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Akayama et al.

[11] **3,909,315**

[45] **Sept. 30, 1975**

[54] **METHOD FOR RAPID COOLING OF HIGH TEMPERATURE METAL PIECES**

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[52] **U.S. Cl.** **148/153;** 148/155; 148/156; 148/157

[51] **Int. Cl.** **C21d 1/62**

[58] **Field of Search** 148/143, 153, 155, 156, 148/157, 3, 12.4, 13

[56] **References Cited**

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Attorney, Agent, or Firm—Wenderoth, Lind & Ponack

[57] **ABSTRACT**

A method of rapid cooling of high-temperature metal pieces having cross-sections such as H-shape, square, rectangular and circular, which comprises arranging a plurality of such hot metal pieces having nearly the same sectional forms in the direction of their widths at a certain distance between two adjacent pieces, and jetting coolant in a greater volume than to make the cooling effect curve develop into the saturation zone, into the spaces, between the facing sides of adjacent pieces; and an apparatus therefor.

2 Claims, 9 Drawing Figures

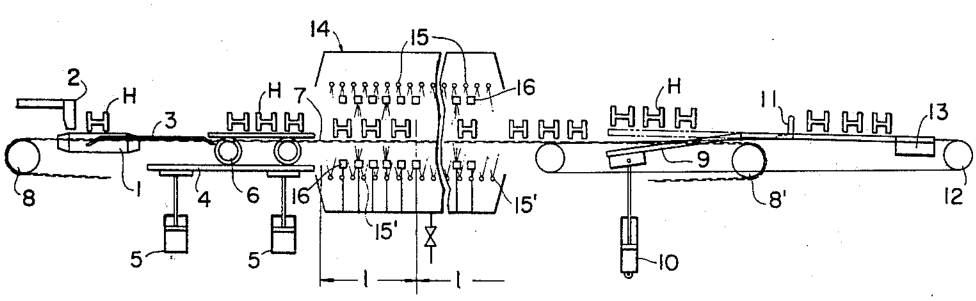


FIG. 1
PRIOR ART

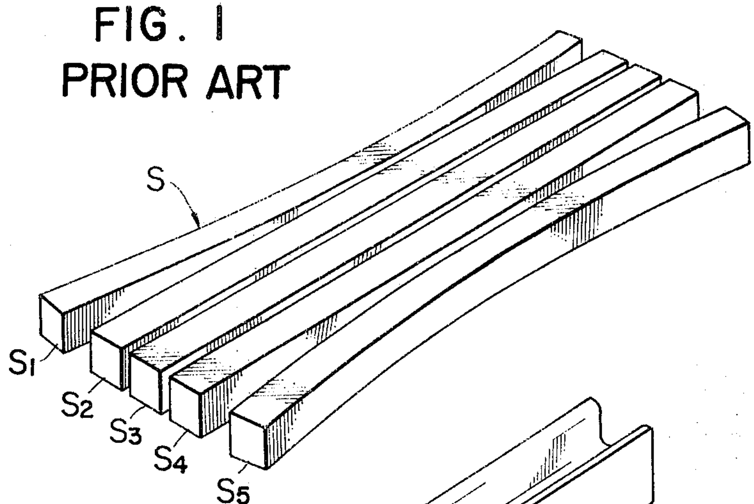


FIG. 2
PRIOR ART

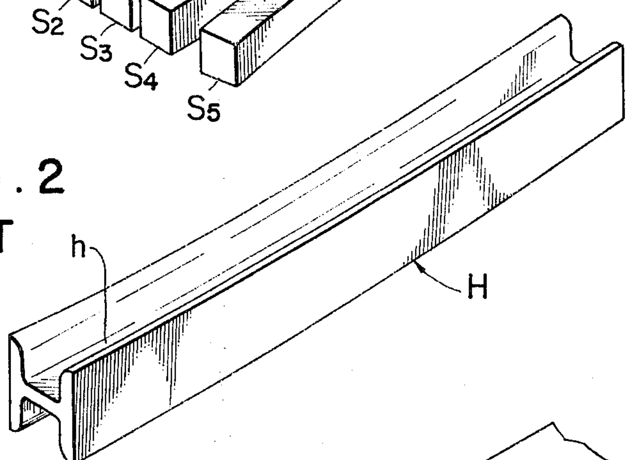


FIG. 3A
PRIOR ART

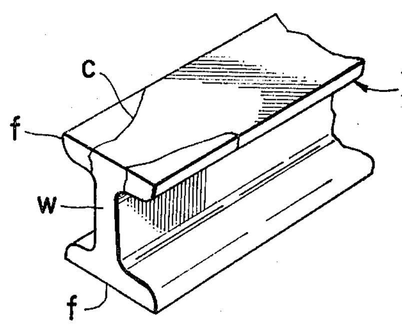


FIG. 3B PRIOR ART

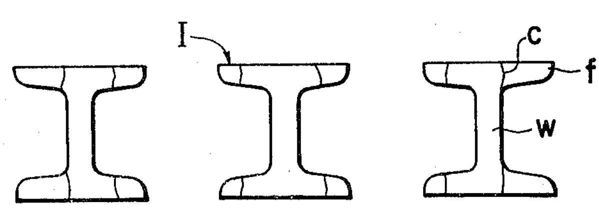


FIG. 4

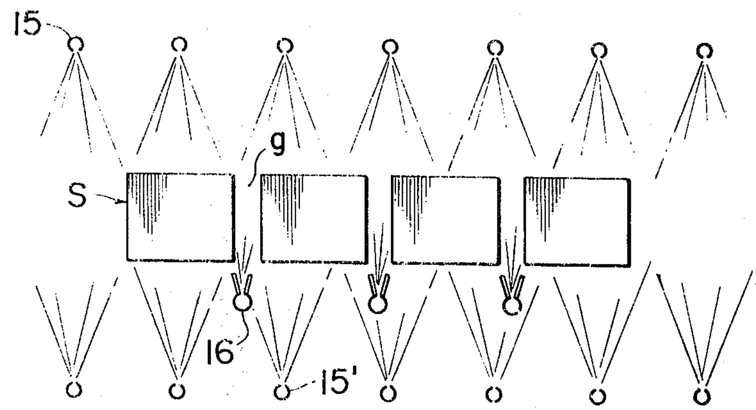


FIG. 5

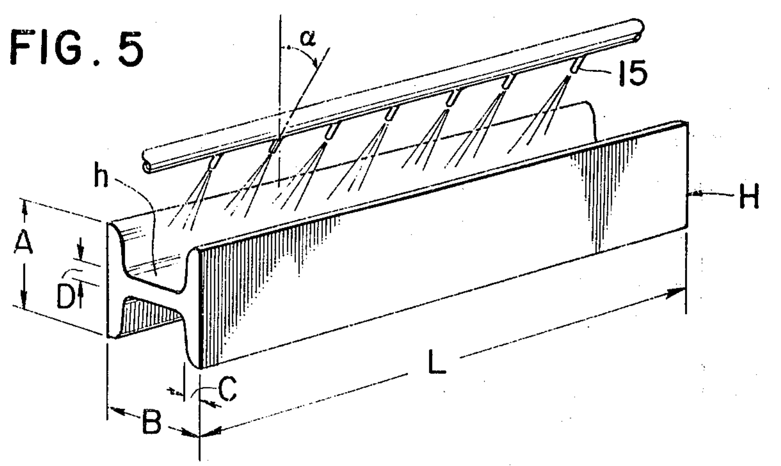


FIG. 6

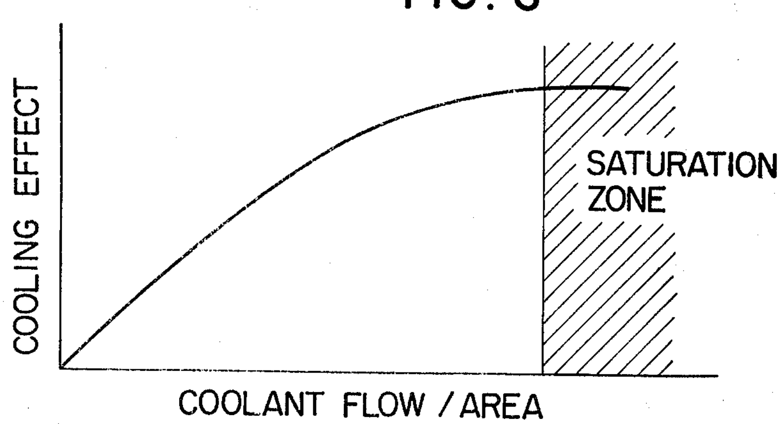


FIG. 7

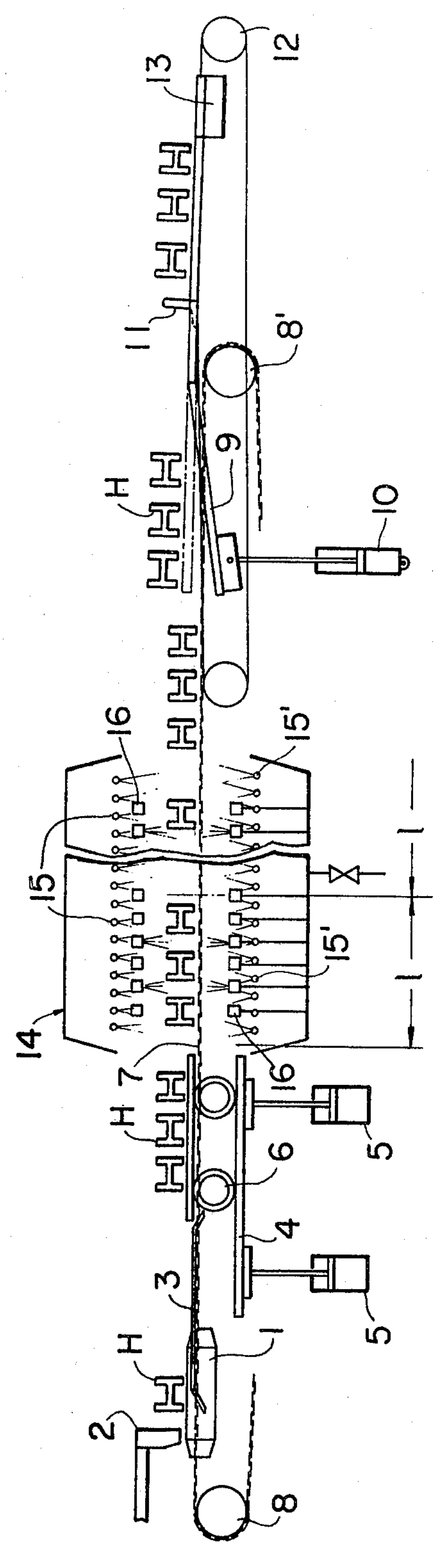
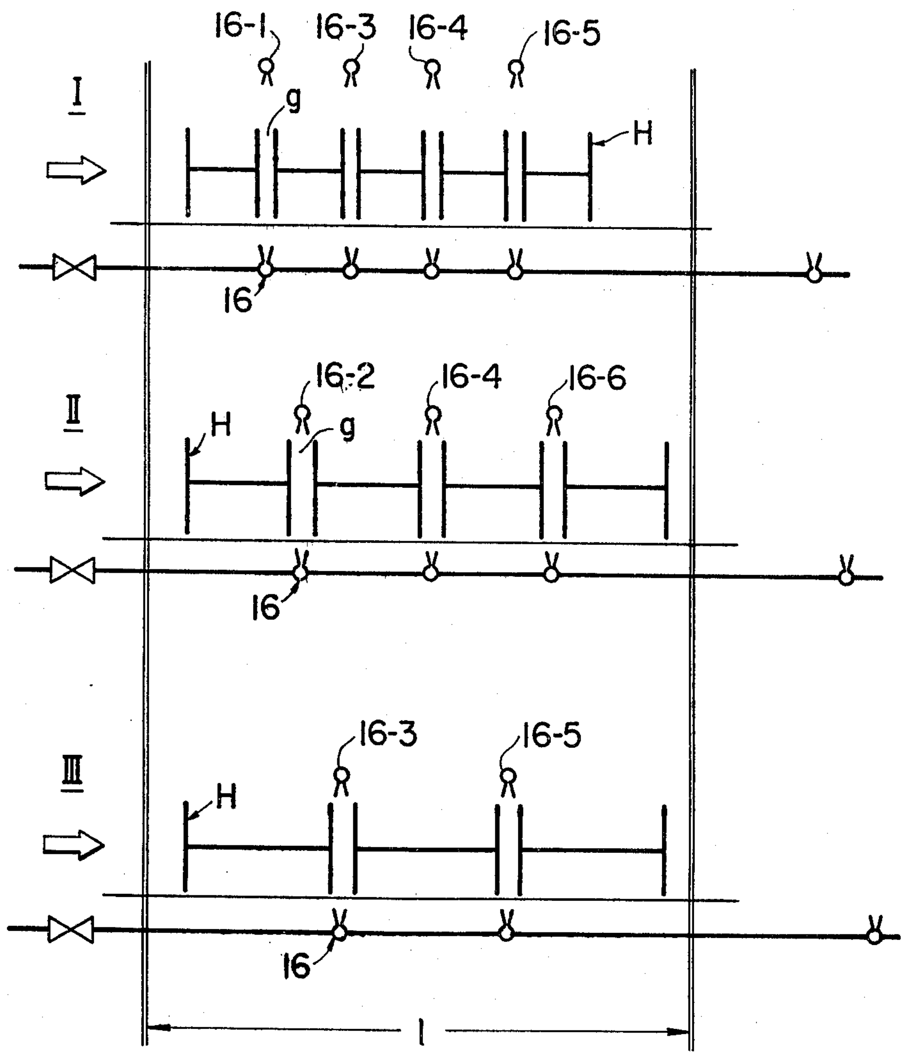


FIG. 8



METHOD FOR RAPID COOLING OF HIGH TEMPERATURE METAL PIECES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of cooling metal pieces of high temperature, and an apparatus therefor. More particularly, the invention is directed toward a method of rapid cooling of high-temperature long-sized metal pieces having cross-sections such as H-shape, square, rectangle and circle, and an apparatus therefor.

2. Description of the Prior Art

It is difficult by conventional methods to cool high-temperature metal pieces having H-shape, square, rectangular, circular, etc. cross-sections at high speed and efficiency for the following reasons:

1. In order to make compact the space for cooling operations metal pieces S are arranged in the direction of their widths, as shown in FIG. 1. As a result, the pieces S_1 and S_5 at both ends of the lot have their ends bend outward because of thermal strain due to the difference in temperature between the surface part of the outward facing side of the lot and the surface part of the side facing the adjacent piece. In general, the number of pieces per lot is limited, because of a variety of materials subject to such cooling and a limited capacity of transportation. This causes the number of lots to increase, hence the greater frequency of distortions, which constitutes a big problem in quality control and operations.
2. As shown in FIG. 2, coolant tends to stay on the concave *h* upper part of metal piece H having an H-shaped cross-section and the upper and lower parts of the piece cool at different rates, causing warping and cracking in the piece.
3. Pieces I having an I-shape cross-section are cooled from two directions; "upward" and "downward", which as shown in FIG. 3, results in the cooling exclusively of the flanges *f* while the web *w* does not cool completely. This uneven cooling, moreover, causes cracks *c*.

SUMMARY OF THE INVENTION

it is an object of the present invention to provide a method of rapid cooling of high-temperature metal pieces without causing warp and cracks therein.

Another object of the present invention is to provide an apparatus for cooling, at high speed and efficiency, high-temperature metal pieces without causing warp and cracks.

Other objects and advantages of the present invention, as well as the abovementioned will become further apparent in the following description of the preferred embodiment in reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective illustration of a material having a square cross-section which has bent because of the cooling by a conventional method.

FIG. 2 is a perspective illustration of a material having a sectional form of H-shape which has bent due to cooling by a conventional method.

FIG. 3A and FIG. 3B are respectively a perspective illustration and a front view of a material having a cross-sectional form of I-shape in which cracks have been caused due to cooling by a conventional method.

FIG. 4 is a sketch showing the arrangement of nozzles for jetting coolant to high-temperature metal pieces according to the present invention.

FIG. 5 is a perspective illustration of jets of coolant to the upper surface of a material having a cross-sectional form of H-shape, according to the present invention.

FIG. 6 is a graph showing relations between the volume of coolant and the cooling effect.

FIG. 7 is a side view of one embodiment of the cooling apparatus for the practice of the method of the present invention.

FIG. 8 is a sketch showing such arrangement of nozzles as to jet coolant into the space between high-temperature metal pieces.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The method of the present invention for cooling hot metal pieces having such sectional form as H-shape, square, rectangle and circle, has its gist in arranging hot metal pieces of nearly the same cross-sectional forms in the direction of their widths at a certain distance between two adjacent pieces and jetting coolant in a greater volume than to make cooling effect curve develop into the saturation zone, into the spaces between the facing sides of two adjacent pieces.

Metal pieces are arranged at a distance between two adjacent pieces set at whichever is greater, about 100 mm or one third of the height of such piece.

Coolant is jetted in great volume into respective spaces *g* between adjacent metal pieces S, as shown in FIG. 4, in order to cool the facing sides of such adjacent pieces, thereby preventing bending of the metal pieces placed at both ends of a lot in the direction of their widths.

These side-jetting nozzles 16 are appropriately selected from a number of nozzles which are provided, the choice of nozzles depending on which are coolant according to the sizes of such metal pieces.

In case of cooling metal pieces H having a cross-sectional form of H-shape, nozzles 15 at the upper level shall have inclination α in the long direction of the concave part *h* of such metal pieces, as shown in FIG. 5, so as to make the coolant run, thereby preventing the warping of the pieces, and so as not to have scale (oxide film) stay in the concave part *h*, thereby facilitating the inspection of surface conditions.

In order to prevent or stabilize to a minimum the difference in cooling temperature between the upper and the bottom parts of metal pieces, coolant is supplied in a greater volume than to make the cooling effect curve develop into the saturation zone, the saturation in this case being so specified that any increase of coolant supply per unit area of metal piece in excess of a certain volume will not increase the cooling speed (°C/min.). (In case of cooling iron by water, 0.1 – 1.0 m^3/m^2 min.)

The cross-sectional forms of metal pieces cooled according to the present invention may be H-shaped (including beam blanks), square, rectangular and circular; as for pieces having circular form, they can be treated by the method of the present invention, with a diameter of greater than about 150 mm subject to the adjustment of water supply, so far as the distance between adjacent pieces, can be maintained during transportation.

The method of the present invention is effective particularly for beam blanks of H-shaped steel pieces, such cooling having been considered difficult to be carried out by conventional methods.

In order to provide sufficient spaces between adjacent metal pieces according to the present invention, it becomes necessary to arrange such metal pieces in the direction of their widths, from the standpoints of space-saving, operational efficiency and economy.

As for the distance between two adjacent metal pieces, the shorter, the better, but, it should be set at more than about **100** mm, in order to avoid heat conduction from other metal pieces. This problem as shown in FIG. **1,** in which one side of the metal piece S_1 is hindered from cooling by the heat conduction and radiation from the metal piece S_2, while the other side of s_1 is free from such influence and cooled sufficiently, therefore producing thermal strain causing bending of the piece S_1. Thus, it is necessary to have a distance sufficient for the avoidance of such this phenomenon between adjacent metal pieces.

Bending of a metal piece may take place, in general, in a range of **5/1000** × the length of the piece, requiring said distance to be two times as long as the above range, **1/100** × the length of the piece, that is, more than **100** mm for **10** m of the piece.

As for a method for preventing metal pieces from heat radiation from other metal pieces, it is so devised that coolant is positively jetted into the spaces between adjacent pieces, in order to have the so produces vapor absorb the radiation heat. That is to say, the metal pieces are surrounded by the vapor, thus being nearly surrounded by a black body, and cooling is made while avoiding heat radiation from the sides, using coolant in sufficient volume for uniform cooling of the facing sides of the metal pieces. In this case, the required distance between adjacent pieces varies according to the thickness of vapor film, but it can be narrowed to about **100** mm when coolant is jetted to the sides of metal pieces in the volume specified according to the present invention.

As the jetting of coolant to the side of metal pieces may not be effective when their height is too great, the distance is set alternatively at more than the height × ⅓.

In providing sufficient space between adjacent metal pieces, the arrangement of them in the direction of their widths is preferred for the reasons of high efficiency, space-saving and structural conveniences. So far as a space sufficient for cooling the sides of metal pieces is obtainable, whatever arrangements will do may be employed.

The following is an embodiment of the present invention with respect to the temperature range of metal pieces:

a. Temperature at the start of cooling: More than **800**°C Uniform cooling is effected, while the metal pieces pass the transformation point.

b. Temperature at the finish of cooling: Less than **500**°C Cooling is not stopped during transformation:

c. Normal cooling temperature: cooling **1,200**°C to **100**°C

d. Normal cooling time: **15** – 30 Minutes

The forced side jetting nozzles according to the present invention are distributed appropriately above and below the cooling apparatus so that the side cooling can be effected together with the top-and-bottom-surface cooling. Particularly in case of cooling metal pieces having an H-shape cross-section, the side cooling cannot be perfectly effected by only using the top-and-bottom-surface-jetting, but also requires the side jetting for perfect cooling. In this case, the following conditions are used:

a. Jetting pressure: More than **2**Kg/cm²

b. Jetting directions: Upward and downward. Nozzles are used in various directions such as vertical or slant ones for an appropriate combination.

c. Nozzle flow and pitch (in the long direction). Nozzles are distributed so as to make the flow at **0.1** – 1.0 m³/m² min. at a pitch of about **200** mm.

The flow of the nozzle is **100** to **200** l/min.

The following is an explanation of the apparatus for providing an appropriate distance between high-temperature metal pieces for the practice of the present invention:

Metal pieces H of about **1,100**°C which have been transported on a roller table **1,** are already grouped into lots, each consisting a predetermined number according to shapes and sizes.

A pusher **2,** which is placed adjacent to the roller table **1,** makes one reciprocation for each of the metal pieces H placed on the roller table **1,** the total number of reciprocations corresponding to the predetermined number of the metal pieces H of one lot, so that all the metal pieces H of the lot can be arranged with an appropriate distance between adjacent metal pieces H, at the predetermined position of a fixed skid **3** which extends in a direction perpendicular to the roller table **1.**

This process can be made to operate automatically by supplying a start signal to the pusher **2** of which the stroke has been set in digital.

The transportation of the metal pieces H having the predetermined distance between each two of them, is so made that the metal pieces H placed on the fixed skid **3** as members of the lot are pushed up to the elevator **5** of a walking beam (or acending-descending skid) **4,** and transported over one stroke of a certain length by a transportation apparatus **6** onto a chain conveyor **7** extending in a direction perpendicular to the transportation direction of the roller table **1.**

Supporting the metal pieces H, the chain conveyor **7** progresses stepwise each step covering the distance of one stroke into a rapid-cooling apparatus **14,** so that the metal pieces H are cooled therein at such pace. Such successive steps are accurately maintained by controlling the strokes of sprockets **8** and **8'.**

Having passed through the rapid-cooling apparatus **14,** the metal pieces H stop on a tilting beam **9** to be pushed up by its elevator **10,** so as to leave the chain conveyor **7.** Then, the metal pieces H are forwarded to a delivery table **13** by the dog **11** of a rope transfer extending from the front end of the conveyor **7** to said table. Said rope transfer is operated by means of a sprocket **12** so as to stop respectively at the inlet of the tilting beam **9** and at that of the dilivery table **13.**

During this period, coolant is continuously supplied in the rapid-cooling apparatus **14** from the upper-and-lower-surface-jetting nozzles **15** and **15'** and some selected ones of the side jetting nozzles **16**; such selection to be made according to the number of metal pieces in the lot.

As coolant water and any water solutions effective for the purpose may be used.

The condition required for jets from the nozzles **16** for enforced side cooling is that some jets of water must be produced at such pressure of more than $3Kg/cm^2$ that will be so effective for heat exchange that the so obtained effect exceeds the extent that the effect develops into the saturation. On the other hand, a jets of water at normal pressure cannot break through the vapor film produced on high-temperature metal pieces at the time of its boiling, and only runs on the films, thus failing in heat exchange with the metal pieces.

The following is an explanation of the selection of side jetting nozzles **16** and a method of transportation by the conveyor.

According to the present invention, top-and-bottom-surface-jetting nozzles **15 15'** are provided together with side-jetting nozzles **16.** The former nozzles jet coolant throughout the operation, while the latter nozzles operate only when a lot of metal pieces passes through them. For instance, only the side-jetting nozzles **16** which happen to be at the positions corresponding to the spaces between adjacent metal pieces, marked with modes I, II and III in FIG. **8,** operate.

For this purpose, the stopping positions of metal pieces in the transportation section **1** of the conveyor are determined according to the number of pieces for each lot. Such case is shown in FIG. **8** with modes I to III. For sets of side-jetting nozzles **16** are required for the space *g* between adjacent metal pieces H in mode I, **3** sets in mode II and **2** sets in mode III. Even if the number of metal pieces in a lot varies, some spaces *g* between adjacent metal pieces H may overlap and one nozzle may be directed to the so overlapping spaces, so that **6** sets in all are sufficient. Selection from these **6** sets is so made that **16 - 1**), **16 - 3, 16 - 4** and **16 - 5** are put into operation in mode I (one lot consisting of **5** pieces); **16 - 2, 16 - 4** and **16 - 6** in mode II (one lot consisting of **4** pieces); and **16 - 3** and **16 - 5** in mode III (one lot consisting of **3** pieces). It may be possible that all **6** sets are continuously kept in operation.

The conveyor **7** moves exactly over the predetermined distance **1** and then stops, repeating such step of movement and stoppage. Moreover, a plurality of the side-jetting nozzles **16** are equally arranged along each section of length **1** closely relating to the stopping position of the conveyor **7.** Therefore the metal pieces can be transported while repeating the cooling of the sides of them.

For instance, the transformation time over the distance **1** is about **10** seconds, and the stopping duration of the conveyor is about **100** seconds.

In case of cooling H-shaped steel material, the top-and-bottom surface-jetting nozzles have a inclination of about **20°** to **30°**, so as to have coolant run away.

Example:

Metal pieces having the an H-shaped cross-section were cooled in the manner shown in FIG. **7.**

Size of each metal piece (See FIG. **5**):

Width of flange A: **280** mm

Distance between the surfaces of flanges B: **350** mm

Thickness of flange C: **80** mm

Thickness of web D: **100** mm

Length L: **10** m

Distance between adjacent metal pieces: **100** mm

Top-and-bottom-surface-jetting conditions:

Pressure: $3Kg/cm^2$

Total flow: $1.0m^3/m^2$ min.

(The ratio in flow between for the upper surface and for the bottom surface: **1 : 1.25**)

Side-jetting condition:

Pressure: $3Kg/cm^2$

Flow: $0.2m^3/m^2$ min.

Result:

Horizontal bending: Almost none (max. **50** mm with a few pieces)

Warp: Almost none (max. **50** mm with a few pieces)

What is claimed is:

1. A method for rapidly cooling steel metal workpieces from a high temperature, which comprises:

arranging a plurality of elongated metal workpieces having substantially the same cross-sections parallel to one another in the direction of their widths, said cross-section of said workpieces being one of irregular and regular geometric, the separation between adjacent workpieces being as small as possible, but sufficient to isolate said workpieces from mutual influence of heat transmission to prevent bending of said workpieces;

continuously jetting over the entire surfaces of said workpieces a coolant at a higher flow rate per unit area of each said workpiece than the saturation rate at which a further increase thereof will not increase the cooling speed of said workpieces by means of nozzles equipped for this purpose;

transporting said workpieces intermittently for a prescribed distance in the direction of their width; and

jetting coolant to both the upper and the lower surfaces of said workpieces and also directly to the spaces between adjacent workpieces while at rest in order to have so produced vapor absorb heat radiation from the sides of said workpieces, said jetting to the intervening spaces being performed by selective nozzles, such selection being made according to the length of said workpieces, whereby cooling may be effected without warping and cracking of the workpieces.

2. The method as claimed in claim **1,** wherein the separation between adjacent high-temperature metal pieces is set at whichever is greater, nearly **100** mm or one third of the height of said metal piece.

* * * * *