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Kubotera et al.

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[45] **Apr. 3, 1973**

[54] **METHOD AND APPARATUS FOR WATER QUENCHING METAL STRIPS**

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July 3, 1970 Japan 45/57977

[52] **U.S. Cl.** ....**266/3 R,** 148/134

[51] **Int. Cl.** **C21d 9/56**

[58] **Field of Search**.............148/12.4, 143, 152, 156; 266/3 R, 4 S, 6 S

[56] **References Cited**

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Primary Examiner—Gerald A. Dost
Attorney—Robert D. Flynn et al.

[57] **ABSTRACT**

In a continuous annealing of low carbon steel strip, the said strip is water cooled to a temperature below 500° C at a position not immersed in water by jetting the quenching water from both sides at an impact pressure of 15 cm water. The apparatus comprises spaced nozzle plates between which the strip is passed, spaced transverse slits being formed in the nozzle plates. Quenching water is jetted through the slits.

6 Claims, 9 Drawing Figures

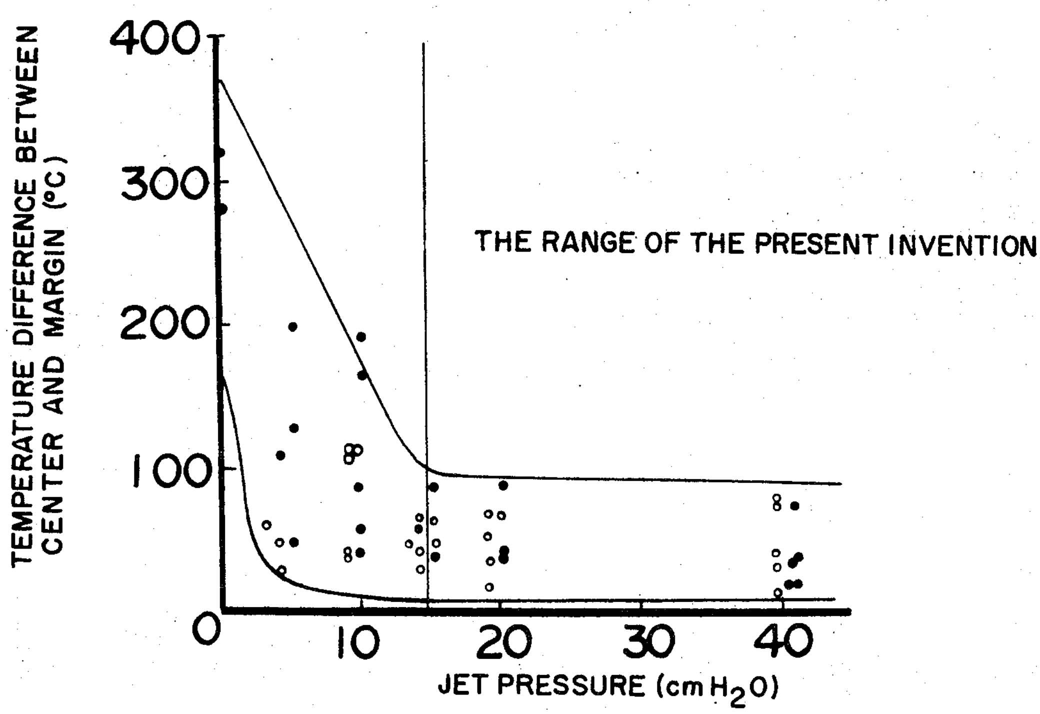


FIG.1

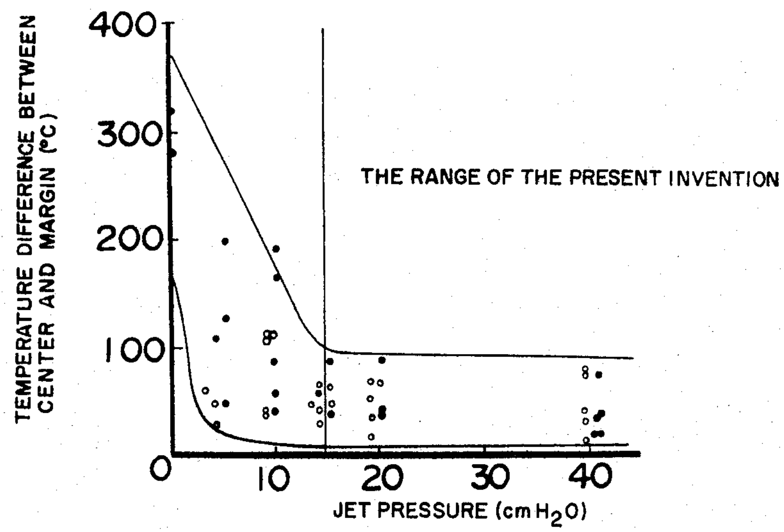
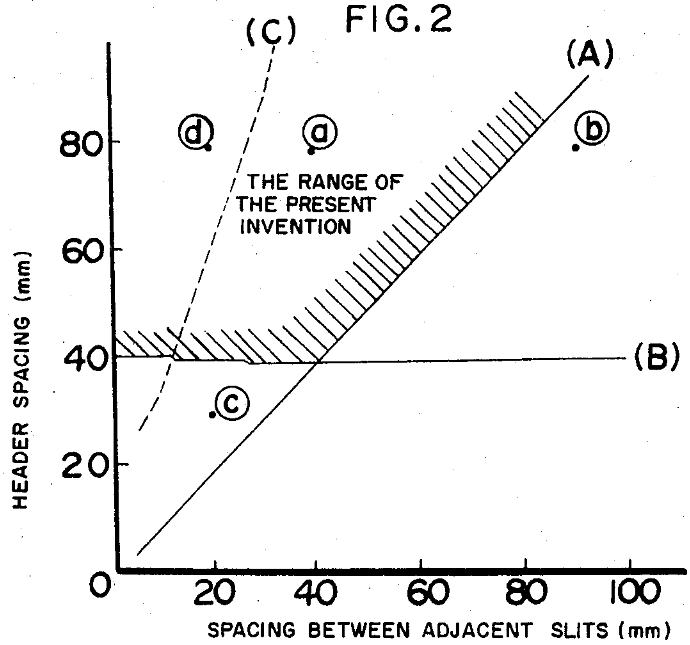

TEMPERATURE DIFFERENCE BETWEEN CENTER AND MARGIN (°C)
400
300
200
100
0
10
20
30
40
THE RANGE OF THE PRESENT INVENTION
JET PRESSURE (cm H_2O)

FIG.2


(C)
(A)
(B)
ⓓ
ⓐ
ⓑ
ⓒ
THE RANGE OF THE PRESENT INVENTION
HEADER SPACING (mm)
80
60
40
20
0
20
40
60
80
100
SPACING BETWEEN ADJACENT SLITS (mm)

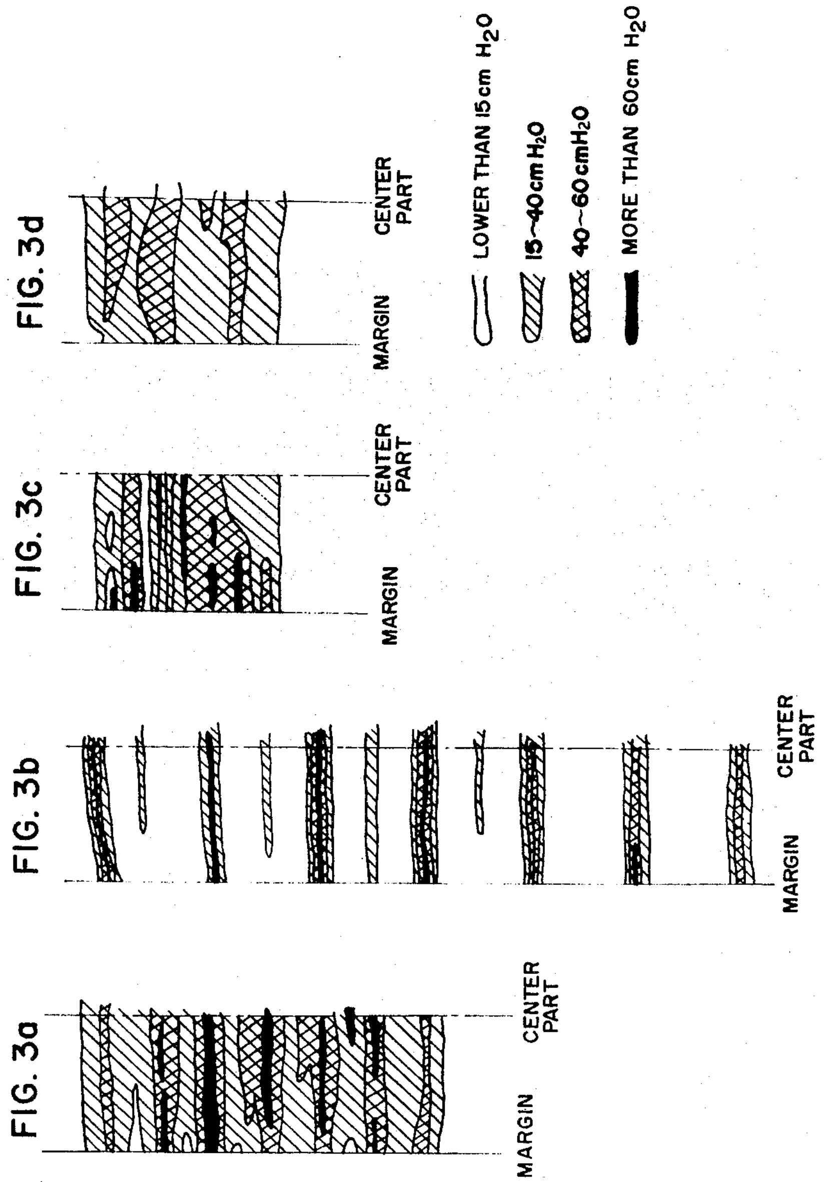


FIG. 3d
MARGIN
CENTER PART
LOWER THAN 15cm H_2O
15~40cm H_2O
40~60cm H_2O
MORE THAN 60cm H_2O
FIG. 3c
MARGIN
CENTER PART
FIG. 3b
MARGIN
CENTER PART
FIG. 3a
MARGIN
CENTER PART

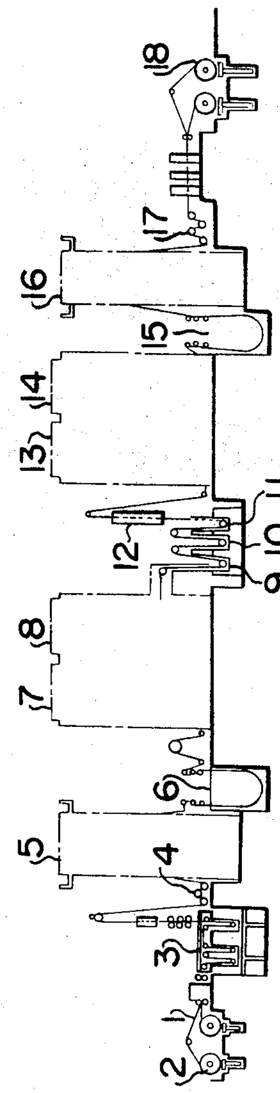


FIG.4

FIG.5

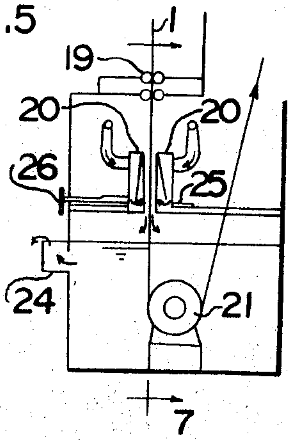


FIG.6

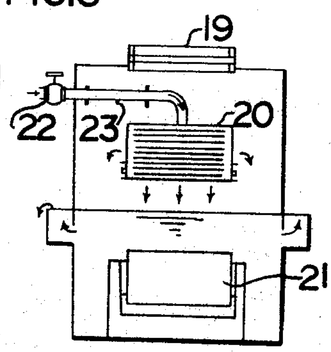


FIG.7

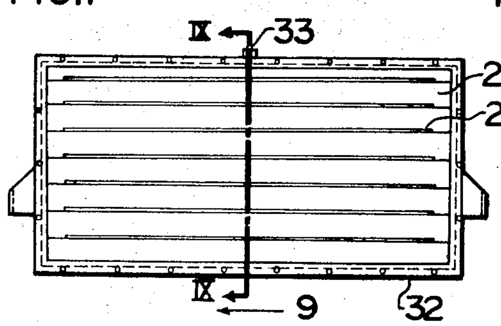


FIG.8

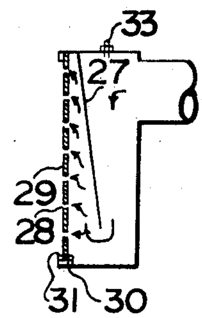
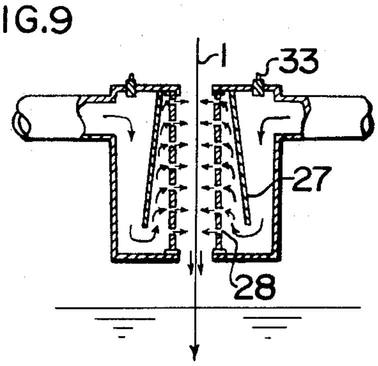


FIG.9



METHOD AND APPARATUS FOR WATER QUENCHING METAL STRIPS

The present invention concerns continuous annealing of low carbon steel strips by shelf treatment, and more particularly to a method and an apparatus of cooling said strips efficiently.

In continuous annealing, the following annealing cycle is employed in manufacturing cold rolled low carbon steel strips; namely heating the cold rolled strips up to 700° – 800° C by radiation heating, quenching to a temperature of less than 500° C at a quenching rate of 500° – 2000° C/sec, maintaining at 400°–500° C for 15 – 60 sec., and subjecting to forced air cooling until the temperature reaches the room (ambient) temperature. The treatment of maintaining the strip at 400° – 500° C for 15 – 60 sec after quenching is hereinafter referred to as Shelf Treatment. In the quenching operation, a vapor film is formed on the surface of the strip as it contacts the quenching liquid and damages the shape of the strip excessively. This causes inconvenience in tracking the moving strip.

We have conducted various experiments with a view to reducing such defects of said water quenching treatment. We have found that the cause of deformed shapes of the strip, such as waves at the edges, occurring during water quenching from 700° – 800° C in accordance with the method described hereinbefore is as follows:

The strip is instantly covered with a vapor film as it comes into contact with the quenching water, which film near the strip margins then rapidly disappears, the resultant further contact of the water with the strip producing nucleate boiling and rapid cooling of the margins. At the center part, on the other hand, a state of film boilding is maintained until the temperature reaches about 500° C. The cooling speed is extremely slow compared to that at the margins. As a result, a difference of more than 300° C is seen between the temperatures at the margins and at the center. The termal stress due to such a difference is the cause for the inferior shapes such as waves. It was found out that when a jet stream of quenching water is brought into contact with the surface of the strip, the impact pressure with which the liquid is jetted onto the strip can positively eliminate the vapor film throughout the width of the strip and the strip can be uniformly cooled.

The present invention will now be described more in detail, references being made to the accompanying drawings in which:

FIG. 1 is a graph showing the relation between the impact pressure of the quenching water on the strip surface and the difference in temperature between the center part of the strip and the margins thereof;

FIG. 2 shows a graph indicating the variation of the jet stream pressure with spacing between adjacent nozzles and spacing between the nozzle plates;

FIG. 3 is a magnified diagram of the part indicated by black dots of the jet stream pressure in FIG. 2;

FIG. 4 is a diagram of continuous annealing apparatus using shelf treatment and apparatus of the present invention;

FIG. 5 and FIG. 6 are side and front views, respectively, of the quenching apparatus;

FIG. 7 is a front view of the jet forming apparatus of FIGS. 5 and 6;

FIG. 8 is a vertical cross sectional view of the apparatus of FIG. 7; and

FIG. 9 is a diagram showing the location of the two jet forming apparatuses in relation to the strip.

More in detail, the relationship between the impact pressure of the jet stream on the strip surface (hereinafter referred to as the impact pressure) and the difference in temperature between the center and the margins of the strip is show in a graph in FIG. 1. The sample used was 1.6 mm thick, 300 mm wide cold rolled steel sheet which had been subjected to a heating temperature of 710° C. The white dots indicate the temperature between the center part and a point 15 mm from the edge, and the black dots show the temperature difference between the center part and a point 45 mm from the edge. It can be seen that a pressure of 5 cm H_2O has some effect, but the graph indicates that a minimum pressure of 15 cm H_2O is necessary in order to secure a stabilized temperature difference of less than 100° C.

In applying the above result to a strip running in an actual operation, an optimum combination of individual spacing between the jets of quenching water in sheet form, and the spacing between the nozzle plates should be determined in order to create a zone wherein the strip is continuously exposed to the quenching liquid in sheet form having an impact pressure of more than 15 cm H_2O for a sufficient period to cool the strip to a temperature below the temperature known as the lower limit of the film boiling (500° C). The length of such a zone is about 60 cm in the case of a line speed of 180 m/min for a strip having 0.8 mm thickness.

FIG. 2 indicates how impact pressure varies in dependence on the various combinations of the spacing between adjacent jet streams and the spacing between the nozzle plates. In this illustrative figure, the slit opening is 2 mm and the hydraulic pressure within the headers is 0.17 kg/cm². When these conditions are changed within the range of 1 – 3 mm and 0.1 – 0.4 kg/cm², respectively, the distribution of the impact pressure does not change remarkably. An example of the impact pressure distribution under the conditions corresponding to the black dots (*a*) to (*d*) in FIG. 2 is shown in FIG. 3.

Under the conditions within the range of the lower right hand side of the line (A), the part where the impact pressure is less than 15 cm H_2O is over large areas of the surface of the strip as is clear from FIG. 3(*b*). This is not suitable for eliminating the vapor film continually. That is, to eliminate the vapor film it is necessary that the spacing between the adjacent jet streams be less than two times the spacing between the nozzle plates and strip. Under the conditions falling in the range on the lower side of line (B) of FIG. 2, the distribution of the impact pressure in the direction of the strip width at the upper and lower parts of the strip within the jet zone becomes non-uniform and the impact pressure at the margins becomes considerably stronger than that at the center. This is not suitable for our purpose of quenching the strip uniformly across its width. Accordingly, it is necessary to space the headers more than 40 mm apart. Thus, the conditions falling in the ranges above the line (A), above the line (B) and to the right of the line (C) are deemed most suitable. In FIG. 3(*a*), the distribution of the impact pressure under the aforegoing conditions at the point (*a*) in FIG. 2 is shown.

As has been stated heretofore, the present invention is based on the experimental results of the inventors and aims to offer a method of cooling and apparatus for use in continuous annealing of low carbon steel strips, using shelf treatment, and jetting the quenching water onto the said strips in the form of transverse sheets of pressurized water spaced along the direction of strip advancement.

Further details of the present invention apparatus is explained by way of an example and of accompanying drawings. The strip used is mild steel containing less than 0.06 wt percent carbon, the size being 0.06 – 1.6 mm thick and 600 – 1800 mm wide. The line speed of the annealing furnace is 60 m/min to 300 m/min.

The diagram showing the whole facilities for continuous annealing which enables the shelf treatment of this invention is shown in FIG. **4** wherein the steel strip **1** is delivered from the entry reel **2**, grease is washed off in the cleansing tank **3**, the strip is sent on to the heating zone **7** via a bridle roll **3**, a looping tower **5**, and a free looping part **6**. After the strip is heated up to 700° – 800° C in the said heating zone **7**, it enters the soaking zone **8** wherein the temperature across the width of the strip is made uniform, and is then quenched to a temperature of less than 100° C in quenching apparatus **9**. The thin scales on the strip surface formed during the cooling operation are washed with hydrochloric acid in the pickling tank **10**. The strip then is passed through water tank **11**, drying zone **12** and then to reheating zone **13** for heating up to the shelf annealing temperature of 400 – 500° C. After it has been maintained at the said temperature in the soaking zone **14** for **15 - 60** seconds, it is passed on to the looping pit **15**, the free loop **16**, and the bridle **17** to be coiled by the tension reel **18**.

The present invention apparatus is characterized in that it has an efficient cooling apparatus **9**, the details of which are shown in the magnified views of FIGS. **5** and **6**. The strip **1** having passed through the soaking zone passes onto the seal rolls **19**, and enters between the jet stream apparatus **20** (which comprises the cooling apparatus of the present invention). The strip is water quenched therein to a temperature of below 100° C, goes over the sink roll **21** and is then sent to the pickling tank. The quenching water is fed to the jetting apparatus **20** by the water feed pipe **22** having a flexible part **23**. After it impinges on the strip surface, the water flows away through a sluice **24** to the reservoir tank. The jetting apparatus **20** is fixedly mounted on a slidable base **25** and the spaces between the nozzle sections may be arbitrarily adjusted by means of the handle **26**.

Further details of the jetting apparatus **20** are shown in FIGS. **7** and **8**. The particular type shown in the Figures is one wherein one header projects more than two uniform sheets of water, each sheet of water extending across the strip width (hereinafter referred to as a box type header). The quenching liquid induced into the two headers, which are provided at symetrical corresponding positions on both sides of the strip **1**, by means of the water feed pipe **22**, is forced in the directions indicated by arrows in the drawings by the baffle plate **27** and jetted through a group of slit nozzles **28** spaced apart in the direction of strip advance and

having rectangular orifices extending across the strip width. The baffle plate **27** acts to maintain the uniformity of each jet stream in the direction of its width as well as to equalize the strength of the jet stream. The nozzle plate **29** is divided into a plurality of dismountable sections so that the distance between the slits, slit openings, and the direction of the jets are optionally selectable in accordance with the individual needs. The said nozzle plate **29** is fixed to the header by means of the bolts **32** through the seat **30** and the frame **31**. Normally the nozzle plate used is 10 to 20 mm thick and the slit opening is about 1 to 3 mm. As is indicated by the impact pressure distribution diagram of FIG. 3-*a*, the impact pressure of the upper jet stream tends to be weakened by the effect of the jet stream of the more central streams, the opening of the upper slit is adjusted to be wider than that of the other, and the directions of the jet streams from the upper slits are deflected downward to increase their impact pressure. This will achieve a still better shape of the strip. The hydraulic pressure within the header is measured by the pressure transformer **33** and is normally kept at 0.1 to 0.4 kg/cm².

A method in accordance with the present invention uses the quenching apparatus as hereinbefore described to quench the strip. More concretely, water jetting apparatus for quenching the strip is provided at corresponding symmetrical locations on both sides of the running strip with more than 40 mm intervals between the nozzle plates, and these jet the quenching water on both sides of the strip to cool the strip to a temperature of less than 500° C under an impact pressure of 15 cm H_2O or more. The spacing between adjacent nozzles in each nozzle plate is less than that between the said nozzle plates.

The method of this invention is further described by way of the following example.

Example 1

A cold rolled steel sheet of 0.8 mm thickness and 300 mm width is heated in non-oxidizing conditions to 710° C, passed between box type headers having various slit spacings and header spacings (as indicated below) at a speed of 100 m/min. The difference in temperature caused at the margins (15 mm from the edge) and the center part of the sample and the shape of the strip after it had passed between the headers were studied. The results are shown in Table 1. The temperature of the quenching liquid is 60° C and the hydraulic pressure with in the headers is 0.17 kg/cm². The opening of each slit is 2 mm, the number of slits being seven on each side, respectively, and the amount of the jetted liquid is 2.4 m³/min for a pair of headers.

TABLE 1

	Jetting conditions: Interval of slits	Interval of headers	Shape	Temp. difference (Measured 4 times)	Remarks	
A	40 mm	80 mm	Fair	20° – 60°C	Conditions FIG.2	(*a*)
B	90 mm	80 mm	Waves	80° – 200°C	” ”	(*b*)
C	40 mm	30 mm	Minor Waves	60° – 150°C	” ”	(*c*)
D	20 mm	80 mm	Fair	40° – 100°C	” ”	(*d*)
E	No jet stream		Bad	300° – 400°C	” ”	

What we claim:

1. Apparatus for jetting quenching water on to a moving metal strip at a position where the strip is not immersed in water, comprising nozzle plates spaced more than 40 mm apart so that the strip can pass between them, and transverse slits on each of said nozzle plates, the slits being spaced apart less than the spacing of the nozzle plates, and the quenching water being jetted through said slits.

2. Apparatus according to claim 1, comprising box type headers which include baffle plates, each header being provided with a nozzle plate made up from adjacent plate sections, the slits of said nozzle plates corresponding to the strip width.

3. Apparatus according to claim 1, wherein said slits run transverse to the direction of strip movement and are spaced apart in the direction of strip movement.

4. The apparatus of claim 1, wherein the impact pressure of a jet is more than 15 cm H_2O.

5. Apparatus according to claim 1, wherein said slits have rectangular orifices extending in a direction across the width of the strip.

6. Apparatus according to claim 1, wherein at least one of said nozzle plates is comprised of a plurality of dismountable and adjustably locatable plate sections for varying at least one of the distances between slits, slit opening size, and the direction of the jets.

* * * * *