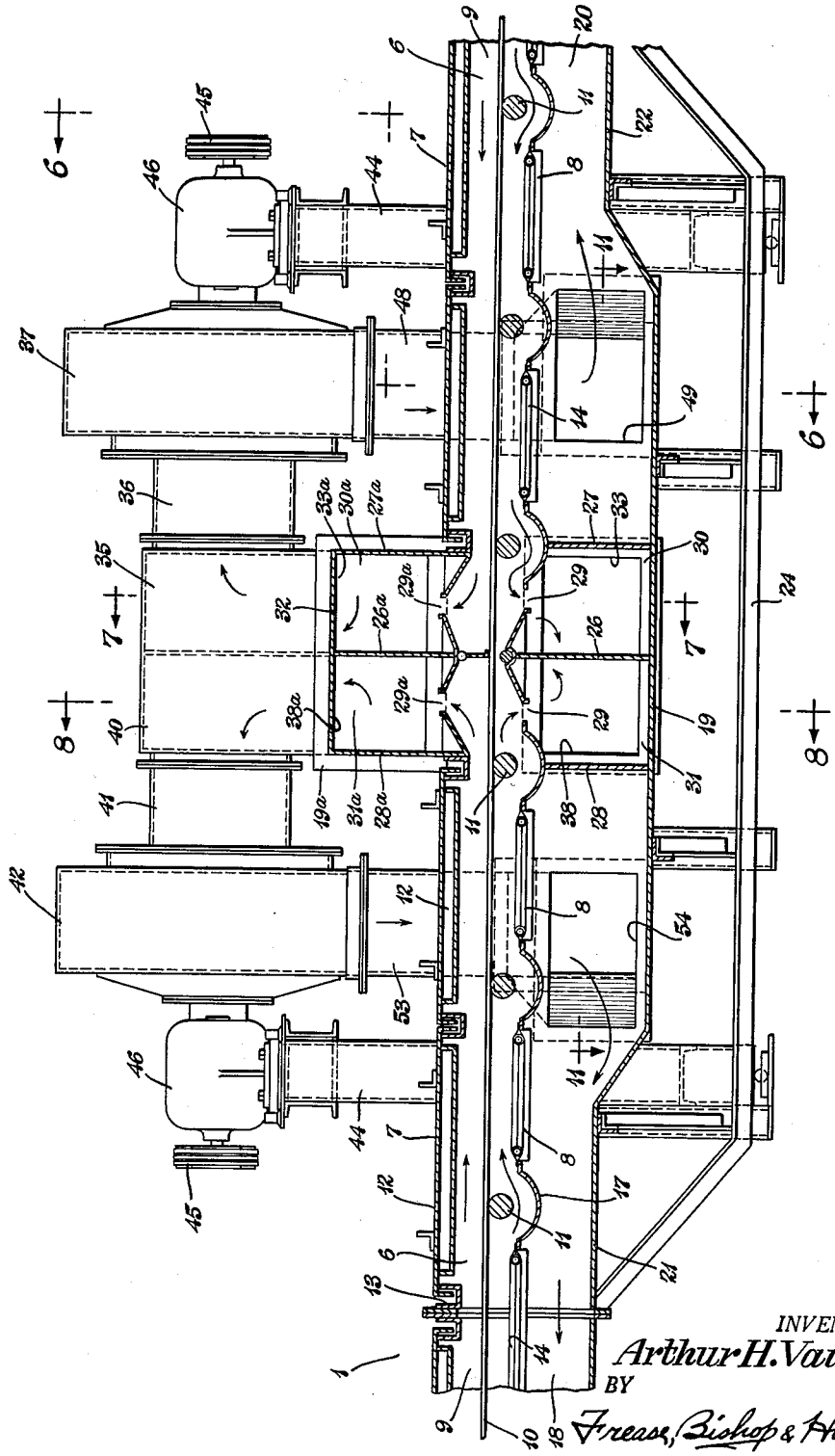


Fig. 3

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FORCED CIRCULATION HORIZONTAL COOLING APPARATUS FOR CONTINUOUS STRIP FURNACE

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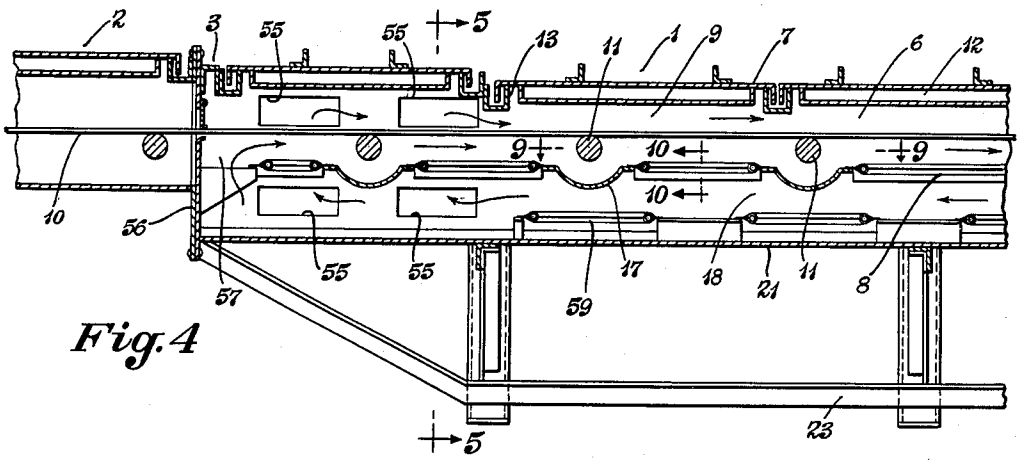


Fig. 4

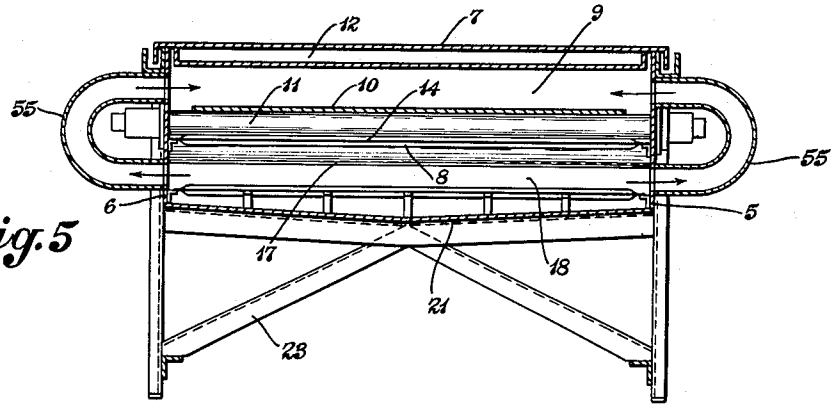


Fig. 5

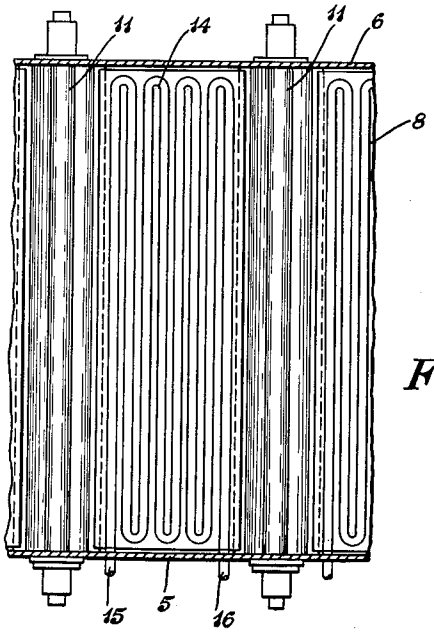


Fig. 9

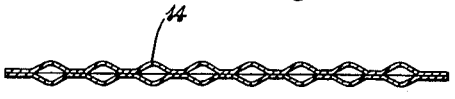
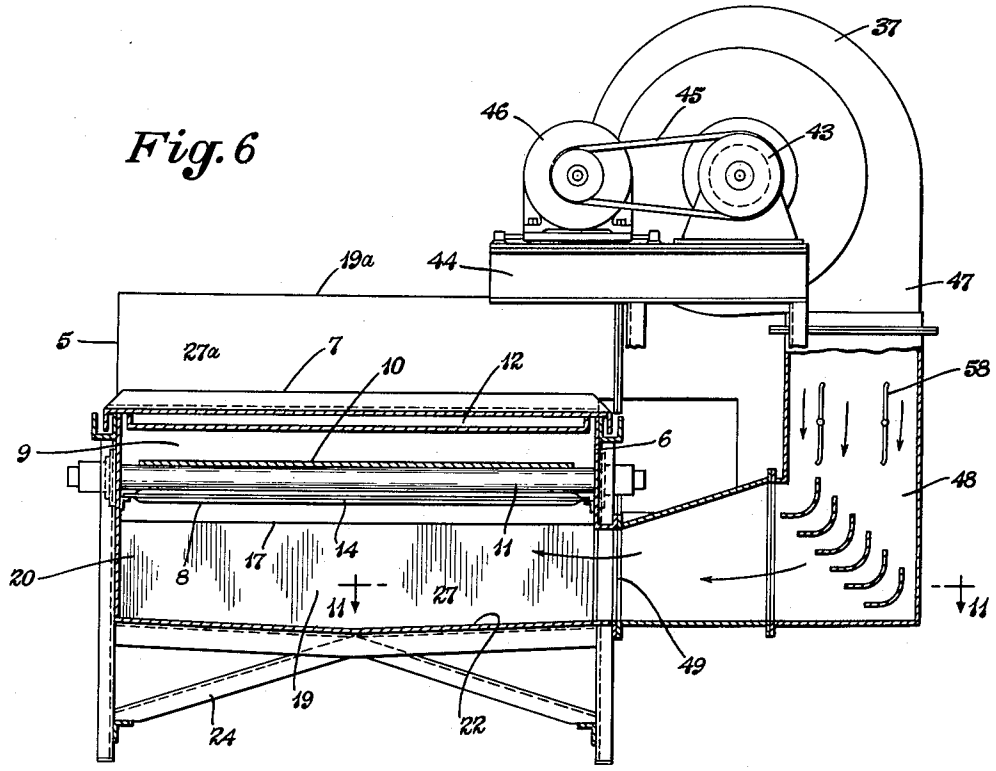


Fig. 10

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Fig. 6



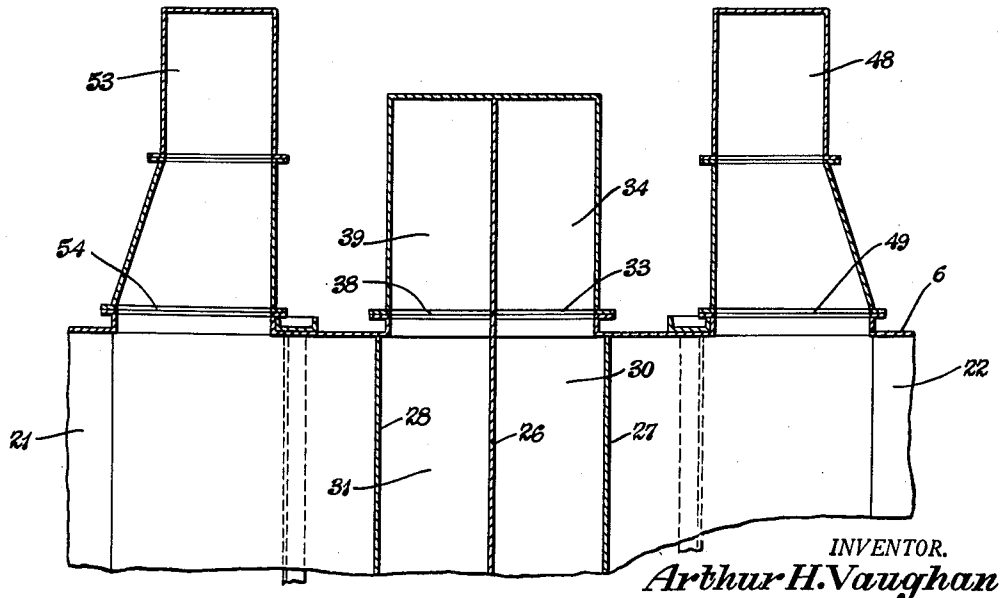


Fig. 11

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FORCED CIRCULATION HORIZONTAL COOLING APPARATUS FOR CONTINUOUS STRIP FURNACE

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Fig. 8

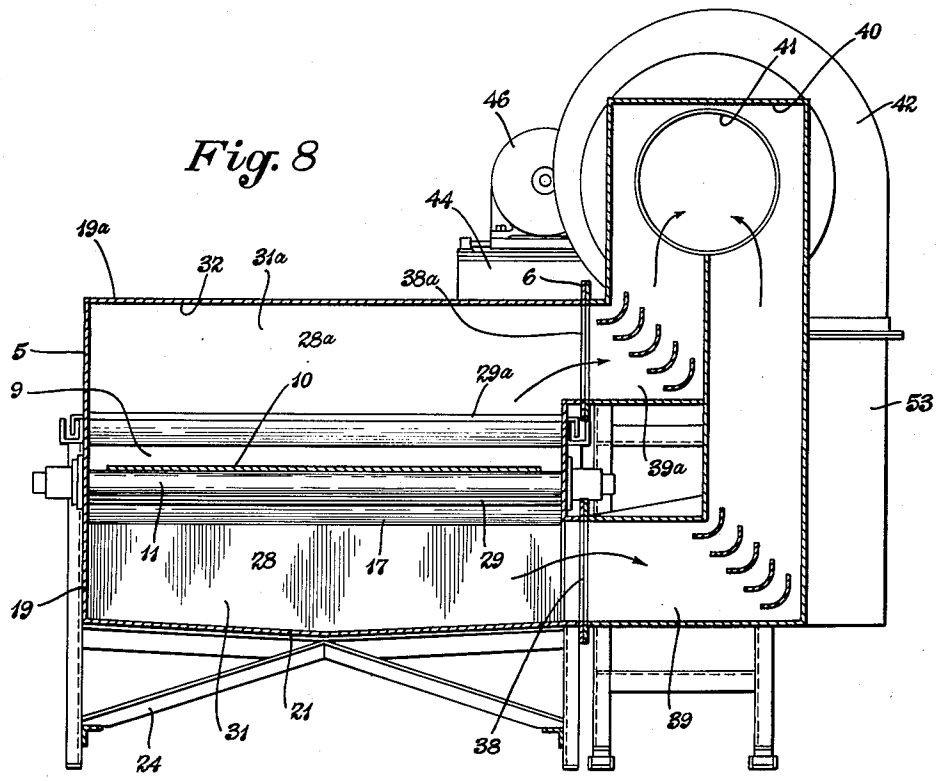
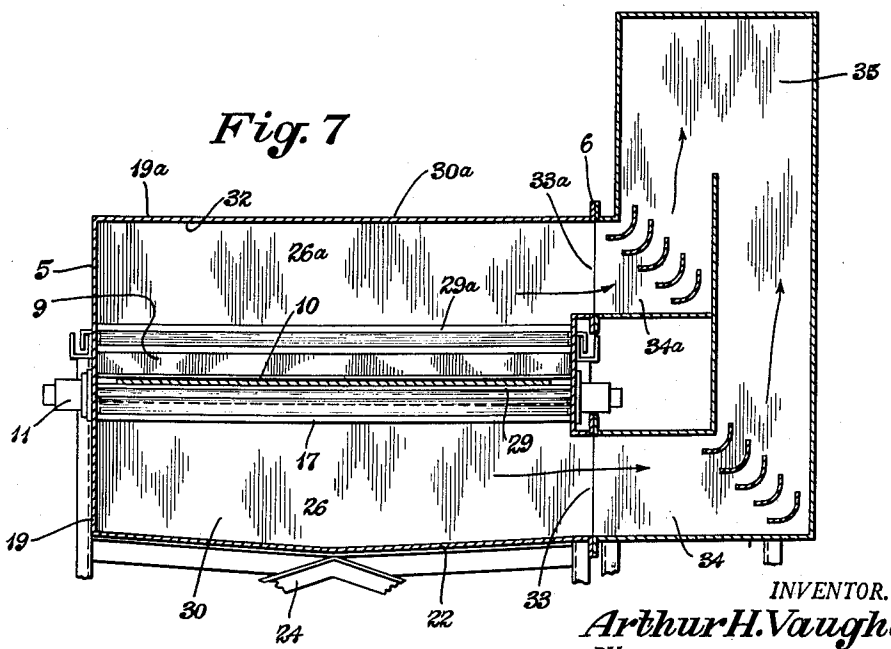


Fig. 7



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2,726,458

FORCED CIRCULATION HORIZONTAL COOLING APPARATUS FOR CONTINUOUS STRIP FURNACE

Arthur H. Vaughan, Salem, Ohio, assignor to The Electric Furnace Company, Salem, Ohio, a corporation of Ohio

Application August 8, 1951, Serial No. 240,938

13 Claims. (Cl. 34—155)

The invention relates generally to a continuous strip bright annealing furnace and more particularly to horizontal forced circulation cooling apparatus associated with such a furnace to enable a continuous strip passed 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 light gauge strip steel of a variety of gauges and analyses it may be desired to provide for the continuous bright annealing of the strip at speeds as high as 200–600 F. P. M. or more. This means that a large strip tonnage may pass through the furnace every hour.

In performing a desired bright annealing operation at high speed on such strip metal, it may be 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. The material then 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 high speed. 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.

In some instances, because of the nature of the strip being treated, it is desirable to cool the strip while passing generally in a horizontal path or paths. This complicates the problem because of the length of strip which must necessarily be in the heating and cooling chambers at any one time in order that the heat treating cycle may be properly carried out. Depending upon the speed of strip travel, the length of strip in the cooling chamber may be relatively large and it is desirable to reduce this strip length and increase the rate of cooling as much as possible in order to reduce space requirements and the size of the cooling equipment.

Cooling of a 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 nature or arrangement of the path of strip travel therethrough.

For economy in the number and size of fans used in a forced circulation cooling system for the cooling chamber of a continuous strip furnace, it is desirable to provide for longitudinal flow of the cooling medium with respect to the strip since in this way the cross sectional area of the stream of cooling medium may be kept small and a large strip area may be served by a relatively small volume of cooling medium circulated at any time interval.

While it is common practice in forced circulation cooling systems to pass a stream of cooling medium in one chamber across the surfaces to be cooled and then to convey the cooling medium to separate cooling equipment where the cooling medium is passed through cooling coils or refrigerating means to extract heat therefrom, such arrangements require additional equipment, space and expense for the separate cooling equipment and the overall size of the entire unit may be larger than desired.

Other problems are present in cooling or extracting heat from the cooling medium used in a forced circulation system. The cooling medium used to avoid oxidation of the strip during cooling, ordinarily must be the same controlled atmosphere that is used in the furnace heating chambers to avoid oxidation during heating. Thus, the problem of unbalanced pressures in such a forced circulation system is two-fold. Loss of controlled atmosphere must be avoided on the one hand, and ingress of air to the cooling chamber must be avoided on the other hand. Either of these events can occur where the pressures at the entrance and exit openings of the cooling chambers are unbalanced.

Finally, from many standpoints, it is most desirable to use water as a means of cooling or extracting heat from the cooling medium in a forced circulation system for the cooling apparatus of a continuous bright annealing or heat treating furnace.

I have discovered a solution to these complex and interrelated problems which involves the provision in apparatus for rapidly cooling a continuously moving strip passing generally in a horizontal path or paths, of a first duct through which the strip passes in one direction, of second duct means for introducing controlled atmosphere cooling medium into the entrance end of said first duct on both sides of the continuously moving strip and for withdrawing such cooling medium from the first duct intermediate the ends thereof, and of third duct means for introducing controlled atmosphere cooling medium into the discharge end of the first duct on both sides of the strip and for withdrawing such cooling medium from the first duct intermediate the ends thereof. I further preferably provide circulating fan means for the second and third duct means. 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 at high velocity along the strip surfaces being cooled thereby at the same time passes along the water cooled walls at high velocity and is rapidly cooled.

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 a strip

moving at high speed may be rapidly and efficiently cooled in a short distance of travel while passing generally in a horizontal direction 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 200–600 F. P. M. 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 generally horizontally in one direction 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 distance through which the strip travels in the cooling chamber, and in which the cooling medium is circulated at high velocity in the same direction as the direction of strip travel in the remainder of the strip travel in the cooling chamber.

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 an 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 for a continuous strip bright annealing furnace in which pressure differential problems in the cooling medium circulating system and particularly in the entrance and exit ends of the cooling chamber 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 overall size of the apparatus to a minimum and obtaining high cooling efficiency.

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 cooling medium is cooled by water cooled cooling surfaces at the same time that it is cooling the strip in the chamber through which the strip passes and in which the cooling medium is also cooled by water cooled cooling surfaces as it is being circulated by its circulating means between its discharge from and reintroduction into the cooling chamber.

In addition, it is an object of the present invention to provide forced circulation cooling apparatus for a continuous strip bright annealing furnace in which two circulating fans and separate cooling systems, one served by each fan, are provided for the cooling chamber through which the continuously moving strip passes in one direction so as to obtain maximum temperature differentials between the strip temperature and the temperature of the cooling medium in each cooling system.

Moreover, it is an object of the present invention to provide forced circulation cooling apparatus for a continuous strip bright annealing furnace in which the strip passes through a cooling chamber continuously in one direction and in which the cooling medium is circulated in a direction contra to the direction of strip travel in that portion of the cooling chamber where the temperature differential between the temperature of the cooling medium and the strip is lowest.

Finally, it is an object of the present invention to provide new apparatus for rapidly and efficiently cooling continuously moving strip as it passes from 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 distinctly and particularly 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 in one direction substantially horizontally over a series of conveyor rolls in said chamber, said chamber being provided with a controlled atmosphere, walls forming duct means through which the strip passes in said chamber, other walls forming a second duct means communicating with one end of and with an intermediate portion of the first duct, still other walls forming a third duct means communicating with the other end of and with an intermediate portion of the first duct, circulating fan means for circulating controlled atmosphere cooling medium in a closed circuit through the second duct means and a portion of the first duct means in the direction of strip travel, other circulating fan means for circulating controlled atmosphere cooling medium in a closed system through the third duct means and through the remaining portion of the first duct in a direction contra to the direction of strip travel, cooling surface means on either side of the strip associated with the first duct, and certain of said cooling surface means being also associated with the second and third duct means.

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

Figure 1 is a diagrammatic longitudinal sectional view of a preferred arrangement of improved cooling apparatus with certain parts broken away;

Fig. 2 is a fragmentary plan view of a portion of Fig. 1;

Fig. 3 is an enlarged longitudinal sectional view similar to Fig. 1 illustrating the central portion of the cooling duct and the two circulating fans associated therewith;

Fig. 4 is an enlarged view similar tot Fig. 3 of the entrance end of the cooling duct shown in Fig. 3;

Fig. 5 is a sectional view taken on the line **5—5**, Fig. 4;

Fig. 6 is a sectional view looking in the direction of arrows **6—6**, Fig. 3;

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

Fig. 8 is a view similar to Figs. 6 and 7 looking in the direction of the arrows **8—8**, Fig. 3;

Fig. 9 is a fragmentary plan sectional view taken on the line **9—9**, Fig. 4;

Fig. 10 is an enlarged fragmentary sectional view taken on the line **10—10**, Fig. 4; and

Fig. 11 is a fragmentary plan sectional view taken on the line **11—11**, Figs. 3 and 6.

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

The improved forced circulation cooling apparatus

generally indicated at 1 is shown diagrammatically in Fig. 1 connected with the exit end of a passage 2 leading from a continuous strip bright annealing furnace. The furnace 2 may have any desired construction and arrangement and ordinarily includes a heating zone, a soaking zone and one or more initial cooling zones in which the continuously moving strip may be cooled to a temperature in the neighborhood of 900° F. The strip, at such temperature and traveling at a speed of as high as say 200 to 600 F. P. M. or more emerges from the furnace passage 2 and must be cooled to a temperature, say about 200° F., at which oxidation will not result on exposure of the strip to the atmosphere. This cooling is accomplished in the forced circulation cooling apparatus 1.

The particular controls of the heating, soaking and initial cooling steps carried out in the furnace form no part of the present invention except that controls are necessary in order to obtain desired metallurgical results in performing a bright annealing or some other heat treating operation upon the continuously moving strip.

In performing a bright annealing operation, the chambers of the furnace 2 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 annealing or heat treatment. In accordance with the present invention the same special or controlled atmosphere is used for filling the various ducts and chambers of the cooling apparatus 1 wherein the rapidly moving strip is rapidly cooled from approximately 900° F. to approximately 200° F. in passing from its entrance end 3 to its exit end 4.

The cooling apparatus 1 preferably comprises side walls 5 and 6, upper walls generally indicated at 7 and lower walls generally indicated at 8 forming a longitudinally horizontally extending cooling duct 9 through which the strip generally indicated at 10 passes in one direction from entrance end 3 to exit end 4. Suitable conveyor rolls 11 are provided at spaced intervals along duct 9 for supporting the strip 10 in its passage through the duct.

The upper duct walls 7 are preferably formed as double walled panel sections 12 supported on cross channel members 13 so as to permit removal of any of the sections 12 when desired. The joints between adjacent panel sections 12 and channel members 13 may be sealed in any usual manner with an asphalt or other similar compound. Cold water is circulated between the spaced walls of each panel section 12 in any suitable manner, not shown.

Referring particularly to Figs. 9 and 10, the lower duct walls 8 of the strip cooling duct 9 are preferably formed of plate coil material, indicated at 14, which comprises two metal sheets having matched corrugations formed therein providing an internal passageway through which water may be circulated from an inlet opening 15 to an outlet 16. The upper and lower duct walls 7 and 8 thus are each formed as cold plate surfaces and the lower walls 8 may be formed below each conveyor roll 11 with a laterally extending concave portion 17 so that substantially the same cross sectional area is provided for the duct 9 throughout its extent.

A second duct 18 is formed in the cooling apparatus 1 extending throughout approximately half the length of the apparatus from the entrance end 3 thereof to suction box means 19. A third duct 20 is formed in the cooling apparatus 1 extending from the suction box means 19 to the exit end 4 of the apparatus 1. Side walls 5 and 6 of the apparatus form the side walls of the ducts 18 and 20, the bottom wall 8 of the duct 9 forms the top wall of ducts 18 and 20, and bottom walls 21 and 22 form the bottom walls of the ducts 18 and 20. The various walls are supported on a suitable structural framework 23, 24 and 25.

Referring particularly to Fig. 3, the suction box 19 is provided with a central lateral partition wall 26 and spaced lateral partition walls 27 and 28 extending between walls 21 and 22 and lower cooling duct wall 8. The lower cooling duct wall 8 is provided with lateral openings 29 by which the lower portions of duct 9 beneath the strip 10 communicate with the chambers 30 and 31 formed in the suction box respectively between walls 26 and 27 and 26 and 28.

A second portion 19*a* of the suction box means 19 is formed above the duct 9 generally similar to the suction box 19, having a central lateral partition wall 26*a* and spaced lateral partition walls 27*a* and 28*a*. The walls 26*a*, 27*a*, and 28*a* extend upward from the upper cooling duct wall 7 to a top suction box wall 32. The upper cooling duct wall 7 is provided with lateral openings 29*a* by which the upper portions of the duct 9 above the strip 10 communicate with the chambers 30*a* and 31*a* formed in the suction box 19*a*, respectively, between walls 26*a* and 27*a*, and 26*a* and 28*a*.

Referring to Figs. 3, 7 and 8, chambers 30 and 30*a* communicate through openings 33 and 33*a* in the cooling apparatus side wall 6, respectively, through ducts 34 and 34*a* with manifold 35, which is connected by duct walls 36 with the intake opening of centrifugal blower or circulating fan 37. Similarly, chambers 31 and 31*a* communicate through openings 38 and 38*a* in the side wall 6, respectively, through ducts 39 and 39*a* with manifold 40, which is connected by duct walls 41 with the intake opening of centrifugal blower or circulating fan 42.

The fan shafts of each of the circulating fans 37 and 42 are journalled in bearings (Fig. 2) 43 mounted on framework 44, and the shafts are driven through V-belt drives 45 by motors 46 also mounted on the framework 44.

The blower outlet 47 (Fig. 6) of circulating fan 37 communicates through a duct 48 with an opening 49 formed in the side wall 6 of the cooling apparatus below cooling duct lower wall 8, thus communicating with third duct 20 adjacent the central portion of the cooling apparatus. Near the exit end of the cooling apparatus the third duct 20 communicates through U-shaped by-pass ducts 50 (similar to the ducts 55 shown in Fig. 5) with the upper portion of duct 9 above the strip 10. The cooling duct lower wall 8 terminates short of the exit end wall 51 at the exit end of the cooling apparatus to provide a passage 52 communicating between the exit end of the third duct 20 and the lower portion of duct 9 beneath the strip 10.

In a similar manner the circulating fan 42 discharges through duct 53 and opening 54 in the cooling apparatus side wall 6, into the end of second duct 18 near the center of the apparatus; and the second duct 18 communicates through by-pass ducts 55 (Fig. 4) with the upper portion of the cooling duct 9 above the strip 10. The cooling duct lower wall 8 terminates short of the entrance end wall 56 of the cooling apparatus to provide a passage 57 communicating between one end of the second duct 18 and the lower portion of the duct 9 beneath the strip 10.

By these means, when the blowers 37 and 42 are operating, there is forced circulation of the controlled atmosphere filling the chambers of the cooling apparatus 1, the gases circulated acting as a cooling medium for the strip 10 passing through cooling duct 9.

Thus, as shown by the arrows in the drawings, the cooling medium discharged from blower 37 passes through duct 48 and opening 49 into third duct 20 below wall 8 and thence to the exit end of the apparatus where the gas flow divides into streams passing through by-pass ducts 50 to the portion of the cooling duct 9 above the strip 10. In other words, the circulated cooling medium is delivered to the exit end of cooling duct 9 on both sides of the strip. The cooling medium then circulates through cooling duct 9 on both sides of the strip in a direction contra to the direction of strip travel until it reaches openings 29 and 29*a* from whence it flows through openings 33 and 33*a* and ducts 34 and 34*a* to the manifold 35 and thence through duct 36 to the intake of the blower 37.

In a similar manner the blower 42 when operating

discharges through duct **53**, opening **54** and second duct **18** to deliver cooling medium through opening **57** and by-pass ducts **55** to the cooling duct **9** at the entrance end of the cooling apparatus on both sides of the strip; and the circulated cooling medium then flows through duct **9** on both sides of the strip in the direction of strip travel to slots **29** and **29***a* and thence through openings **38** and **38***a* and ducts **39** and **39***a* to manifold **40** and through duct **41** to the intake of fan **42**.

Accordingly, the two described circulating systems circulate cooling medium in the duct **9** through which the strip is passing in one direction, from the ends of the duct toward the center thereof on both sides of the strip. When the circulating gases reach the central region of the duct they are withdrawn therefrom to the circulating fans and are again recirculated.

The blowers **37** and **42** are operated in such manner as 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 maintained if the cooling medium is circulated at all times in a direction opposite to the direction of strip travel, nevertheless difficulties are encountered in providing for such cooling medium flow. Thus, if the gaseous cooling medium were circulated from the exit end of the cooling duct to the entrance end thereof before being withdrawn and recirculated, pressure differentials would result at the exit and entrance ends of the duct which could be accompanied by a substantial loss of cooling medium at one end of the duct or ingress of atmospheric air through the duct which might result in oxidation of the strip being cooled.

The arrangement by which the cooling medium is introduced into the cooling duct **9** at both ends thereof and thence flows to the central portion of the duct avoids these difficulties and provides for balanced pressures at the ends of the cooling duct. Referring to Fig. 6, the outlet duct for either or both of the fans **37** and **42**, such as the outlet duct **48** of fan **37**, may be provided with dampers **58** by which the respective pressures in the two circulating systems may be accurately balanced.

Thus, the arrangement 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 last half of the cooling duct **9** and in the same direction as the direction of strip travel in the first half of the cooling duct **9**. This arrangement has further advantages and particularly so when the cooling medium circulating systems are divided and served by separate fans.

In the first half of the cooling duct **9**, the strip is at a substantially higher temperature than in the last half of the cooling duct **9**. While the cooling efficiency of the circulating oooling medium from one standpoint is less in the first half of the duct **9** than in the last half thereof, because the cooling medium flows in the same direction as the direction of strip travel in the first half rather than contra to the direction of strip travel in the last half of the duct **9**, nevertheless rapid cooling results because of the higher temperature differential between the strip temperature and the temperature of the cooling medium in the first half of the cooling duct than in the last half of the duct. This greater temperature differential enables the loss of cooling effectiveness, due to cooling medium flow in the same direction as the direction of strip travel, in the first half of the duct to be counteracted. Likewise, in the last half of the duct the contra direction of cooling medium flow offsets to some extent the reduced cooling effect due to a low temperature differential.

While it is understood that a single circulating fan could be used and the partitions **26** and **26***a* in the suction boxes **19** and **19***a* eliminated, nevertheless it is desirable to maintain two independent circulating systems because by so doing the mean temperature of the circulating cooling medium in the last half of the cooling duct can be maintained lower than in the first half of the cooling duct. In this manner, a maximum temperature differential between the temperature of the cooling medium and the temperature of the strip may be maintained in the last half of the duct.

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 **37** or **42**. As previously described, the walls of the duct **9** are formed as cold plate surfaces by the provision of the platecoil material **14** and the double walled panel sections **12** through each of which cold water is circulated. By forming the walls as cold plate surfaces in either of the manners indicated, with the cold plate surfaces disposed near to and parallel to the plane of strip travel whereby the cooling medium flows in simultaneous contact with the strip and cooling surfaces, the cooling medium being circulated at high velocity through the duct **9** passes along the cold plate surfaces at high velocity and is cooled by convection by the cold plate surfaces at the same time that the circulating cooling medium is cooling the strip **10** in duct **9**.

The cold plate surfaces provided by these water cooled 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 throughout the length of the cooling duct **9**.

In addition, as best shown in Figs. 1 and 4, additional water cooled platecoil material cold plate surfaces **59** and **60** may be provided at spaced intervals adjacent the bottom walls **21** and **22** of the second and third or return ducts **18** and **20**. Thus, the cold plate surfaces **59** and **60**, in addition to the underside of the cold plate surfaces **14** which form the lower wall **8** of the duct **9**, cool the circulating cooling medium in its travel through the second and third or return ducts **18** and **20** before the same is introduced into the cooling duct **9**.

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 duct **9** from, say, 900° F. to 200° F. using water as the ultimate cooling means and without requiring special refrigeration or other similar equipment for cooling the cooling medium circulated in the two forced circulation systems.

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. The result of this arrangement is that the blowers are 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% contra flow of the cooling medium with respect to the direction of strip travel, the pressures at the entrance and exit ends of the cooling chamber **9** 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 construction of forced circulation systems for either heating or cooling 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 the stream of gas first in contact with the surface to be cooled and then through cooling coils. In contrast, another important feature of the present invention is that the circulated 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 overall size of the apparatus is greatly reduced.

A cooling unit is shown in the drawings consisting of two separate forced circulation systems discharging cooling medium into the cooling duct at the extreme ends thereof and circulating the same through such duct to the central region of the duct. Separate circulating fans for each system are desirable for the reasons indicated where only one unit is used. Sometimes where operating requirements such as temperatures, gauges, widths and speeds may necessitate provisions for additional cooling, two or more such units may be arranged in tandem or may be located one above another. In such cases where the capacity of the installation requires a plurality of units connected together in tandem, a single fan may be used to serve both systems of each unit without serious loss in cooling capacity because the greater the number of units, the less is the loss of cooling capacity due to the use of a single fan for each unit.

In the foregoing description, the walls of the duct **9** each have been described as being formed of cold plate surfaces by the provision of the platecoil material **14** and the double wall panel sections **12** through each of which cold water is circulated. It is to be understood, however, that these walls may be formed in any desired or usual manner and water cooled cooling pipes or coils may be mounted in the duct **9** adjacent the top and bottom walls thereof to provide the cold plate cooling surfaces. Thus, the term "cold plate surfaces" as used herein is intended to include cooling surfaces formed in any of the described manners either of platecoil material, or as double walled water cooled walls, or as water cooled pipe coils.

Accordingly, the present invention provides a new and different forced circulated cooling apparatus for a continuous strip furnace which incorporates the new and advantageous features described, overcome 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 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-combinatons and elements, and mechanical equivalents apparent to those skilled in the art are set forth in the appended claims.

I claim:

1. Apparatus for cooling continuously moving strip including an elongated cooling duct having a strip entrance and exit points, means for passing hot strip metal longitudinally through said cooling duct, cooling means associated with interior surfaces of said cooling duct and located generally parallel with the plane of the strip and on opposite sides thereof, a return duct system divided into two portions by a plurality of partition walls communicating with said cooling duct adjacent said entrance and exit points and at an intermediate point, one wall of said return system being formed by said cooling means, means for supplying protective atmosphere cooling medium gas to said ducts, and fan means for circulating said cooling medium through said ducts, the fan means being so constructed and connected with said ducts that the flow of cooling medium between said strip entrance point and said intermediate point is in one direction relative to the direction of strip travel, and that the flow of cooling medium in said cooling duct between said strip exit point and said intermediate point is in the opposite direction relative to the direction of strip travel.

2. The construction set forth in claim 1 in which the cooling means comprises water cooled cold plate surfaces positioned in the cooling duct relatively close to the strip, and in which the cooling medium circulated through the cooling duct is in simultaneous contact with the cold plate surfaces and the surfaces of the strip.

3. The construction set forth in claim 1 in which the cooling medium flow induced by the fan means is in opposite directions in the entrance and exit portions of the cooling duct, whereby the pressures at the strip entrance and exit points are maintained substantially equal.

4. In apparatus for cooling continuously moving strip, walls forming a cooling duct through which the strip is adapted to pass, another wall spaced from one of the cooling duct walls and forming therewith a return duct, a first partition wall transverse the return duct walls and located intermediate the ends of the return duct walls, a second partition wall spaced from the first partition wall between the first partition wall and one end of the return duct transverse the return duct walls, means connected with the first and second partition walls forming a suction box, means communicating between the suction box and cooling duct on both sides of the strip, circulating fan means having an inlet communicating with the suction box and having an outlet communicating with the return duct adjacent the second partition wall and between the second partition wall and said one end of the return duct, said circulating fan means discharging controlled atmosphere into said return duct through said outlet and withdrawing controlled atmosphere from said cooling duct through said suction box, there being an opening formed at said one end of the return duct in one of the return duct walls forming a communication between the return duct and the adjacent end of the cooling duct on one side of the strip, manifold means connected with said one end of the return duct and said adjacent end of the cooling duct on the other side of the strip, and cooling surface means associated with an interior surface of the cooling duct on either side of the strip.

5. The construction set forth in claim 4 in which the cooling surface means includes cold plate surfaces extending in close proximity to and substantially parallel with both sides of the strip.

6. The construction set forth in claim 4 in which the cooling surface means comprise cold plate surfaces forming the top and bottom wall interior surfaces of the cooling duct.

7. The construction set forth in claim 4 in which the cooling surface means are formed as water cooled surfaces, and in which at least one of the walls of the return duct also has cooling surface means associated with an interior surface thereof.

8. The construction set forth in claim 4 in which the cooling surface means comprise cold plate surfaces forming the top and bottom walls of the cooling duct, and in which the cooling surface means further comprise cold plate surfaces in the return duct.

9. The construction set forth in claim 4 in which the cooling surface means comprise a cold plate surface wall forming the top wall of the cooling duct, a cold plate surface wall forming a common wall between the cooling duct and the return duct, and cold plate surface means disposed in the return duct spaced from said cold plate surface common wall.

10. In apparatus for cooling continuously moving strip, walls forming a cooling duct through which the strip is adapted to pass, another wall spaced from one of the cooling duct walls and forming therewith a return duct, spaced partition walls transverse the return duct

walls and located intermediate the ends of the return duct walls, suction box means connected with the spaced partition walls, means communicating between the suction box means and cooling duct on both sides of the strip, circulating fan means having inlet communication with the suction box means and having outlet communication with the return duct between the partition walls and the ends of the return duct, said circulating fan means discharging controlled atmosphere into said return duct through said outlet communication and withdrawing controlled atmosphere from said cooling duct through said suction box means, there being an opening formed at each end of the return duct in one of the return duct walls forming communication between the return duct and the corresponding end of the cooling duct on one side of the strip, manifold means connected with the return duct and the adjacent end of the cooling duct on the other side of the strip at each end of the return duct, and cooling surface means associated with an interior surface of the cooling duct on either side of the strip.

11. In apparatus for cooling continuously moving strip, walls forming a cooling duct having entrance and exit ends through which the strip is adapted to pass, another wall spaced from one of the cooling duct walls and forming therewith a return duct substantially coextensive with the cooling duct from entrance to exit ends of the cooling duct, a first partition wall transverse the return duct walls and located intermediate the ends of the return duct walls, a second partition wall spaced from the first partition wall between the first partition wall and the entrance end of the return duct transverse the return duct walls, a third partition wall spaced from the first partition wall between the first partition wall and the exit end of the return duct transverse the return duct walls, means connected with the first and second partition walls forming a first suction box on the entrance side of the first partition wall, means connected with the first and third partition walls forming a second suction box on the exit side of the first partition wall, means communicating between the first suction box and cooling duct on both sides of the strip, means communicating between the second suction box and the cooling duct on both sides of the strip, first circulating fan means having an inlet communicating with the first suction box and having an outlet communicating with the return duct adjacent the second partition wall and between the second partition wall and the entrance end of the return duct, second circulating fan means having an inlet communicating with the second suction box and having an outlet communicating with the return duct adjacent the third partition wall and between the third partition wall and the exit end of the return duct, said circulating fan means discharging controlled atmosphere into said return duct through said outlets and withdrawing controlled atmosphere from said cooling duct through said suction boxes, there being openings formed at the entrance and exit ends of the return duct in one of the return duct walls forming communication respectively between the entrance and exit ends of the return and cooling ducts on one side of the strip, manifold means connected at each end of the return duct with the corresponding end of the cooling duct on the other side of the strip, and cooling surface means associated with an interior surface of the cooling duct on either side of the strip.

12. In apparatus for cooling continuously moving strip, substantially coextensive walls forming side by side cooling and return ducts having entrance and exit ends with a common wall therebetween, the strip being adapted to pass through the cooling duct, means forming communication respectively between the entrance and exit ends of the return and cooling ducts on one side of the strip through the common wall, manifold means connected respectively between the entrance and exit ends of the return duct and the cooling duct on the other side of the strip, spaced partition walls transverse the return duct walls and located intermediate the ends of the return duct walls, suction box means connected with the spaced partition walls, means communicating between the suction box means and cooling duct on both sides of the strip, circulating fan means having inlet communication with the suction box means and having outlet communication with the return duct between the partition walls and the ends of the return duct; said circulating fan means discharging controlled atmosphere into said return duct through said outlet communication along the return duct in each direction to the ends thereof, then through the common wall communication between the return duct and the cooling duct at the ends thereof, then along the cooling duct from either end toward the location of the suction box means, and then into and through the suction box means and through the inlet communication to the fan means; cooling surface means associated with an interior surface of the cooling duct on either side of the strip and associated with at least one wall of the return duct, and the common wall between the cooling and return ducts being formed as a cold plate surface wall.

13. Apparatus for cooling continuously moving strip in a controlled atmosphere comprising first and second walls forming a cooling duct having entrance and exit ends through which strip is adapted to pass in one direction, a third wall spaced from and parallel to the second wall forming with the second wall a return duct coextensive with the cooling duct from entrance to exit ends thereof, the second wall having an aperture at each end providing communication between corresponding ends of the cooling duct and the return duct on one side of the strip, means communicating between one end of the return duct and one end of the cooling duct on the other side of the strip, means communicating between the other end of the return duct and the other end of the cooling duct on the other side of the strip, three spaced partition walls transverse the return duct and located intermediate the ends of the return duct, means connected with said partition walls forming first and second suction box means, means communicating between each suction box means and the cooling duct on both sides of the strip, first and second circulating fan means having inlet communications respectively with the first and second suction box means and having outlet communications with the return duct respectively between the partition walls and the entrance and exit ends of the return duct, the fan means circulating controlled atmosphere cooling medium at high velocity through a portion of said cooling duct on both sides of the strip in the direction of strip travel and through the remainder of the cooling duct on both sides of the strip in a direction contra to the direction of strip travel, and cooling surface means forming the walls of the cooling duct and at least one wall of the return duct.

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