United States Patent

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[54] **METHOD AND APPARATUS FOR COOLING WIDE CONTINUOUS METAL CASTINGS, PARTICULARLY STEEL CASTINGS**

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[52] **U.S. Cl.** **62/64,** 134/151, 164/89, 239/598, 266/6

[51] **Int. Cl.** **B22d 27/04**

[58] **Field of Search** ..164/128, 126, 283, 89; 62/373, 62/64; 134/151, 122; 239/598; 266/6

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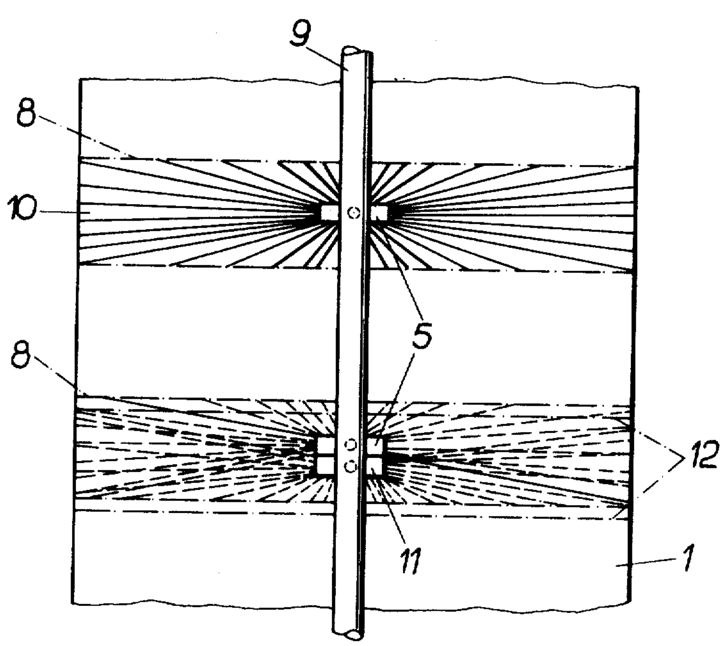
[57] **ABSTRACT**

A method for cooling wide continuous metal castings uses cooling water jets which impinge on the casting surface in the secondary cooling zone and which are produced with a slanting or arched characteristic. The jets are distributed over the width and length of the casting to form a cohering jet covering the width of the casting and having its greatest cooling power in the longitudinally extending central zone of the casting. The kinetic energy of the cohering jet is controlled to be intentionally smaller in the marginal impinement zones along the casting and, with increasing distance from the casting surface, the kinetic energy is increased, from the margins to the central zone of the casting, in proportion to the quantity of heat to be extracted locally. Apparatus for practicing the method includes spray cone nozzles which are contiguous to each other, and a supply line extending substantially centrally of the casting is adjustable in height during the cooling operation.

9 Claims, 6 Drawing Figures



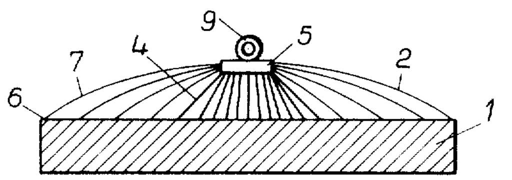


Fig. 1

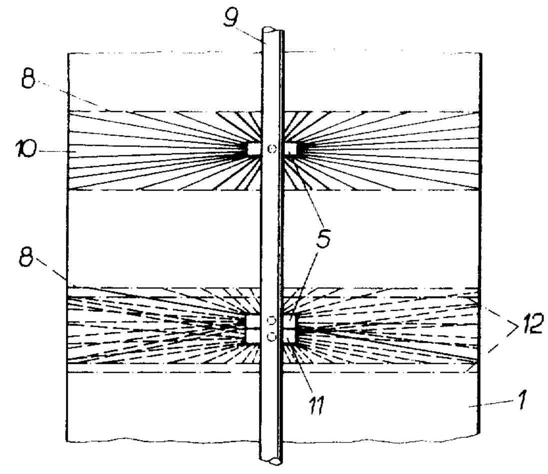


Fig. 2

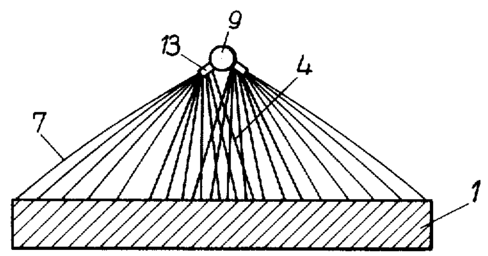


Fig. 3

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Fig. 5

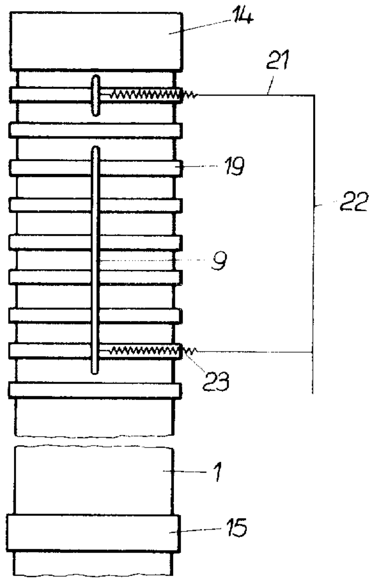
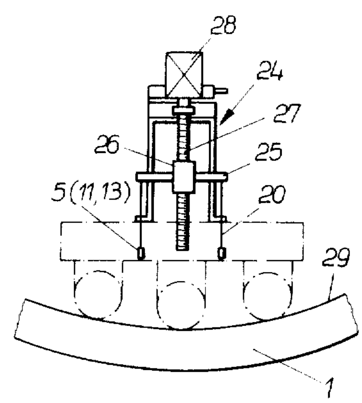


Fig. 6



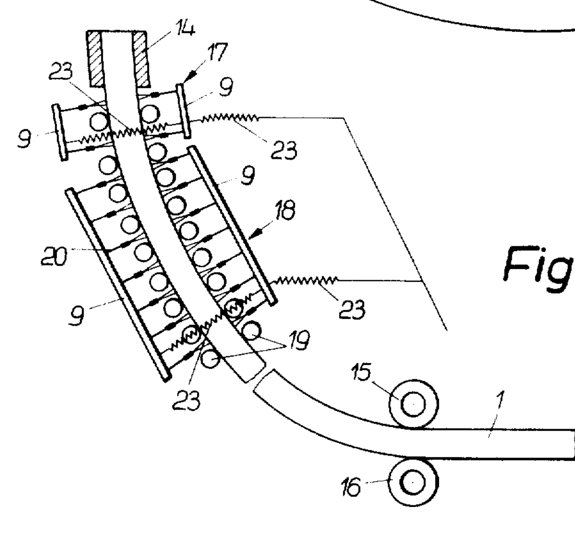


Fig. 4

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METHOD AND APPARATUS FOR COOLING WIDE CONTINUOUS METAL CASTINGS, PARTICULARLY STEEL CASTINGS

BACKGROUND OF THE INVENTION

It is known practice to form conical spray jets for the purpose of surface cooling of continuously cast slabs, that is, relatively wide continuous castings, with the impingement surface being in the form of an ellipse. To remove the heat flowing from the interior of the casting to the surface, the width of the casting is covered with a plurality of such elliptical impingement areas. The basic form of the ellipse, as well as the pressure conditions prevailing inside the spray cone, cause individual planes, in the nature of the impingement ellipses, lying side-by-side over the width of the casting.

To provide a cohering spray area, the ellipses may be applied either in overlapping fashion or in spaced relation. The interstices produced by the spacing can be covered by arranging a second row or course of ellipses, with a subsequent row filling the interstices of a preceding row. The results is still a cooling which, considered for a cross sectional plane of the casting, is still rather irregular. Although several parallel rows of ellipses can be placed close together in the direction of movement of the casting, the disadvantages of different cooling, in time, of a selected surface point still remains.

For slab castings, a minimum casting rate pertains, so that a cross sectional strip to be cooled is subjected to a new cooling much later in the longitudinal direction. Such a cooling method thus does not allow, as very advantageous, the observance of certain cooling curves with a desired formation. In the production of continuously cast slab material without internal or external cracks, for a variety of material grades, the spraying of the casting surface, in the secondary cooling zone, must be accurately controlled. Theoretically, it is accepted that the temperature at the surface of the slab must be reduced gradually and linearly from the exit of the mold to the termination of the solidification. The temperature of the surface at the end of the solidification should not be less than 750° to 800° C. Exceptions are austenitic steels, which can be cooled for lower temperatures without suffering damage.

An inevitable difficulty for an optimum cooling method lies in the increase of the heat transfer coefficient between that inside the mold and the beginning of the secondary cooling zone. While inside the mold 500 to 700 k cal/m^2·h·° C are removed, generally the heat transfer coefficient between the slab surface and the water at the beginning of the secondary cooling zone is only 300 k cal/m^2·h·° C, whereas, at the end of the zone, it is about 800 k cal/m^2·h·° C. Thus, the difficult heat transfer conditions form an as yet unresolved complex of a cooling method. In practice, it is attempted to avoid drastic cooling differences between the mold and the secondary cooling zones, but such efforts do not always have the desired success.

SUMMARY OF THE INVENTION

This invention relates to a method for cooling wide continuous castings of metal, particularly steel, with the aid of cooling water jets, which impinge on the surface of the casting in the secondary zone and which jets are produced with a slanting or arched characteristic and are distributed over the width and the length of the casting. The invention is also directed to novel apparatus for practicing the method.

A primary objective of the present invention is to effect a uniform cooling over the width of the casting and, over and above this, to arrange for a controlled cooling over the length of the continuous casting. The first part of the problem to be solved thus relates to the difficulty of favorably cooling the rectangular slab cross section, while the second part of the problem to be solved is to be brought into direct relationship with the individual parameters of casting rate, cross section size and material quality. As the point of novelty over the prior art, the present invention is directed to meeting the goal of providing a technologically and economically useful cooling method.

In accordance with the invention, the entire problem is solved by providing a cohering jet covering the width of the casting and having its greatest cooling power in this central zone. The kinetic energy of the jet is intentionally smaller in the marginal impingement zones, and the kinetic energy is increased, with increasing distance from the surface of the casting, in proportion to the quantity of heat to be extracted locally. The factor of slow cooling at the center and faster cooling at the edges, because of the greater specific surface, can be taken into account with the invention method. Furthermore, and in contrast to the prior art, a strip extending the full width of the slab is cooled uniformly without any interruption.

An essential feature of the invention is to cool the edges of the slab cross section less intensively, that is, to utilize the kinetic energy inherent in the spray jet for conveying the cooling water into the marginal zones, while using, in the center of the casting, the greater kinetic energy for conveying greater quantities of cooling water. The intensity of the cooling in the central zone of the casting results from the necessity of removing greater quantities of heat from the central zone. As these processes occur practically simultaneously over the entire width of the slab, the objective of the invention, of bringing about uniformity of the temperature in a single cross section plane of the continuous casting, is attained. The controlled removal of the heat in one cross sectional plane of a continuous slab can now form the basis for cooling the casting, viewed relative to its length, in a very specific manner in dependence on the casting rate and material quality, that is, to control a certain cooling curve.

An additional feature, which is not always necessary, but which results, in certain cases, in stabilization of the conditions, is that the rollers supporting the casting have applied thereto, over their full length, a cohering jet of cooling water. As is known, the heating of the rollers occurs in a manner dependent on the temperature conditions in the center of the casting and at the edges of the casting. The rollers used for supporting the casting remove heat therefrom by contact with the casting. Naturally, the heat transfer from the casting to the rollers occurs in proportion to the temperatures prevailing at the surface of the casting, which temperatures are known to differ from the central zone to the edges of the casting. The application of the method of the invention, as used for cooling the surface of the casting, to cooling the supporting rollers thus serves not only to cool the casting but to cool the rollers themselves, so that they, as well as the casting, are relieved from the danger of cracking.

In accordance with a further feature of the invention method, the cohering jet is guided, over the surface to be cooled in swinging movements. Difficulties with respect to the heat transfer conditions, as mentioned above, for example, the magnitude of the heat transfer coefficient, are based mainly on the appearance of the Leidenfrost phenomenon. In a first phase, the cooling water, arriving at ambient temperature, is transformed into steam, whose thermal conductivity is low. If then, in accordance with the invention method, a discontinuous supply of the spray jet occurs, the vapor phase can be washed away so that a more intimate contact occurs between the casting surface and the cooling water. Individual vapor bubbles can remain only a short time and are then washed away. A vapor formation occurs in the shortest intervals of time, whereby the heat removal can be effected to a high degree.

The known objective has, among other things, the apparatus wise disadvantage that a plurality of nozzles are required to distribute, on the casting surface, the spray water required per unit of time. From this, there results a necessity for a complicated control mechanism, which is disadvantageous especially when changing the dimensions of the casting and readjusting the supporting roller frame. Aside from this, the cost of the installation increases considerably due to the use of the necessary non-rusting pipes or conduit, of which a considerable number of running meters is required.

The invention eliminates these and other disadvantages of prior art arrangements in that a single supply line, extending along the longitudinal axis or center line of the casting, includes nozzle connections arranged sequentially in the running direction of the casting centrally of the width of the casting, and only one connecting line, to the main feed line, for each cooling zone is required. Besides the saving in instrumentation, non-rusting pipes and conduits and the number of nozzles, the installation is much less complicated and conversion work is greatly simplified. Thus, the invention is distinguished by the fact that the method goes hand in hand in a particularly advantageous manner with the apparatus.

With this arrangement, the nozzle connections can be provided either with individual flat nozzles or with several singly operable nozzles, of different flow cross section steps or stages. Flat nozzles, in the sense of this invention, possess larger flow cross sections with corresponding channel division, so that the deficiency of a narrow nozzle cross section is obviated. Previously harmful depositions, or entrained components, of the cooling water change the discharge cross sections of the nozzles less, or else exert a less corrosive effect on the surfaces of the nozzles. Still, it is not necessary in accordance with the invention to forego an operational conversion, for example, adjustment of different pressures, different quantities and like variables influencing the cooling. Thus, two cross-section steps or stages may be provided, the two nozzles being arranged one behind the other in the running direction of the casting.

An especially novel form of the apparatus which, accordingly, should be emphasized from its procedural as well as its apparatus-technical effect, results from the fact that a pair of spray cone nozzles, known per se, are placed together obliquely and without spacing, so that the two adjacent inner cone slopes extend vertically parallel, and the outer cone slopes are directed toward the edges of the casting. Such a pair of contiguous spray cone nozzles produces, in the central zone of the casting, a high kinetic energy of the spray jet and consumes, for the spray jets directed to the edges of the slab, the same energy quantity for conveying the spray water. Of course, this effect can be intensified by suitable formation of the aperture cross section of the nozzle, to produce a greater difference between the desired smaller kinetic energy and the larger one, in the zones of the marginal edge and the central zone of the slab casting, respectively.

An additional advantage of the invention results in the fact that the supply line of a cooling zone is operationally adjustable in height by means of a motor, with a flexible reinforced hose line being interposed between the connecting line and the main feed line. Variations of the pressure conditions, such as variations of the quantities of required cooling water, demanded during the operation, can readily be effected, especially with the concept of incorporating the spray water regulation in the overall control system of the continuous casting installation.

An object of the invention is to provide an improved method for cooling wide continuous castings of metal, particularly of steel.

Another object of the invention is to provide an improved apparatus for cooling wide continuous metal castings, particularly steel castings.

A further object of the invention is to provide such a method and apparatus and which uniform cooling of the entire cross sectional area of a continuous casting is effected without any interruptions or gaps in the area being cooled.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a basic diagram of the operation of the invention cooling method with controlled regulation, a continuous slab casting being shown in transverse cross sections;

FIG. **2** is a partial top plan view corresponding to FIG. 1;

FIG. **3** is a view, similar to FIG. **1**, but illustrating an alternative spray jet production;

FIG. **4** is a somewhat diagrammatic plan view of a continuous casting installation including the cooling apparatus embodying the invention;

FIG. **5** is a top plan view of the slab casting operation illustrated in FIG. **4**, and further illustrating the division into individual cooling zones; and

FIG. **6** is an enlarged view illustrating a detail, of FIG. **4**, to a larger scale, and represents a side view of the continuous casting from the viewing direction according to FIG. **4**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, a continuous casting 1 has a rectangular cross section and, in practice, has, for example, dimensions of 1350·160 to 2100·300mm. The slab cross sections may also be much smaller such as, for example, 450·65mm. Usually at least two different slab cross sections are involved and are to be cast in a single installation. When converting the installation, work with respect to supporting roller adjustment and adjustment of the spray nozzles becomes necessary.

Referring to FIG. 1, for the uniform cooling of the slab cross section, a single jet 2, having either a conical or arched characteristic, exerts, in the central zone 3 of casting 1, a particularly intensive heat removal through the high kinetic energy of the jets 4. The cooling water jets 4 issue under greater pressure from the flat nozzle 5, with always a larger quantity of cooling water impinging in the central zone 3 of the casting than in the marginal zones or edges 6. The coolant jets 7 for the casting edges 6 have their kinetic energy purposely kept lower so that, although a uniform spraying of the peripheral edges 6 is effected, a much smaller quantity of coolant, per unit of time, is supplied to the peripheral edges 6.

Referring to FIG. 2, for the cooling of a wide transversely extending strip 8, as illustrated by the dash-dot lines, the flat nozzle 5 is sufficient, and this nozzle is connected to supply line 9 having a correspondingly large flow cross section. Of marked interest in FIG. 2, is the theoretically rectangular impingement area 10 which can be obtained, in practice, by correspondingly ray-shaped discharge apertures of flat nozzle 5. The resulting jet pattern is favored by the fact that the more far-reaching jets 7 always extend above the lower jets 4, in such a manner that intersections of any kind, and hence the disturbances and the flow profile do not occur.

In the example of execution illustrated in FIG. 2, there is a combination of two flat nozzles 5 and 11 which differ from each other by having different discharge cross sections. Only due to the contiguous arrangement there results a displacement, which is insignificant for the cooling process, as indicated by the dash-dot line 12, but the coolant jets 4 and 7 may exhibit considerable differences in kinetic energy.

FIG. 3 illustrates another arrangement for the production of cooling water jets 4, of high kinetic energy, or of cooling water jet 7 of a less kinetic energy. In practice, there are used nozzles which have conical jet characteristics rather than arched characteristics. The nozzles are so slanted as to result in a shortening of the path of jets 4, and accordingly, these jets impinge with greater kinetic energy in the central zone of continuous casting 1. On the other hand, the outer jets 7 distribute themselves over a larger area for which, in any event, only a lesser heat extraction is required, and these jets 7, at the end of their longer path, have a lower kinetic energy. Nozzles 13, for accomplishing this, are so designed, that there are enough shaped discharge apertures to produce the impingement areas 8 and 12, as shown in FIG. 2.

Referring to FIG. 4, the primary cooling of continuous casting 1 occurs in mold 14. Casting 1 issues from mold 14 and reaches, with the aid of the propelling force of conveying rollers 15 and 16, continuously in two secondary cooling zones 17 and 18, for example. In secondary cooling zones 17 and 18, a relatively large number of rollers 19 support casting 1 from both surfaces. As best seen in FIG. 5, in each secondary cooling zone 17 and 18, respective supply lines 9 extend centrally of the width of casting 1. Each supply line has nozzle connections 20 disposed at least between adjacent supporting rollers 19. At most, therefore, these nozzle connections are provided between each pair of supporting rollers and over and above the peripheries of the supporting rollers. Supply lines 9 are connected to main feed line 22 by connecting lines 21. To make possible raising and lowering of supply lines 9, for example, in particular, to take into account different casting widths, which constitutes a special advantage of the invention, reinforced flexible hose lines 23 of corresponding large flow cross section are interposed between connecting lines 21 and the supply lines 9.

In cooling zone 17 below mold 14, there are, in particular, on the upper surface of the casting two nozzle connections 20, as best seen in FIG. 6, and these are fastened to a device 24. The device 24 consists essentially of a nozzle connection retainer 25 with a spindle nut 26, a spindle 27 threadably engaged in nut 26, and a spindle drive motor 28 mounted on nozzle retainer 25. Generally speaking, motor 28 can serve to adjust, on the basis of either a manual control or an automatic control, the distances of nozzles 5, 11 or 13 from the casting surface 29, or can serve to effect, through a simple device 24, swinging of the nozzles 5, 11 or 13.

Such secondary cooling zones 17 and 18 can be arranged in any desired member and sequence on the upper and lower surfaces of the casting, to adapt to the casting metallurgical requirements. When casting a continuous slab 2000·200mm, for example, the operation of the apparatus involves adjusting the distance of nozzles 5, 11 or 13 from casting surface 29 before casting, and controlling the water quantity, during casting, by regulation of the water pressure. In the course, of casting, the distance of the nozzles from the casting surface is varied in accordance with the heat extraction requirements.

The advantages of the invention may be classified in two main groups. From the aspect of process technology, the intensity of the cooling over the slab width can be adjusted better than hitherto known, and in particular, the feature of coolings varying slab widths is taken into account in a novel manner.

From the aspect of apparatus technology, there are also essential advantages. The number of nozzles and pipes for the water supply, including the control valves, is greatly reduced as compared to known apparatus. The secondary cooling zones 17 and 18 are more accessible, and thus the upkeep of the secondary cooling devices, and also the elimination of the consequences of the possible breaking of the casting, are facilitated and accelerated. The casting surface quality can be influenced essentially with simple means in the course of casting by technical control measures. By the enlargement of the nozzle spray apertures, generally the requirements of water purity are greatly reduced, so that there is no need for the construction of an expensive water purification plant and the use of pipes of stainless steels.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. In a method for cooling roller-supported wide continuous metal castings, particularly steel castings, using cooling water jets which impinge on the casting surface in the secondary cooling zone and which jets are produced with a slanting or arched characteristic and, in use, are distributed over the width and the length of the casting, the improvement comprising: forming a cohering jet, centered on the longitudinal centerline of the casting, covering the width of the casting in a single continuous substantially rectangular pattern extending across the casting and having its greatest cooling power in the longitudinally extending central zone of the casting; controlling the kinetic energy of the jet to be intentionally smaller in the lateral marginal impingement zones along the casting; and, with increasing distance from the casting surface, increasing the kinetic energy, from the lateral margins of the casting to the central zone thereof, in proportion to the quantity of heat to be extracted locally.

2. In a method for cooling roller-supported wide continuous metal castings, the improvement claimed in claim 1, including applying the cohering jet of cooling water to the casting supporting rollers throughout the full lengths thereof.

3. In a method for cooling roller-supported wide continuous metal castings, the improvement claimed in claim 1, including oscillating the cohering jet over the surface to be cooled.

4. In apparatus for cooling roller-supported wide continuous metal castings, particularly steel castings, using cooling water jets which impinge on the casting surface in the secondary cooling zone and which jets are produced with a slanting or arched characteristic and, in use, are distributed over the width and the length of the casting, the improvement comprising, in combination, a single supply line extending parallel to the longitudinal center line of the casting in each secondary cooling zone; nozzle connections included in said single supply line and arranged sequentially in the running direction of the casting along the longitudinal center line of the casting; a respective nozzle secured to each nozzle connection to direct a respective cohering jet, centered on the longitudinal center line of the casting, covering the width of the casting in a respective substantially rectangular pattern extending across the casting; a main feed line, and a respective single connecting line, for each secondary cooling zone, connecting said main feed line to the respective supply line for the cooling zone.

5. In apparatus for cooling roller-supported wide continuous metal castings, the improvement claimed in claim 4, in which said nozzle connections are provided with single flat nozzles.

6. In apparatus for cooling roller-supported wide continuous metal castings, the improvement claimed in claim 4, in which said nozzle connections are provided with plural individually operable nozzles of different flow cross section stages.

7. In apparatus for cooling roller-supported wide continuous metal castings, the improvement claimed in claim 4, in which said nozzle connections are provided with a pair of spray cone nozzles arranged in contiguous oblique arrangement with the two adjacent inner sloping sides of the cones extending vertically parallel and the outer sloping sides of the cones directed onto the casting margins.

8. In apparatus for cooling roller-supported wide continuous metal castings, the improvement claimed in claim 4, in which each supply line is adjustable in height during operation; adjusting means including a motor connected to each supply line to adjust the same in height; and respective flexible reinforced hose lines connecting each connecting line with said main feed line.

9. In apparatus for cooling roller-supported wide continuous metal castings, the improvement claimed in claim 4, in which each nozzle connection is disposed, longitudinally of the casting, between a pair of adjacent supporting rollers.

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