United States Patent

Kunioka et al.

[15] **3,659,428**

[45] **May 2, 1972**

[54] **METHOD FOR COOLING STEEL MATERIALS**

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[73] Assignee: **Nippon Kokan Kabushiki Kaisha**

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[30] **Foreign Application Priority Data**

Dec. 1, 1969 Japan....................................44/95896

[52] **U.S. Cl.**...................................**62/64,** 239/434, 239/568, 239/597, 264/28

[51] **Int. Cl.**..**F25d 17/06**

[58] **Field of Search**.....................134/34, 36; 264/28; 62/64; 239/434, 568, 597

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Primary Examiner—Meyer Perlin
Assistant Examiner—Ronald C. Capossela
Attorney—Flynn & Frishauf

[57] **ABSTRACT**

A method for spray cooling hot metal products in which a small amount of water is atomized in a large air flow passing through a throttling nozzle so that a two phase high speed jet is directed against the hot metal. The water is injected into the air stream between a compressed air reservoir and the throttling portion of the nozzle.

3 Claims, 15 Drawing Figures

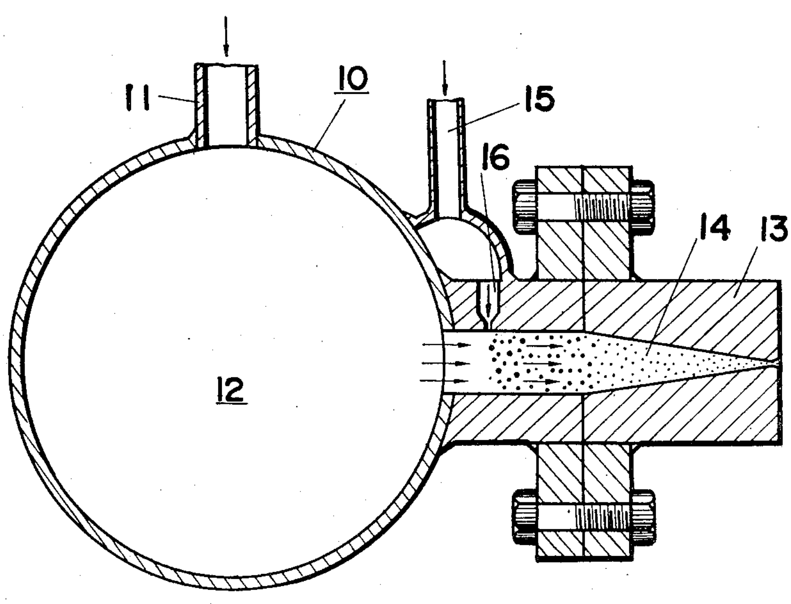


FIG. 1

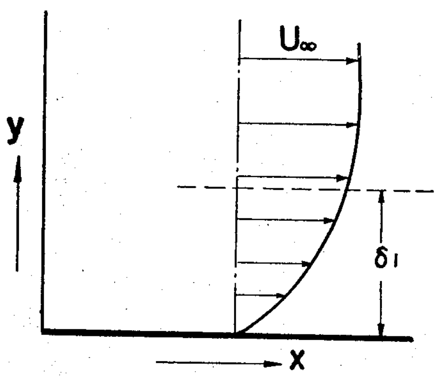


FIG. 2

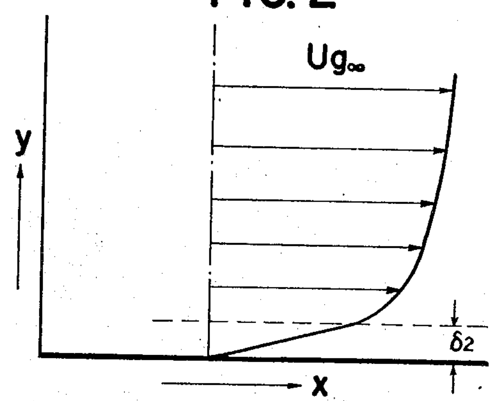


FIG. 3

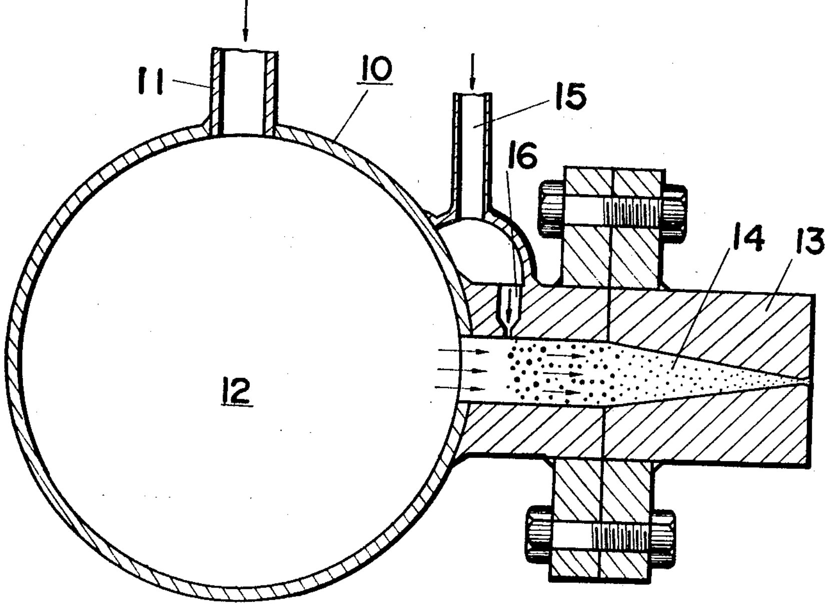


FIG. 4a

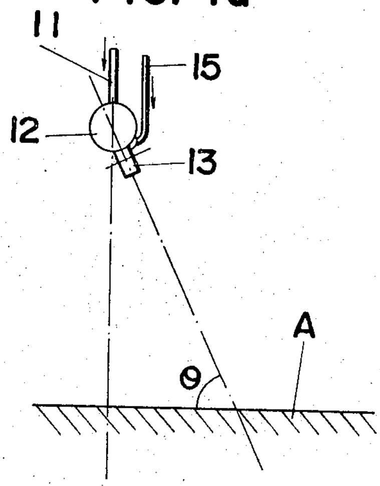


FIG. 5a

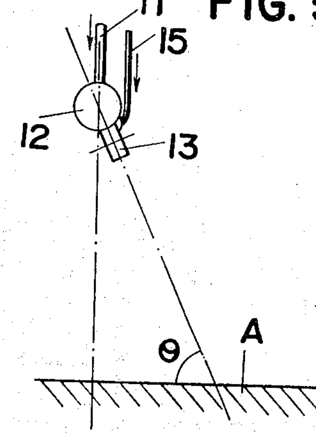


FIG. 4b

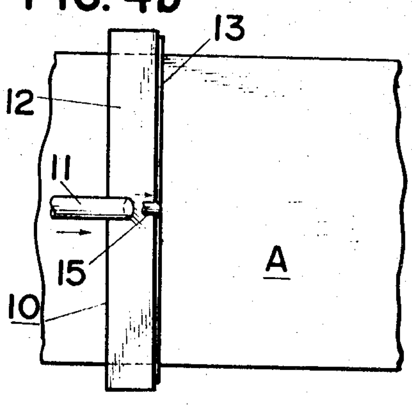


FIG. 5b

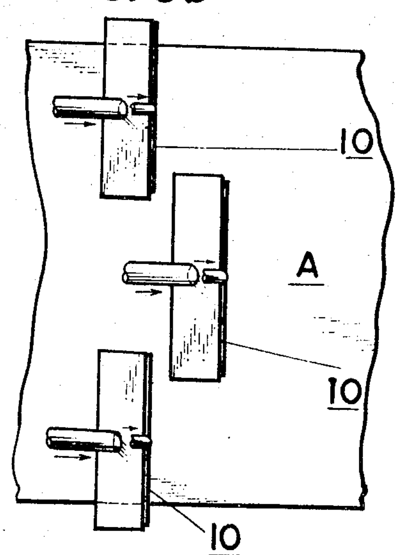


FIG. 6a

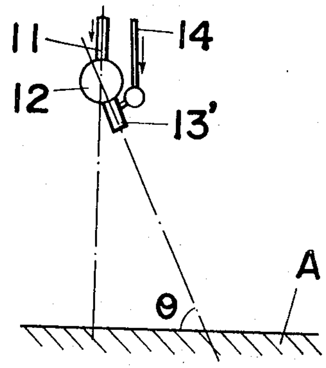


FIG. 6b

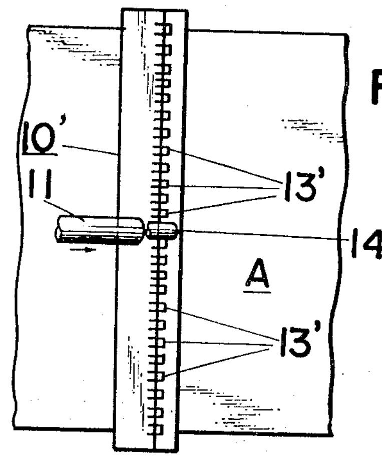


FIG. 7a

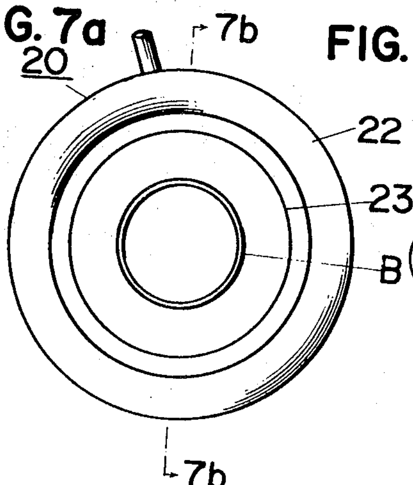


FIG. 7b

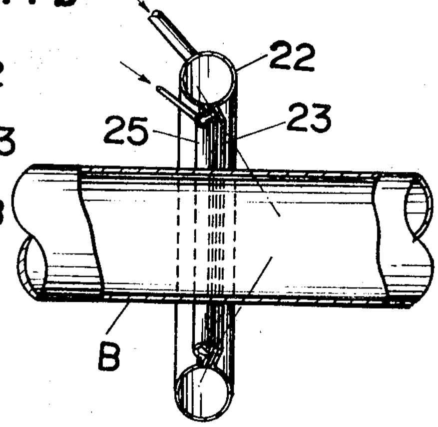


FIG. 8a

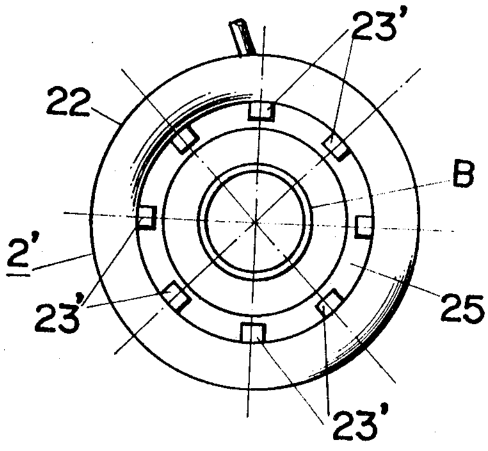


FIG. 8b

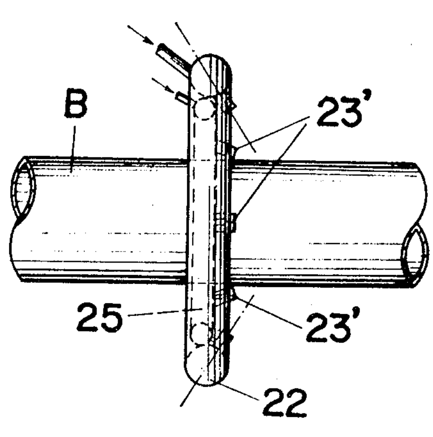


FIG. 9

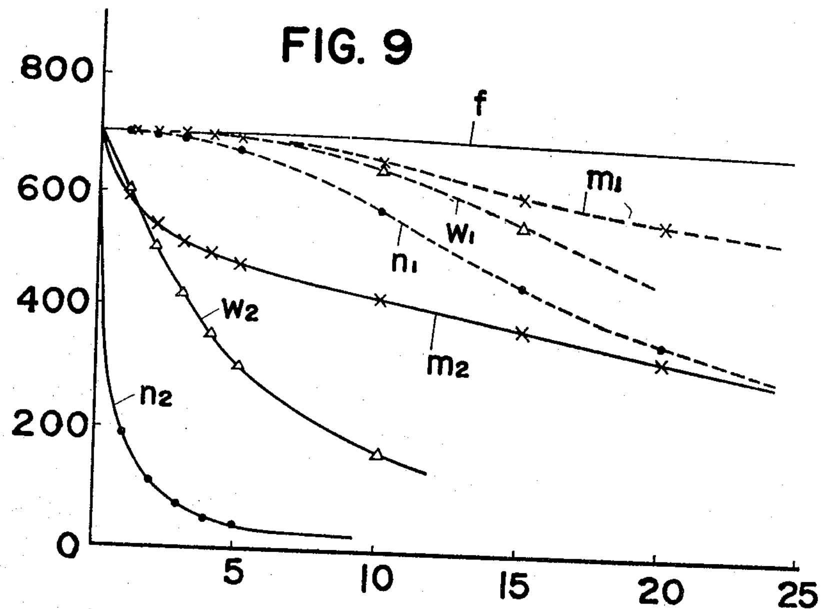
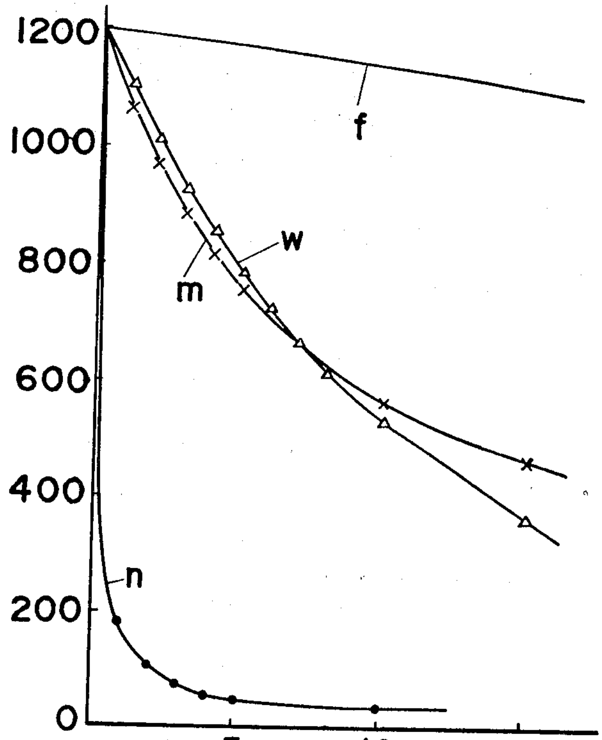

800
600
400
200
0
5
10
15
20
25
f
m1
w1
n1
w2
m2
n2

FIG. 10


1200
1000
800
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w
m
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METHOD FOR COOLING STEEL MATERIALS

The present invention relates to a method for cooling various kinds of hot steel products such as hot billets or blooms and pipes, cooling of various hot objects, for example, cooling continuously cast sections, slabs billets, blooms after cogging, hot rolled sheet material or the like, hardening of refined steel material, direct hardening immediately after hot rolling, quenching immediately after the rolling, quenching after the normalizing of very thick steel plates, heat treatment of hot steel pipes and the like.

Heretofore, methods for cooling hot steel plates or hot billets have been classified into two groups: cooling methods generally using air, and cooling methods using water. The simplest method of using air is natural cooling, and an artificial method comprises cooling by jet currents using high pressure air. In the methods using water, pressure water jet methods and laminar flow methods are known. In the case of natural cooling, however, a spacious yard for steel material is needed because of the slow cooling rate, and there is a similar drawback even when high pressure air is used.

On the other hand, cooling by pressure water requires a large quantity of water and at the same time, a film of steam is formed on the hot billet, so that there is a disadvantage that the cooling efficiency is low unless relatively high pressure is used. In the case where laminar flow is used, there is again a drawback that a larger quantity of cooling water is required than in the previous case of high pressure water.

Accordingly, a method has been suggested in which cooling is effected by using both water and compressed air. In that cooling method, there are provided a large number of nozzles for cooling water and independent thereof, a large number of nozzles for compressed air, and spray of cooling water which has been produced by minutely atomizing the cooling water is sprayed uniformly all over the surface of the steel, thus accelerating the speed of application of the spray to the steel by the pressure air current directed to said cooling water spray current, so that upflow of the spray current, produced by contact between high temperature steel and said spray current, is suppressed. With such a method of cooling, not only are a large number of nozzles required, which renders the apparatus complicated, but also a large quantity of water is required. Furthermore, as the compressed air current and the spray current of cooling water are so adapted that they collide at the surface of the billets, the cooling water is scattered by air, and the cooling efficiency is decreased.

The object of the present invention is to eliminate the disadvantages of the various methods of cooling heretofore employed, and to provide a method of cooling which performs cooling effectively and rapidly with a small amount of cooling water.

In the present invention, one of the characteristic points thereof is that, in order to perform rapid cooling at high efficiency with a small quantity of water, a small quantity of cooling water is blown into a large volume air flow, atomizing the liquid into a mist by high speed air current, and causing it to collide upon hot billets as a two-phase jet.

In this case, in order to give the liquid drops of the cooling water the same current velocity as that of the air jet, the liquid is caused to blow out after being mixed and atomized with air in the nozzle, and to accelerate it to the same current velocity as that of the air current, the cooling water is blown or injected in front of the throttling portion of the nozzle, and the throttling of the nozzle is effected as slowly and smoothly as possible. By this measure, the cooling efficiency is much improved.

In the case where hot steel is cooled by means of vapor or liquid, the heat transmission due to convection increases in proportion to the temperature gradient at the surface of the hot steel, other conditions being constant. Thus, when liquid alone is sprayed onto the material to be cooled, as the current velocity cannot be increased so much, the surface layer (σ_1), at a given flow velocity ($V\infty$) and temperature, becomes thick and it is impossible to increase the heat transmission. That is, the quantity of heat transmission (q) is obtained from

$$\begin{aligned} q &= h\Delta T \\ &= k\left(\frac{\partial T}{\partial y}\right)y=0 \\ &= \frac{k}{\delta}\Delta T \end{aligned} \qquad (1)$$

where

h: ratio of heat transmission,

k: ratio of heat transmission of liquid,

ΔT: (surface temperature) - (bulk temperature of liquid)

From equation (1), it is seen that the rate of heat transmission becomes small when the temperature gradient is small, that is, the surface layer (σ_1) is thick.

On the other hand, in the case of vapor-liquid mixing fluid, it is possible for the jet speed to obtain the same high speed of flow (supersonic speed of flow) as the gas flow, if the quantity of liquid is small as compared with the quantity of vapor. Accordingly, by cooling with such a fluid, the surface layer of liquid becomes extremely thin, so that the temperature gradient on the surface of the hot steel material becomes large, and the heat transmission can be increased.

The present invention is characterized by the above discussed technical concept.

The invention will now be described with particular reference to a preferred embodiment illustrated in the drawings in which:

FIG. 1 is a diagram showing a flow state of liquid in a conventional cooling using liquid alone,

FIG. 2 is a diagram showing a flow state of vapor-liquid mixed flow of the method according to the present invention;

FIG. 3 is an enlarged sectional view of the nozzle used in the present invention;

FIGS. 4, 5, and 6 are views showing different ways in which the apparatus for carrying out the present invention may be used for the cooling of steel plates; in each of the drawings, *a* and *b* show side view and plan views, respectively,

FIGS. 7 and 8, show ways in which the method may be applied to cooling of pipes, wherein FIG. 7*a* shows a front view, FIG. 7*b* shows a section through line 7*b* — 7*b* in FIG. 7*a*, FIG. 8*a* is a front view, and FIG. 8*b* is a side elevation,

FIG. 9 is a diagram showing temperature changes in various methods of cooling including those according to the present invention in the case of cooling steel plates, and

FIG. 10 is a diagram showing temperature changes comparing the conventional water cooling method with the method according to the present invention, in the case of pipe cooling.

In a preferred embodiment, cooling of steel plates and pipes is particularly selected, but it is to be understood that the present invention is not limited to such embodiments for it is possible to utilize the present invention for cooling of all hot steel products such as plates billets or blooms.

Referring to the drawings, **10** designates a nozzle device, and it comprises a cylindrical reservoir **12** for compressed air communicating with a blow pipe **11** for compressed air, nozzle **13** having a slit-shaped spray hole **14** formed integral with said reservoir **12**, and a feed pipe **15** for cooling water which is connected near the base portion of said nozzle **13**. The feed pipe for cooling water **15** opens into the blow hole **14** in front of the throttle portion of the blow hole **14** of the nozzle, and the cooling water is supplied into the nozzle through a feeding port **16** having a small diameter provided in the nozzle. The nozzle **13** has substantially the same length as said reservoir **12**. The cooling water supplied into the nozzle **13** is atomized as mixture with the compressed air blown from the reservoir **12**, and accelerated to the same speed as that of the compressed air at the gentle and smooth throttle portion of the blow hole **14**, and then blown against material to be cooled through the blow hole **14**.

An appropriate flow ratio (in weight ratio) of the cooling water and the compressed air (quantity of cooling water/quantity of air) is 1.0 to 5.0. The cooling power is dependent upon the current speed at the time of contact with the hot steel plates, so that it is possible to adjust the cooling rate by means of changing the blow speed. Usually sufficient cooling speed can be obtained when the flow speed is 10 m./sec. or more.

In some cases, however, a higher cooling speed is required, and the flow speed may be 100 m./sec. or more (may also be the speed of sound), and the cooling effect becomes 8×10^4 K. cal./m.^{2}·h·° C., and an extremely high cooling power can be obtained.

FIGS. **4** through **6** show cooling of steel plates by a method and apparatus according to the present invention, and in which FIG. **4** shows an example where the cooling is effected on steel plates having a narrow width. In this case, a reservoir **12** for compressed air and nozzle **13** of the nozzle device **10** extend over the full width of the steel plate A, and a single blowing pipe **11** for compressed air and a feed pipe **15** for cooling water are communicated at the central portion of the nozzle device.

FIG. **5** shows cooling of steel plates having a large width, and a plurality of nozzle devices **10** having the same shape as the nozzle device **10** shown in FIG. **4** are used in parallel.

The nozzle device **10'** shown in FIG. **6** is different from those shown in FIGS. **4** and **5**, and a large number of nozzles **13'** are connected in parallel to the reservoir **12**. With such a nozzle device, it is possible to cool a wide steel plate with a single nozzle device, and this facilitates the piping arrangements of the compressed air and the cooling water. However, there is no substantial difference between the nozzle devices shown in FIGS. **4** through **6** and the nozzle device shown in FIG. **3**.

Any relative angle θ, ranging from 1° to 90°, between the steel plate A and the blowing direction of the nozzle, may be used.

Referring to the temperature change in the case of cooling hot steel plate in FIG. **9**, it will be noted that the cooling efficiency according to the present invention is excellent as compared with other methods of cooling. In the drawing, the curve f shows the temperatures at the surface and at the center of a steel plate having a thickness of 20 mm. and naturally cooled; W is a temperature curve for water cooling (insertion into a water tank), and w_1 and w_2 show temperatures at the center and at the surface, respectively. The curves m, n are temperature curves for cooling according to the present invention, the curves m show cooling of a steel plate having a thickness of 40 mm. at a flow rate of 15 m./sec., and m_1 and m_2 show temperatures at the center and surface, respectively. The curves n shows cooling of a steel plate having a thickness of 40 mm. at a flow rate of 70 m./sec., and n_1 and n_2 show temperatures at the center and surface, respectively.

In FIGS. **7** and **8**, there are shown the case in which pipes are cooled. In these embodiments, the nozzle device **20** is formed into an annular shape surrounding the pipe B to be cooled, and at the central portion of which, the pipe to be cooled is inserted and cooled.

The nozzle device **20** shown in FIG. **7** consists of a reservoir **22** formed into an annular shape for compressed air and a nozzle **23**. The cooling water is supplied through a feed pipe **25** for cooling water extending along the same circumference as said nozzle **23**. The nozzle in the nozzle device **20** shown in FIG. **7** is formed into a continuous ring.

On the other hand, in the nozzle device **20'** according to FIG. **8**, the nozzles **23'** are not formed continuously but are formed intermittently each projecting in radial direction. The other points of the device are the same as those shown in FIG. **7**.

Referring now to FIG. **10**, in which surface temperature changes are shown for the case of cooling an 80 A welded pipe, it is seen that substantially the same cooling effect is obtained when using the cooling method according to the present invention at a flow rate of 15 m./sec., and water cooling (inserting into water). It will also be seen that a far better cooling rate is obtained when it is cooled at a flow rate of 70 m./sec. In FIG. **10**, the curve f is the temperature curve in the case of water cooling; m, n are the temperature curves for the method according to the present invention, in which m is the curve for a flow rate of 15 m./sec., and n is for a flow rate of 70 m./sec., respectively.

The advantages obtained by the method of the present invention are enumerated as follows:

1. An excellent cooling rate can be obtained using a small quantity of cooling water;

2. It is possible to adjust the cooling rate by changing the flow rate of air;

3. Because the cooling is effected by means of a slit-shaped nozzle, an extremely small area is required for cooling the material; and

4. Because the cooling is effected relatively quickly, the workability is much improved.

We claim:

1. A method of rapidly cooling hot metals which comprises injecting a relatively small quantity of cooling water into a relatively large gaseous air stream flowing through a nozzle, the weight ratio of water to air being from 1:1 to 5:1, thereby forming a two phase flow stream, accelerating said flow stream into a high speed jet flowing at a rate of at least 10 m./sec. by forcing said stream through said nozzle, and impinging said high speed jet on said hot metal.

2. A method as claimed in claim **1**, wherein said metal is steel.

3. A method as claimed in claim **2**, wherein the speed of said jet is between 10 m./sec. and 100 m./sec.

* * * * *