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(54) **Method and apparatus for cooling steel strips.**

(57) A method and apparatus for cooling steel strips by means of a cooling liquid in a continuous annealing line. The cooling liquid is forced to flow as steady flows along both surfaces of a steel strip in directions opposite to moving directions of the steel strip. An apparatus comprises flow rectifier plates in opposition to both the surfaces of the steel strip to form flow passages between the steel strip and the flow rectifier plates for forcing the cooling liquid through the flow passages, at least one cooling liquid supply port on a downstream side of the moving steel strip and at least one cooling liquid exhaust port on an upstream side of the moving steel strip. In order to control the cooled steel strip temperature, part of the cooling liquid used for cooling the steel strip is mixed with fresh cooling liquid to control temperature of cooling liquid to be used for cooling by adjusting a mixing ratio of the used and fresh cooling liquids, thereby keeping temperature of the cooled steel strip within a predetermined target temperature range.

EP 0 210 847 A2

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METHOD AND APPARATUS FOR COOLING STEEL STRIPS

This invention relates to a method of cooling steel strips in continuous annealing lines and an apparatus for carrying out the method, and more particularly to a method and an apparatus for effectively cooling steel strips to target temperatures in controlled manner irrespective of change in amount of the steel strips and change in temperature of supplied cooling water due to seasonal factors.

Steel strips to be surface-treated or used for deep-drawing are generally subjected to heat-treatment such as heating, soaking and cooling in succession, so called "continuous annealing" after cold rolling in order to give predetermined mechanical properties to the steel strips.

Recently, it has been widely used to pass steel strips at higher speeds through the above continuous annealing lines to increase the treating capacity to great extent for reasons such as increased demand of very thin steel strips less than 0.3 mm. Accordingly, furnace installations for continuous annealing have been unavoidably elongated and enlarged to give rise to problems such as construction cost and spaces and in operation which will be explained hereinafter.

Namely, as the furnaces become elongated and enlarged, so-called "thermal inertia" of the furnaces increases to take much time for varying heat-treatment conditions, and other various problems arise such as serpentine movements of steel strips and heat-buckle.

This invention intends to effectively solve the problems particularly in the last cooling stage among the various problems arising with the operation of furnaces at high speeds.

As cooling methods used for the continuous annealing treatment, there have been the gas-jet cooling, roll cooling and immersing cooling, which carry out the cooling by jetting cooled atmosphere gas against steel strips, winding steel strips about rolls in which a cooling medium passes, and immersing steel strips in a cooling bath, respectively. The cooling speed increases in order of the gas-jet cooling, roll cooling and immersing cooling.

In case of cooling steel strips in a cooling zone in a continuous annealing line from a recrystallization temperature to a temperature at which they do not oxidize in the air, it is generally considered that the most effective cooling is to use the gas-jet cooling and/or roll cooling on a high temperature side and the immersing cooling on a low temperature side.

Various immersing cooling methods have been proposed. For example, Japanese Patent Application Publications Nos. 11,931/82 and 11,933/82 disclosed cooling methods wherein a plurality of cooling baths are used controlling supply of the cooling water or spray cooling or mist cooling is combined with immersing cooling to cool steel strips effectively, while furthermore the temperature of the cooling water used for cooling is made as high as possible to use it advantageously as hot water.

The immersing cooling is usually used in cooling steel strips from temperatures of the order of 250-300°C at which saturated solid solution carbon scarcely changes to temperatures at which temper color does not occur in the air. When the cooling speeds in such an immersing treatment are too fast, it encounters a difficulty as to aging due to solid solution carbon. Recently, non-aging material has been used such as very low-carbon added with Nb whose solid solution carbon is previously fixed by a third element. With such a non-aging material, any high cooling speed does not cause any problem. Therefore, it has been expected to increase the cooling speed in the final cooling in order to achieve higher speed operation, higher productivity and higher efficiency.

However, the immersing cooling methods as disclosed in the Japanese Patent Application Publications Nos. 11,931/82 and 11,933/82 include the following problems.

(1) It is necessary to supply the cooling water into the cooling bath in order to prevent the temperature rise of the cooling water. In this case, however, the cooling water flows only in an upper layer in the bath but scarcely flows in a lower layer. As a result, when a hot steel strip is immersed into the cooling water, steam films occur on surfaces of the strip owing to the relatively lower temperature cooling water in the upper layer. As it is difficult to remove or break the steam films, the cooling efficiency has a limitation unavoidably. In order to increase the cooling speed and efficiency, therefore, immersing cooling apparatus need to be large-sized to disadvantageously increase construction cost and spaces. Moreover, it is almost impossible to modify existing apparatuses for the purpose of increasing the cooling speed.

(2) As above described, the cooling water does not flow uniformly everywhere in the bath, so that the temperature distribution is not uniform, adversely affecting the steel strips to be cooled.

(3) In case of using the cooling water exhausted from the immersing cooling bath as hot water, at least two immersing baths are needed which make the apparatus large-sized, and complicated controlling such as cascade controlling is required.

Fig. 1 illustrates variations in heat transfer coefficient when steel strips are cooled in the manner of the prior art. The ordinate indicates the heat transfer coefficient and the abscissa denotes temperature difference between the steel strips and the cooling water. Black points and black triangular points indicate data when the steel strips are fed in parallel directions and vertical directions relative to surfaces of the cooling water.

Within the range in which the temperature difference between the strips and cooling water is small, the heat transfer coefficient increases as the temperature difference increases, because steam films scarcely occur on the surfaces of the strips. As the temperature difference further increases, steam films occur violently to separate the cooling water and steel strips by thick steam films which would adversely affect the cooling effect. This tendency is acute in the zone where the temperature difference is larger. As a result, the heat transfer coefficient is lowered as shown in the right hand of Fig. 1.

As seen from Fig. 1, the heat transfer coefficient in case of the horizontal feeding of the strips is somewhat larger than that of the vertical feeding. It is considered that the steam escapes upward easier in the latter case than in the former case.

There is an upper limitation of the heat transfer coefficient, at the most 5,000 Kcal/$m^2 \cdot h \cdot {}^\circ C$ in the cooling methods of the prior art.

It is an object of the invention to provide a method and apparatus for cooling steel strips, which eliminate all the disadvantages of the prior art and carry out the cooling treatment of steel strips with high efficiency.

In order to achieve this object, according to the invention said cooling liquid is forced to flow as steady flows along both surfaces of a steel strip in directions opposite to moving directions of the steel strips.

According to the invention, the apparatus for cooling steel strips by means of a cooling liquid, comprises flow rectifier plates in opposition to both surfaces of a steel strip to form flow passages between the steel strip and the flow rectifier plates for forcing the cooling liquid through said flow passages, at least one cooling liquid supply port on a downsteam side of the moving steel strip and at least one cooling liquid exhaust port on an upstream side of the moving steel strip.

It is another object of the invention to provide a method and apparatus for cooling steel strips, which control temperatures of cooled steel strips at an exit to alway stably cool the steel strips to temperatures of a predetermined range without being affected by the normally expected factors such as amount of steel strips to be cooled, cooling water temperature and the like.

In order to achieve this object, according to the invention, part of the cooling liquid used for cooling the steel strip is mixed with fresh cooling liquid to control temperature of cooling liquid to be used for cooling by adjusting a mixing ratio of the used and fresh cooling liquids, thereby keeping temperature of the cooled steel strip within a predetermined target temperature range.

To carrying out this feature, the apparatus according to the invention comprises a control system which comprises a thermometer, a flow adjusting valve and a flow meter respectively for the cooling water exhausted from the flow passages, a thermometer, a flow adjusting valve and a flow meter respectively for the cooling water newly supplied to the flow passage, a thermometer for detecting temperature of the steel strip leaving the flow passages, an arithmetic unit for calculating amounts of the exhaust and new cooling waters to be mixed, flow controllers for controlling the flow adjusting valves in response to signals from the arithmetic unit, and a mixer for mixing the exhaust and new cooling waters through the flow adjusting valves.

In order that the invention may be more

clearly understood, preferred embodiments will be described, by way of example, with reference to the accompanying drawings.

Fig. 1 is a graph illustrating a relationship between heat transfer coefficient and temperature difference between steel strip and cooling water in immersing cooling according to the prior art;

Fig. 2 is a schematic perspective view illustrating the principle of cooling according to the invention;

Fig. 3 is a graph illustrating a relation between relative speed v_r cooling water to steel strips and heat transfer coefficient α;

Fig. 4 is a sectional view illustrating a cooling apparatus according to the invention;

Fig. 5 is a perspective view of the apparatus shown in Fig. 4;

Figs. 6, 7 and 8 are schematic views illustrating other embodiments of the invention;

Fig. 9 is a schematic view illustrating another embodiment of the invention;

Fig. 10 is a sectional view of a principal part of the apparatus shown in Fig. 9;

Fig. 11 is a graph illustrating a relation between cooling water temperature at entry and steel strip temperature at water cooling jacket exit with constant amount of steel strips;

Fig. 12 is a graph illustrating a relation between amount of steel strips and steel strip temperature at water cooling jacket exit with cooling water temperature at entry being substantially constant;

Fig. 13 is a schematic view illustrating the cooling apparatus with a control system for maintaining the cooled steel strip temperature according to the invention;

Fig. 14 is a flow chart for the control system shown in Fig. 13;

Fig. 15 is a graph illustrating a relation between amount of steel strips and steel strip temperature at water cooling jacket exit when cooled steel strip temperature is controlled according to the invention; and

Fig. 16 is a graph illustrating a relation between amount of steel strips and steel strip temperature at water cooling jacket exit when cooled steel strip temperature is controlled in actual operation according to the invention.

Fig. 2 illustrates symbolically the cooling method according to the invention wherein a steel strip S is raised upward. A cooling water W conditioned in a steady flow is supplied onto one side of the steel strip S. The cooling water W is turned downward at a location where it is in contact with the strip to flow in a direction opposite to a moving direction of the strip.

As above described, the cooling water as a whole is forced to flow opposing to the movement of the steel strip S, thereby eliminating any staying of the cooling water which would occur in the prior art cooling method and rapidly removing or breaking steam films produced on the surfaces of the steel strip. Accordingly, high efficiency cooling of the steel strip can be accomplished.

Assuming that the moving speed of the steel strip S is v_s(m/s), the flowing speed of the cooling water is v_w(m/s), and the downward direction is positive, the relative speed v_r(m/s) of the cooling water W with respect to the steel strip S is indicated by the following equation.

$$v_r = v_w - v_s \qquad \ldots \quad (1)$$

The inventors investigated the relation between such relative speed v_r and heat transfer coefficient α (Kcal/m$^2 \cdot$h$\cdot$°C). Results of the investigation are shown in Fig. 3. As seen from Fig. 3, the heat transfer coefficient α becomes larger in proportion to the relative speed v_r. It has been found that the relation therebetween is approximately indicated by an equation (2).

$$\alpha = 5600\ v_r^{0.68} \qquad \ldots \quad (2)$$

In this case, when the relative speed v_r is for example 10 m/s, the heat transfer coefficient α is 26,800 Kcal/m²·h·°C.

Referring back to Fig. 3, the heat transfer coefficient is at the most 5,000 Kcal/m²·h·°C in the cooling method of the prior art which is only less than a fraction of those in the present invention.

Fig. 4 illustrates in section a preferred embodiment of the invention whose principal part is shown in the perspective view of Fig. 5. Flow rectifier plates 1a and 1b are arranged on both side of and in parallel with a steel strip S to form a cooling water jacket for introducing a cooling water along both surfaces of the steel strip under rectified or steady condition. Sealing rolls 2a, 2b and 3a and 3b serve to prevent the cooling water from escaping at front and rear ends of the flow rectifier plates. Reference numeral 4b denotes sealing plates provided on both sides of the rectifier plates. These sealing plates are jointed to form sealings at the sides of the rectifier plates, which prevent the cooling water from escaping at the sides of the rectifier plates and at the same time serve to position the rectifier plates in assembling.

The rectifier plates are provided with

cooling water inlets 5a and 5b and cooling water outlets 6a and 6b. Pressure pumps 7a and 7b supply the cooling water into the water cooling jacket formed by the rectifier plates. Deflector rolls 8 and 9 serve to turn the moving direction of the steel strip S.

The cooling water introduced through the inlets 5a and 5b into the jacket formed by the rectifier plates flows in clearances or flow passages formed by the steel strip S and the flow rectifier plates 1a and 1b in directions opposite to the moving direction of the strip S and leaves through the outlets 6a and 6b provided at the other end of the jacket. In this manner, the effective cooling is achieved by forcing the cooling water through the relatively narrow clearances between the steel strip S and the flow rectifier plates 1a and 1b.

Figs. 6-8 illustrate modifications of the cooling apparatus according to the invention. The apparatus shown in Fig. 6 comprises three sets of flow rectifier plates along the moving line of the steel strip S. Apparatuses shown in Figs. 7 and 8 comprise flow rectifier plates arranged in U and W shapes, respectively.

Final cooling of steel strips was effected using the cooling apparatus shown in Fig. 4 under the following conditions.

Dimension of steel strip	Thickness: 0.3 mm, Widthness: 900 mm
Treated strip	60 T/h
Temperature of strip at commencement of cooling	150°C
Temperature of supplied cooling water	30°C
Temperature of strip after cooled	60°C
Thickness of cooling water flow passage	about 6 mm

The cooling water used for the above treatment was approximately 40 T/h. The temperature of the cooling water on the exit side was about 70°C.

The steel strips were uniformly cooled in their width direction by the above cooling treatment. Ununiform cooling and troubles caused by steam films were completely prevented.

According to the method of the prior art, cooling water of about 60 T/h was required for treating the same amount of steel strips as the above. Therefore, considerable saving of cooling water was accomplished according to the invention.

As can be seen from the above description, according to the invention steel strips are cooled with remarkably high efficiency in comparison with the prior art. Accordingly, the treating faculty in the continuous annealing treatment is considerably increased. Moreover, the invention can provide a small-sized cooling apparatus.

Referring to Fig. 9 illustrating another embodiment of the invention, if a water cooling jacket is formed in a U-shape, a leg portion 31c of the U-shaped jacket into which a steel strip is introduced tends to obstruct the flow of the cooling water. In order to obtain a large cooling faculty, therefore, it is required to consider the resistance of the leg portion 31c to the water flow. This resistance Δh can be calculated by the following equation according to the theory of weir.

$$\Delta h=\left(\frac{3Q}{2\times C\times B\times\sqrt{2g}}\right)^{2/3}\times 10^{3}=683\times\left(\frac{Q}{B}\right)^{2/3} \quad \ldots \quad (3)$$

where Δh is difference in water head (mm), Q is flow rate (m^3/s), C is coefficient of resistance (≅0.6), B is width of jacket (width of weir) and g is acceleration of gravity.

Accordingly, the cooling water flows smoothly without obstructing the cooling effect, if the difference h in level between surfaces of water in the legs 31a and 31c is determined to fulfil the following equation.

$$h \geqq 683 \times \left(\frac{Q}{B}\right)^{2/3} \quad \ldots \quad (4)$$

In the present invention, the clearances between the steel strip and the flow rectifier plates are very small, so that the pressure loss tends to be large. Accordingly, it is required to increase the capacity of the cooling water supply pumps and power required for driving the pumps. In order to solve this problem, nozzles 36 are preferably provided for assisting the flow of cooling water as shown in Figs. 9 and 10. As shown in Fig. 10, slit nozzles 36 are arranged in the cooling jacket in the moving direction of the strip or somewhat inclined to the strip for jetting cooling water, which will compensate for the pressure loss due to the cooling water jacket. The nozzles 36 are supplied with cooling water through piping 37 by means of a supply pump 8. Although the nozzles 36 are arranged one on each side of the steel strip, a plurality of nozzles may be provided on each side of the strip.

Moreover, the steel strip between deflector rolls 32 in the horizontal portion 31b of the water cooling jacket tends to deform in catenary to cause difference in cooling effect between upper and lower sides of the strip. In this case, it is considered to increase the tensile force acting upon the strip to reduce the catenary deformation of the strip. However, such a tensile force has a limitation because too high tensile force causes breakage of the strip. In order to prevent this, it is effective to incline the horizontal portion of the cooling water jacket as shown in Fig. 9. It is preferable to locate the end of the horizontal portion 31b on the side of the leg 31a higher than the other end on the side of the leg 31b in consideration of the flowing direction of the cooling water.

According to the above embodiments, steel strips can be cooled with higher efficiency in comparison with the prior art, thereby enabling the treating capacity of the continuous annealing to be remarkably improved.

In the above embodiments, however, the temperature of steel strips subjected to the cooling treatment is sometimes changed out of a predetermined temperature with variation in amount or weight of steel strips to be treated and with variation in supplied cooling water temperature, for example, due to seasonal variation.

Fig. 11 illustrates the relation between the supplied cooling water temperature and the temperature of cooled steel strips in case of the amount or weight of the steel strips 40 T/h passed through the cooling apparatus. As seen from Fig. 11, the temperature of the cooled steel strips becomes out of the predetermined temperature range when the supplied cooling water temperature is too high or low.

Fig. 12 illustrates the result of investigating the relation between the amount or weight of steel strips and the temperature of cooled steel strips in two cases of the cooling water temperature of 40°C and 30°C. It is clearly evident that as the amount of the steel strips increases, the temperature of the cooled steel strips becomes higher and frequently out of the predetermined temperature range.

Following embodiments have for their objects to provide a method of controlling temperatures of cooled steel strips at an exit of the cooling apparatus to always stably cool the steel strips to temperatures within a predetermined range without being affected by the normally expected factors such as amount of steel strips to be cooled, cooling water temperature and the like.

Fig. 13 schematically illustrates a control system together with a cooling apparatus with a cooling jacket. Flow rectifier plates 11a and 11b form a water cooling jacket 11 for forcedly introducing a cooling water along both surfaces of steel strips under a steady condition. Deflector rolls 12 turn the steel strip in the water cooling jacket 11 which is supplied with the cooling water through a cooling water supply pipe 13. A reservoir 14 for storing the used cooling water is provided with a pump 15.

With the cooling apparatus constructed as above described, the cooling water is introduced into the water cooling jacket at a supply port provided on a downstream side of a moving passage of the steel strip S and is forced through the water cooling jacket 11 in a direction opposite to a moving direction of the steel strip during which the cooling water cools the steel strip with high efficiency until the cooling water leaves an exhaust port. According to the embodiment, a part of the cooling water exhausted from the apparatus is circulated to use again for adjusting the temperature of the cooling water.

The cooling system comprises a return pipe 16 for circulating the exhausted cooling water, a thermometer 17 for detecting the temperature of the exhausted cooling water, a flow adjusting valve 18 for the circulating water, a flow meter 19 for the circulating water, a fresh cooling water supply pipe 20 including a thermometer 21, a flow adjusting valve 22 and a flow meter 23 for the fresh cooling water, and a thermometer 24 for detecting the temperature of steel strips leaving the cooling apparatus.

An arithmetic unit 25 calculates amounts of the circulating and fresh cooling waters to be mixed with each other to obtain cooling water at a predetermined temperature on the basis of data detected by the respective detectors. The calculated results are inputted into flow controllers 26 and 27 whose output adjust openings of the flow adjusting valves 18 and 22, respectively. In this manner, the circulating and fresh waters adjusted in their required amounts are mixed in a mixer 28 to obtain cooling water at a predetermined temperature which is supplied through the supply pipe 13 into the cooling jacket 11. Reference numeral 29 denotes wringer rolls for removing water from steel strips leaving the water jacket.

The arithmetic operation in the arithmetic unit 25 will be explained hereinafter.

It is assumed that an allowable temperature range of a target cooling temperature T_{so} is as indicated by the following formula (5).

$$T_{so1} \leqq T_{so} \leqq T_{so2} \qquad \ldots \quad (5)$$

An amount Q of cooling water to be supplied is indicated by amounts Q_c and Q_N of the circulating and fresh cooling waters as follows.

$$Q = Q_c + Q_N \qquad \ldots \quad (6)$$

There is a relation (7) between a set cooling water temperature T_w, circulating water temperature T_{wc} and fresh cooling water temperature T_{WN}.

$$Q_c : Q_N = \frac{T_w - T_{WN}}{T_{wc} - T_{WN}} : \frac{T_{wc} - T_w}{T_{wc} - T_{WN}}$$

Namely,

$$(T_w - T_{WN})Q_N = (T_{wc} - T_w)Q_c \qquad \ldots \quad (7)$$

From the equations (6) and (7), values of Q_c and Q_N are calculated.

$$Q_c = \frac{T_w - T_{WN}}{T_{wc} - T_{WN}} Q \qquad \ldots \quad (8)$$

$$Q_N = \frac{T_{wc} - T_w}{T_{wc} - T_{WN}} Q \qquad \ldots \quad (9)$$

First, whether the steel strip temperature T_{so}, detected by the thermometer 24 is in the range of the equation (5) is judged. When it fulfills the equation (5), values of Q_c and Q_N are calculated on the basis of the detected temperature T_{WN} and T_{wc} by means of the equations (8) and (9).

On the other hand, if the steel strip temperature T_{so}, is above an upper limit, the set cooling water temperature T_w is lowered by a constant value.

$$T_w = T_w - a \qquad \ldots \quad (10)$$

On the contrary, if the steel strip temperature T_{SO}, is below a lower limit, the set cooling water temperature T_w is raised by a constant value.

$$T_w = T_w + a \qquad \ldots (11)$$

Next, amounts of circulating and fresh cooling water Q_C and Q_N are calculated on the basis of a newly set water temperature T_w by the use of the equations (8) and (9). In this case, the water temperatures T_{WC} and T_{WN} detected by the thermometers 17 and 21 are used.

The above operation is summarized as a flow chart shown in Fig. 14.

Fig. 15 illustrates the relation between the steel strip temperature at exit and amount or weight of steel strips when the cooling water temperature is controlled in the manner above described.

Steel strips were cooled by the use of the cooling apparatus and the control system shown in Fig. 13 under the following conditions.

Dimension of steel strips:	1 mm thickness, 2000 mm width
Amount of cooling water :	13.2 T/h (Fresh cooling water: 3.3 T/h, Circulating cooling water: 9.9 T/h)

Cooling water temperature:	(Fresh cooling water: 10°C, Circulating cooling water: 50°C)
Target temperature after cooled :	50-60°C
Initial amount of steel strips :	20 T/h

Under the above conditions, the amount or weight of the steel strips to be passed was progressively increased. When the amount became 40 T/h, the temperature of the steel strips at the exit was about to exceed the upper limit of the target temperature 60°C. The ratio of the fresh cooling water to the circulating water was changed to 7.1 T/h to 6.1 T/h to lower the cooling water temperature to 30°C. As a result, the temperature of the cooled steel strips lowered to 50°C. The cooling operation was continued. However, when the amount of steel strips became 65 T/h, there was again a tendency of the cooled steel strip temperature to exceed 60°C. The ratio of the fresh cooling water to the circulating water was changed to 11 T/h to 2.2 T/h to lower the cooling water temperature to 20°C. As a result, the cooled steel strip temperature lowered to 50°C. Thereafter, the cooled steel strip temperature did not exceed 60°C even when the amount of steel strips was increased to 80 T/h. Even when the amount of steel strips was changed from 20 T/h to 80 T/h, the cooled steel strip temperature at the exit was kept within the target temperature within 50-60°C.

According to the invention, the temperature of cooled steel strips in cooling treatment in continuous annealing line can be kept in a predetermined target temperature range without being affected by varying factors such as variation in amount of steel strips.

It is further understood by those skilled in the art that the foregoing description is that of preferred embodiments of the disclosed method and apparatus and that various changes and modifications may be made in the invention without departing from the spirit and scope thereof.

Claims

1. A method of cooling steel strips by means of a cooling liquid in a continuous annealing line, wherein said cooling liquid is forced to flow as steady flows along both surfaces of a steel strip in directions opposite to moving directions of the steel strips.

2. A method as set forth in claim 1, wherein said steel strip is guided through a U-shaped passage in which the steel strip is cooled by the cooling liquid.

3. A method as set forth in claim 1, wherein said steel strip is guided through a W-shaped passage in which the steel strip is cooled by the cooling liquid.

4. A method as set forth in claim 1, wherein part of the cooling liquid is jetted into the cooling liquid cooling and flowing along the surfaces of the steel strip.

5. A method as set forth in claim 1, wherein part of the cooling liquid used for cooling the steel strip is mixed with fresh cooling liquid to control temperature of cooling liquid to be used for cooling by adjusting a mixing ratio of the used and fresh cooling liquids, thereby keeping temperature of the cooled steel strip within a predetermined target temperature range.

6. A method as set forth in claim 1, wherein the steel strip is cooled in a final cooling stage in the continuous annealing line.

7. An apparatus for cooling steel strips by means of a cooling liquid, comprising flow rectifier plates in opposition to both surfaces of a steel strip to form flow passages between the steel strip and the flow rectifier plates for forcing the cooling liquid through said flow passages, at least one cooling liquid supply port on a downstream side of the moving steel strip and at least one cooling liquid exhaust port on an upstream side of the moving steel strip.

8. An apparatus for cooling steel strips as set forth in claim 7, wherein said flow rectifier plates are provided on both sides with sealing plates jointed thereto to prevent the cooling water from escaping at the sides of the rectifier plates.

9. An apparatus for cooling steel strips as set forth in claim 7, wherein said flow passages are formed in U-shaped passages.

10. An apparatus for cooling steel strips as set forth in claim 7, wherein said flow passages are formed in W-shaped passages.

11. An apparatus for cooling steel strips as set forth in claim 9, wherein a cooling liquid surface level on a side of the cooling liquid supply port is higher than that on a side of the cooling liquid exhaust port by a distance h calculated by the following formula,

$$h \geqq 683 \times \left(\frac{Q}{B}\right)^{2/3}$$

where Q is flow rate (m^3/s) of the cooling liquid in the flow passages and B is width of the flow passages.

12. An apparatus for cooling steel strips as set forth in claim 9, wherein a connecting portion for connecting two vertical portions of the U-shaped flow passages is inclined such that one end of the connecting portion on a side of the vertical portion having the cooling liquid supply port is higher than the other end of the connecting portion on a side of the vertical portion having the cooling liquid exhaust port.

13. An apparatus for cooling steel strips as set forth in claim 7, wherein at least one pair of cooling liquid jetting nozzles is provided one on each side of the steel strip in the flow passages, a jetting direction of each the cooling liquid jetting nozzle being directed in parallel with a moving direction of the steel strip or inclined toward the steel strip at some angles.

14. An apparatus for cooling steel strips as set forth in claim 7, wherein said apparatus comprises a control system which comprises a thermometer, a flow adjusting valve and a flow meter respectively for the cooling water exhausted from the flow passages, a thermometer, a flow adjusting valve and a flow meter respectively for the cooling water newly supplied to the flow passage, a thermometer for detecting temperature of the steel strip leaving the flow passages, an arithmetic unit for calculating amounts of the exhaust and new cooling waters to be mixed, flow controllers for controlling said flow adjusting valves in response to signals from the arithmetic unit, and a mixer for mixing the exhaust and new cooling waters through said flow adjusting valves.

FIG_1
PRIOR ART

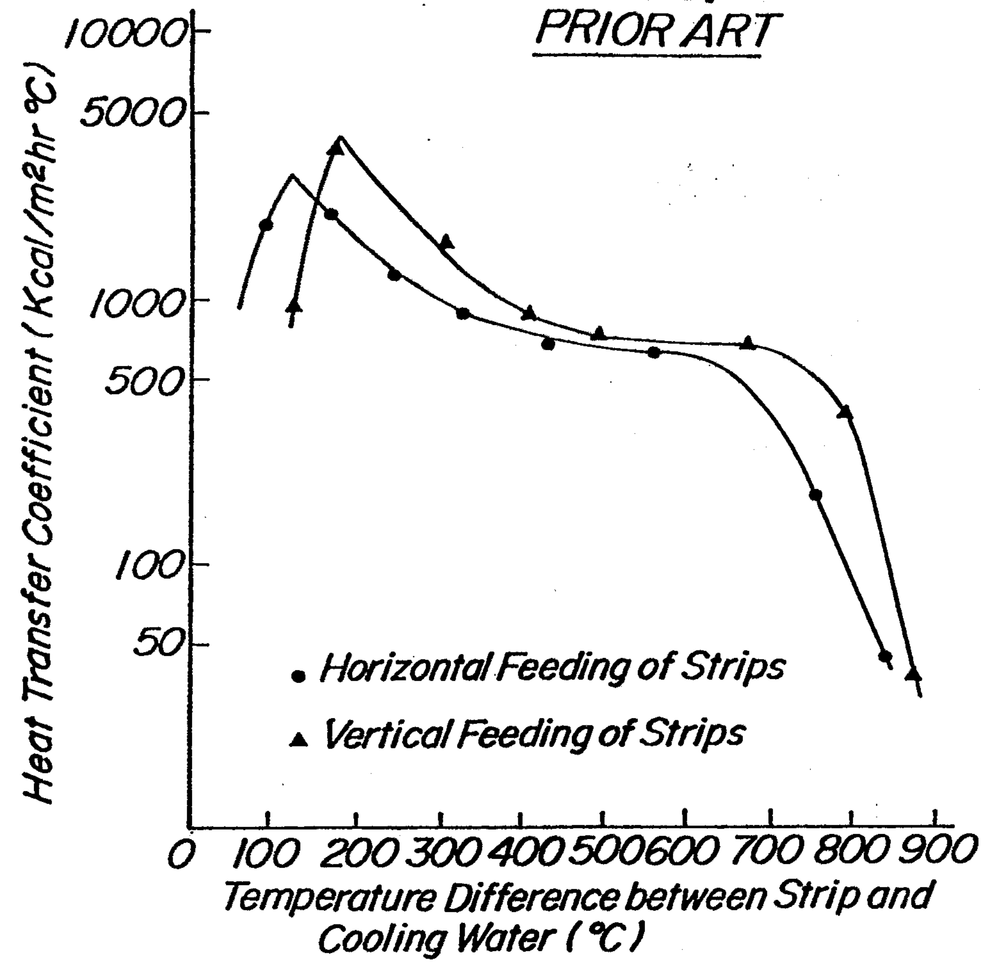


FIG_2

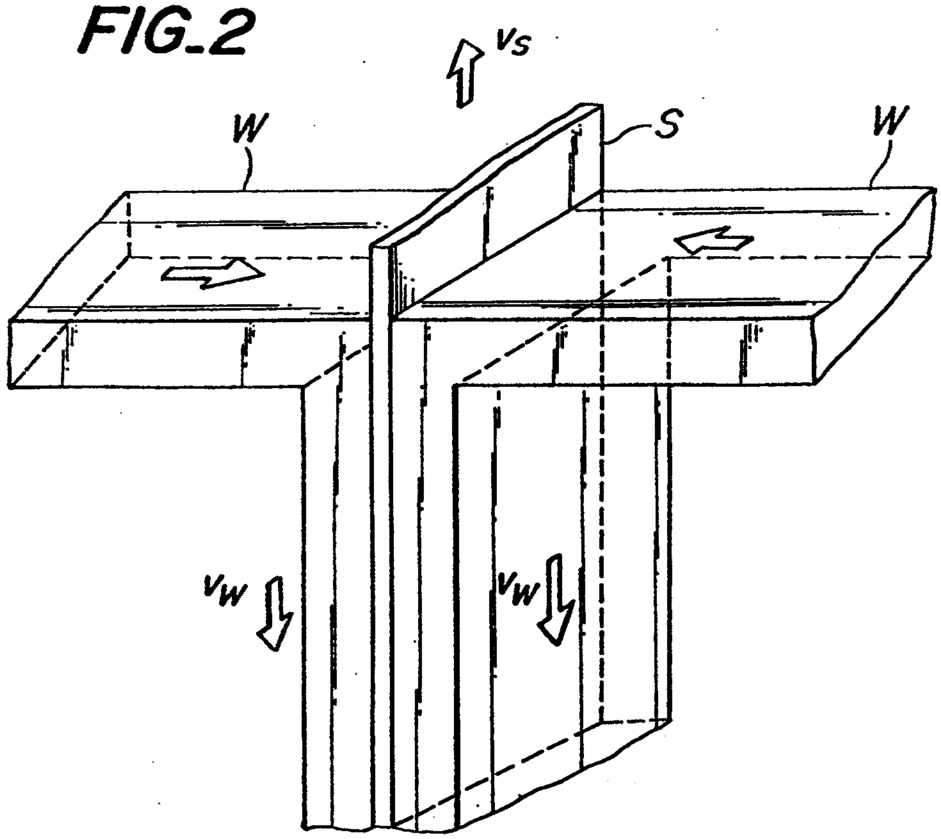


FIG_3

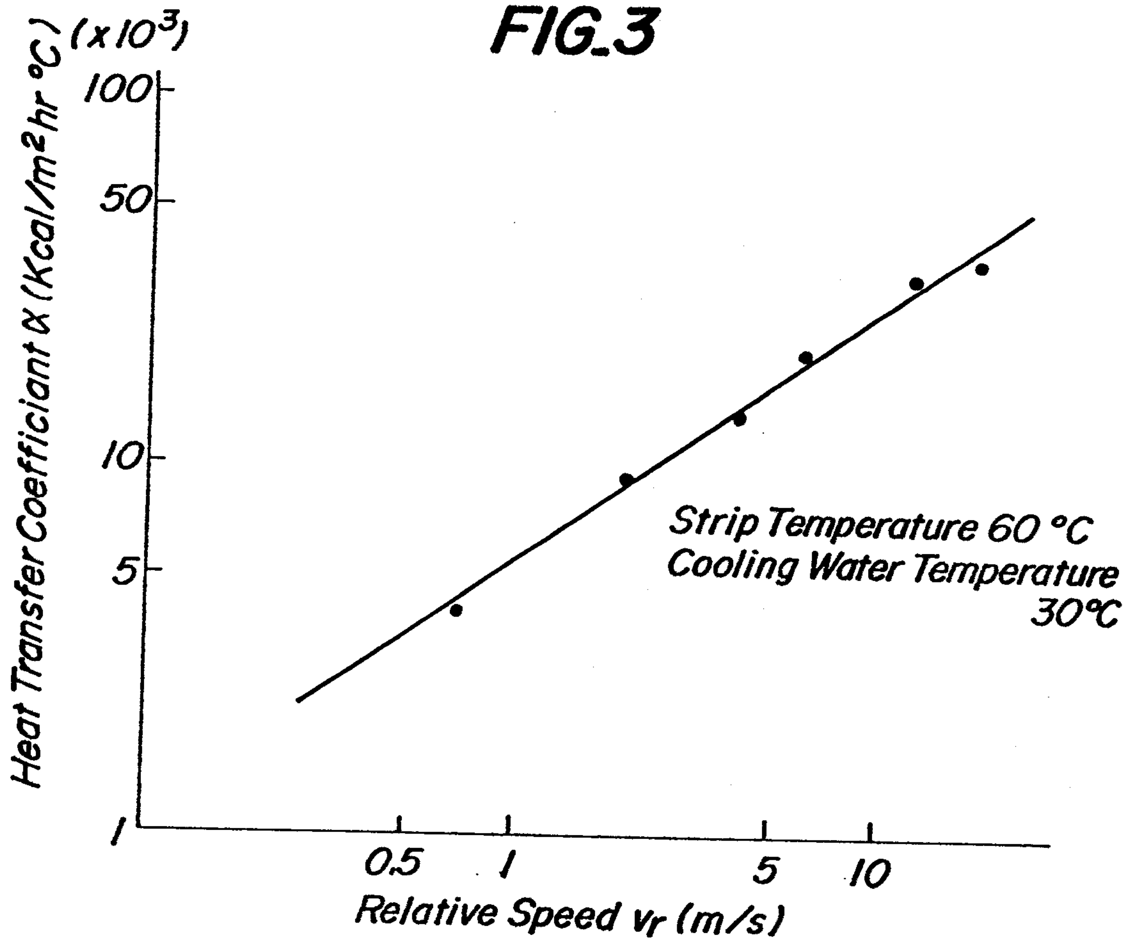


FIG_4

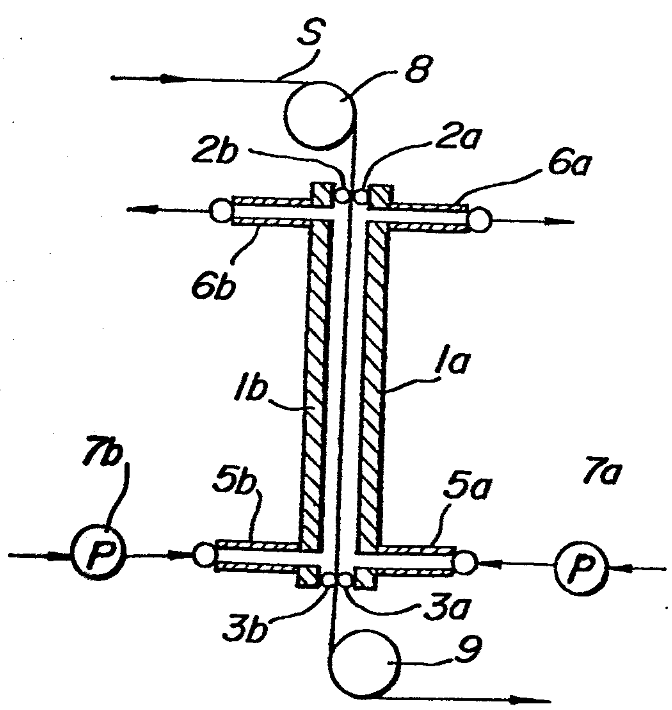


FIG_5

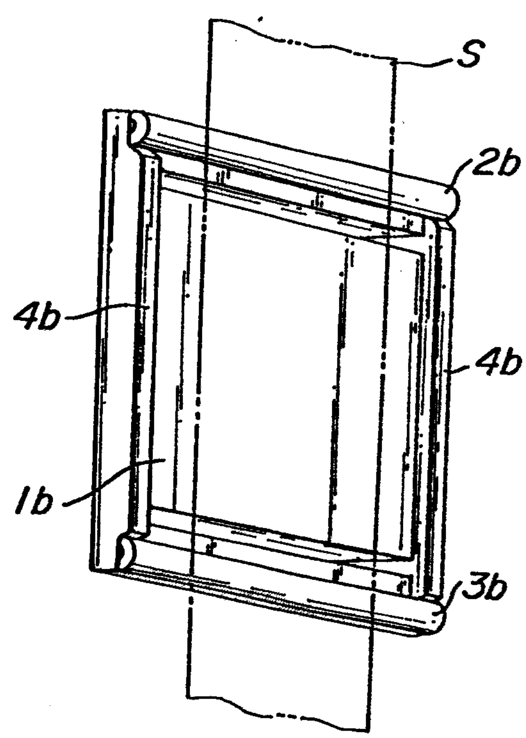


FIG_6

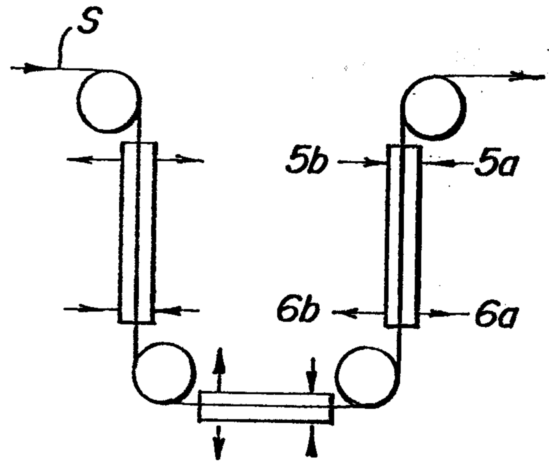


FIG_7

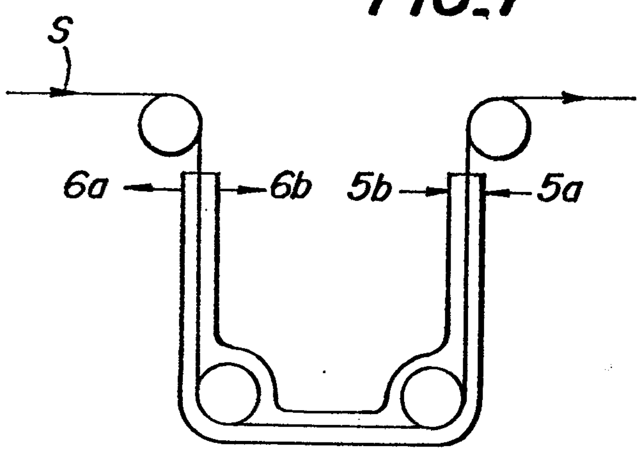


FIG_8

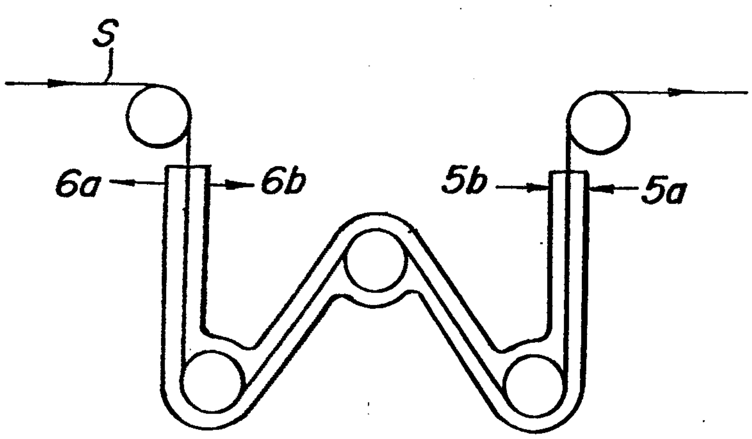


FIG_9

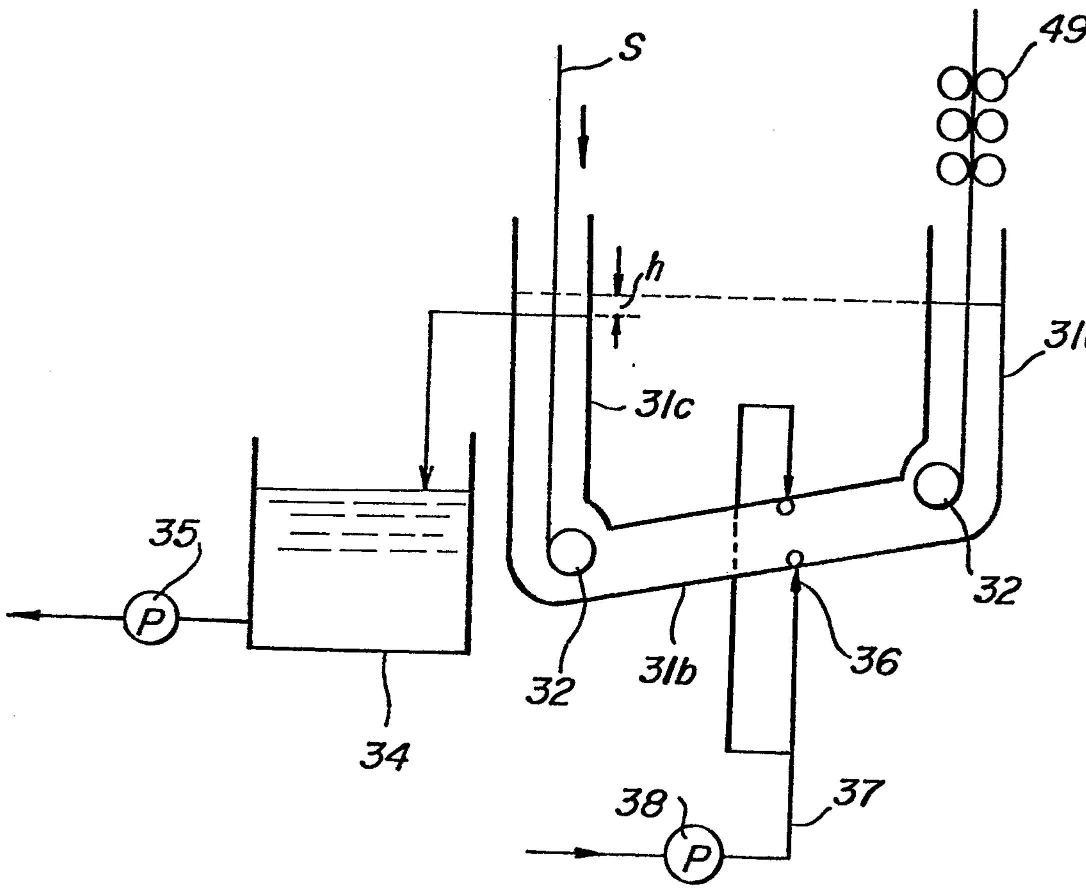


FIG_10

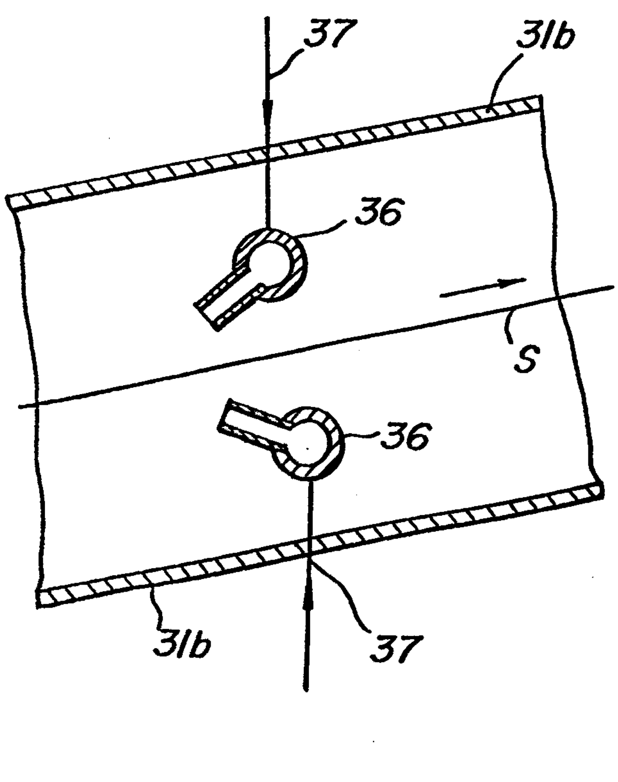


FIG_11

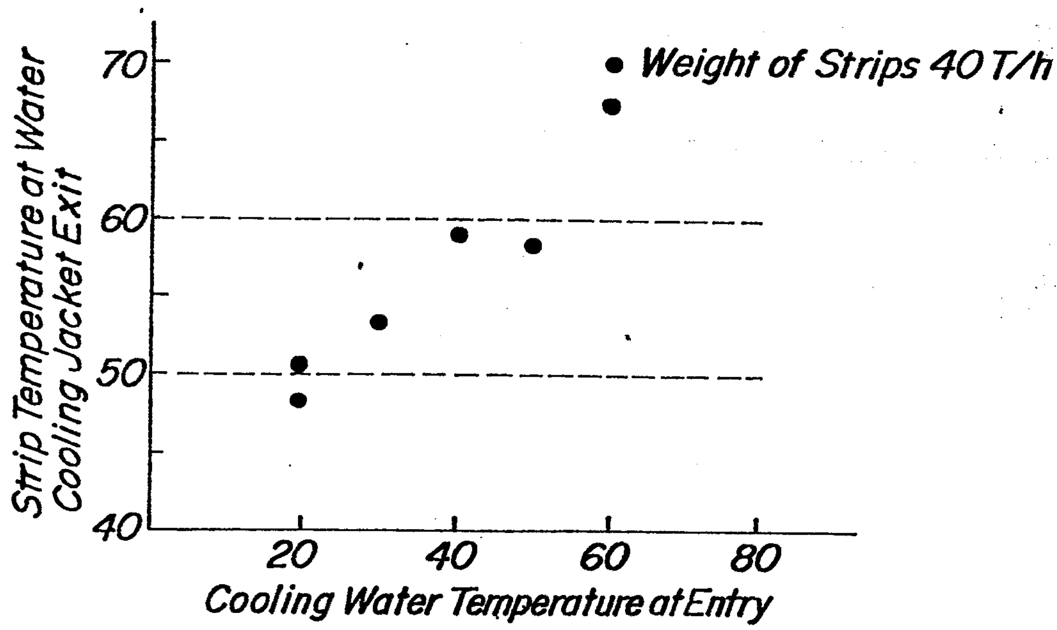

Weight of Strips 40 T/h
Strip Temperature at Water Cooling Jacket Exit
70
60
50
40
20
40
60
80
Cooling Water Temperature at Entry

FIG_12

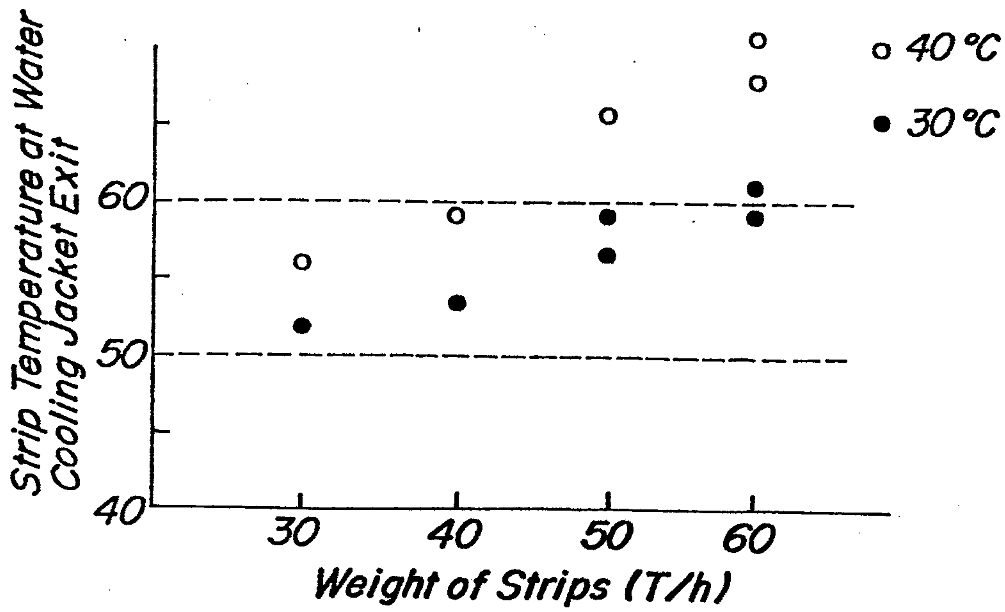

40 °C
30 °C
Strip Temperature at Water Cooling Jacket Exit
60
50
40
30
40
50
60
Weight of Strips (T/h)

FIG. 13

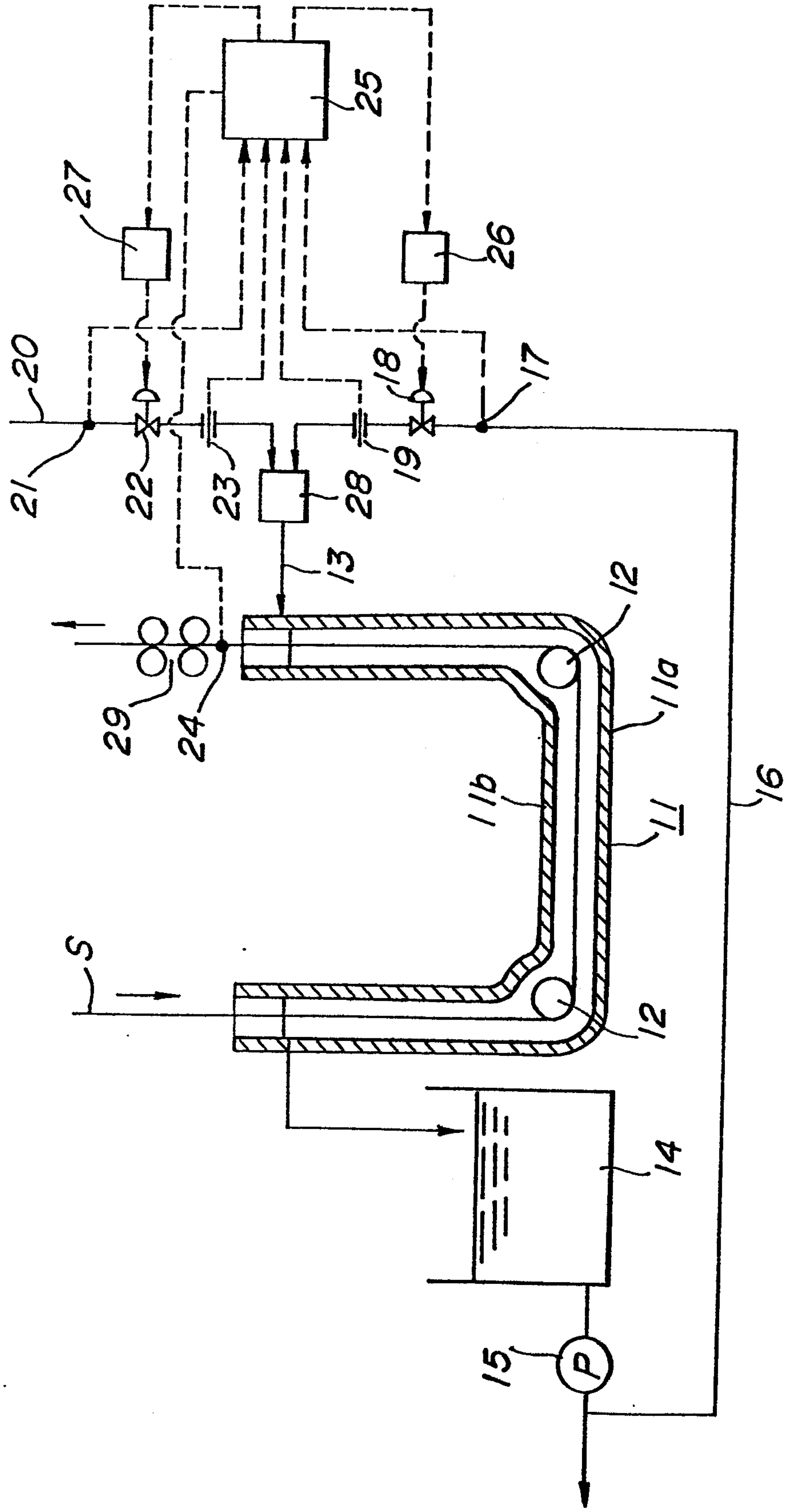


FIG_14

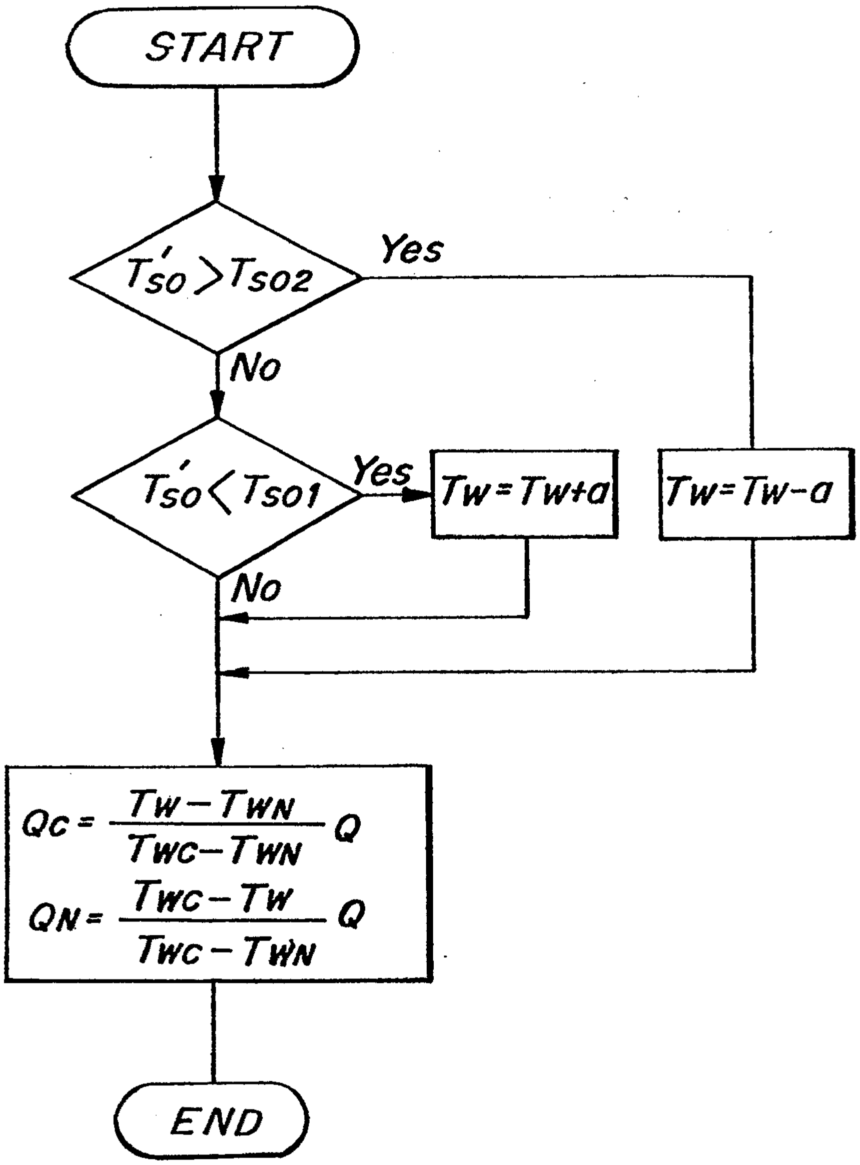

START
T'so > Tso2
Yes
No
T'so < Tso1
Yes
Tw=Tw+a
Tw=Tw-a
No
Qc = (Tw - TwN)/(Twc - TwN) Q
QN = (Twc - Tw)/(Twc - TwN) Q
END

FIG_15

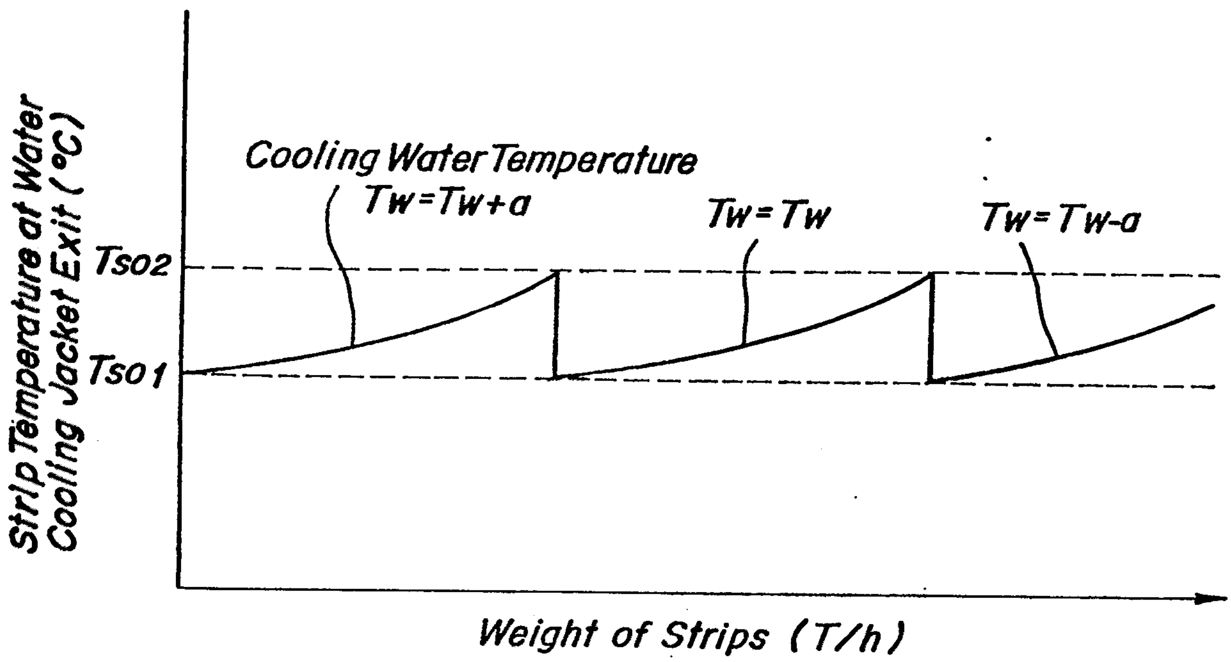
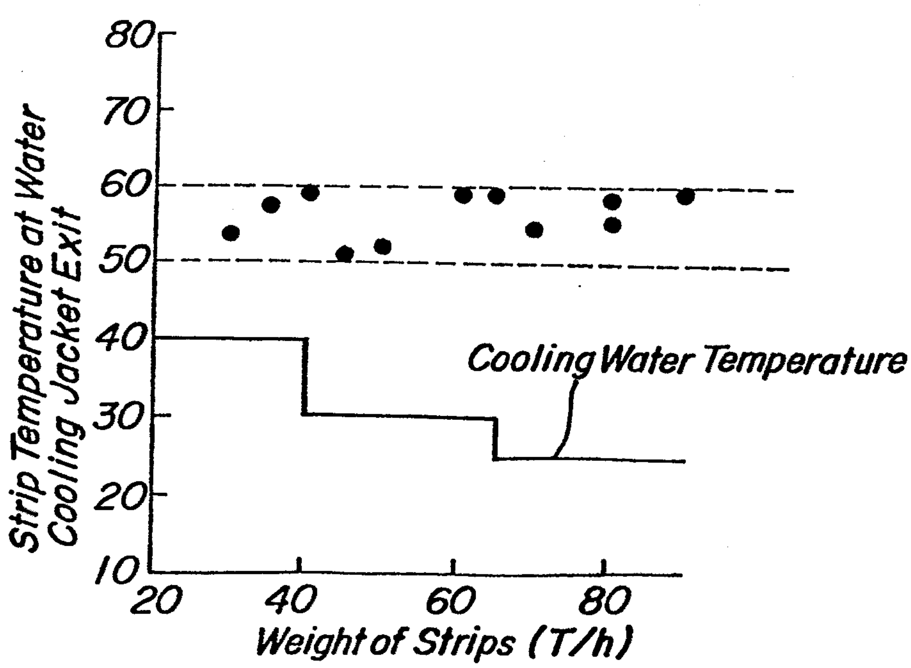

Strip Temperature at Water Cooling Jacket Exit (°C)
Cooling Water Temperature
Tw=Tw+a
Tw=Tw
Tw=Tw-a
Tso2
Tso1
Weight of Strips (T/h)

FIG_16


Strip Temperature at Water Cooling Jacket Exit
80
70
60
50
40
30
20
10
20
40
60
80
Cooling Water Temperature
Weight of Strips (T/h)