METHOD OF COOLING CAST MEMBERS FROM A CONTINUOUS CASTING OPERATION

Filed May 29, 1967 4 Sheets-Sheet 1

FIG. 1

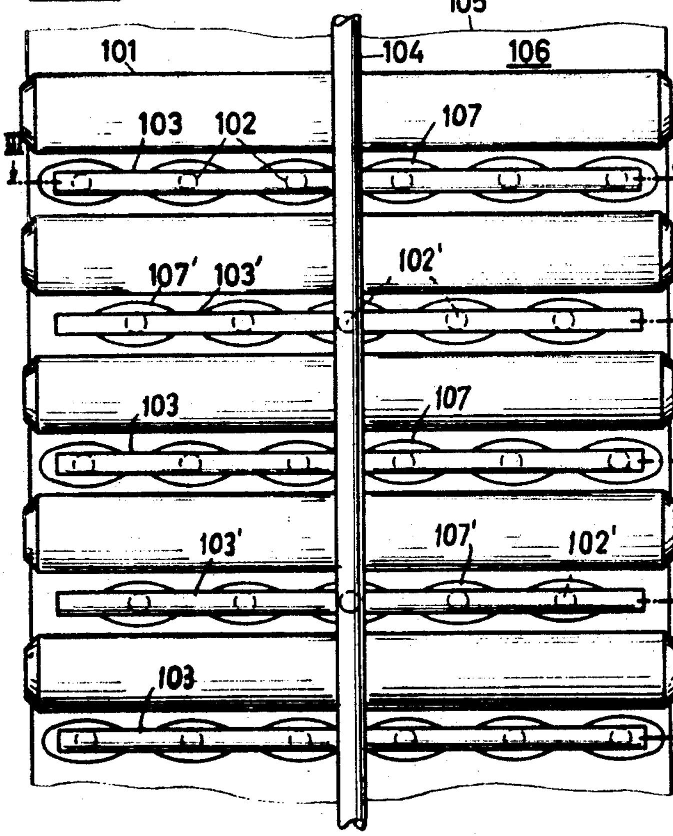

FIG. 2

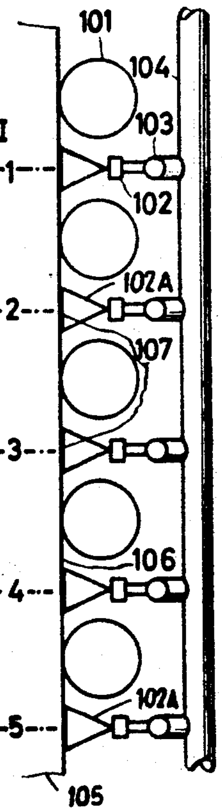

FIG. 3

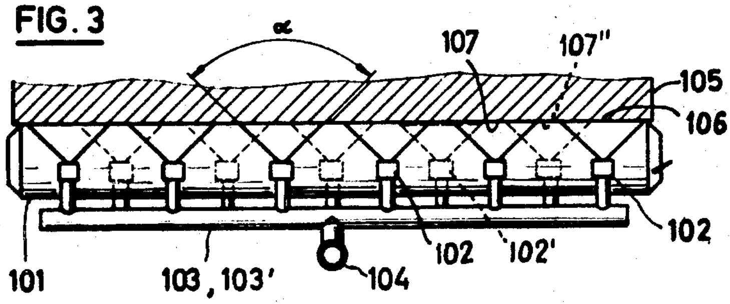

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FIG. 4

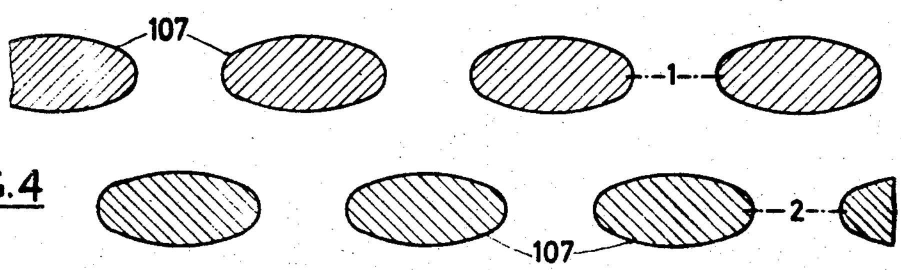


FIG. 5

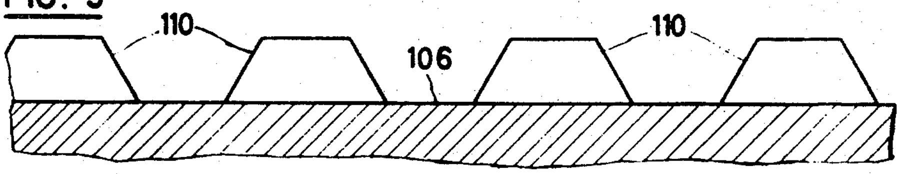


FIG. 6

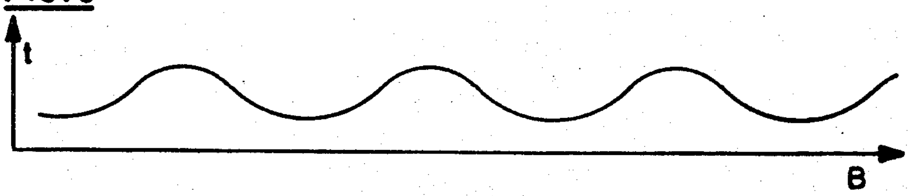


FIG. 7

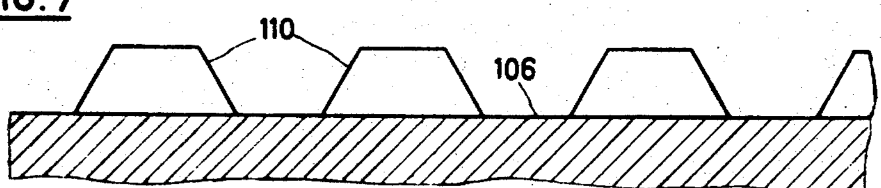


FIG. 8

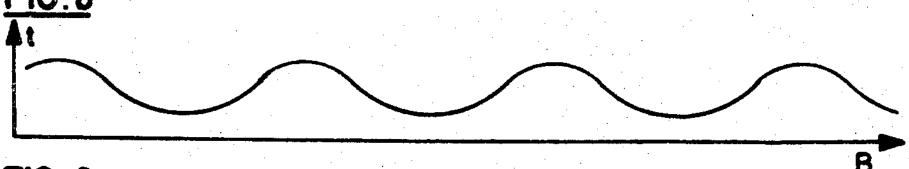
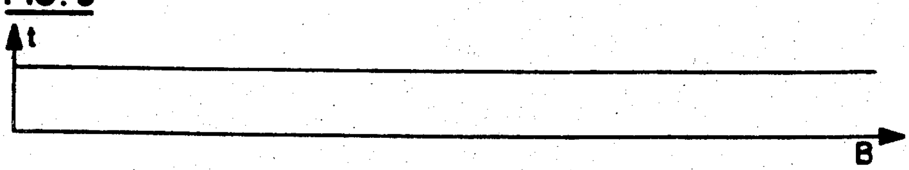


FIG. 9



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Sept. 23, 1969 M. E. BURKHARDT ET AL 3,468,362

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FIG. 10

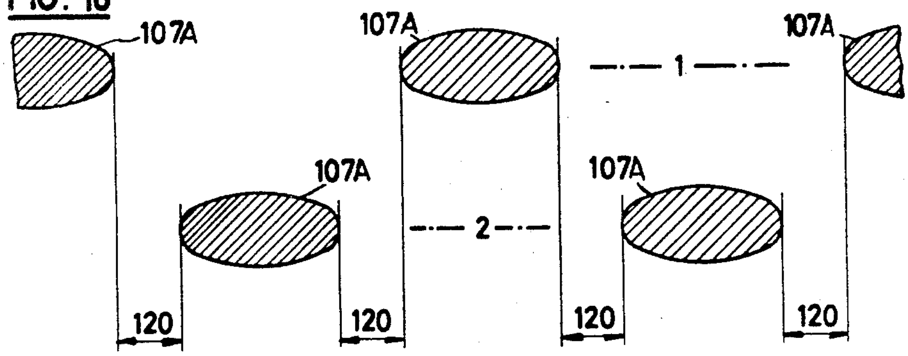

FIG. 11

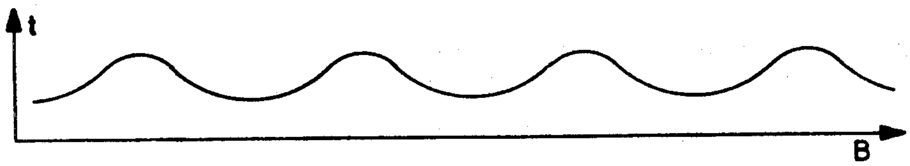

FIG. 12

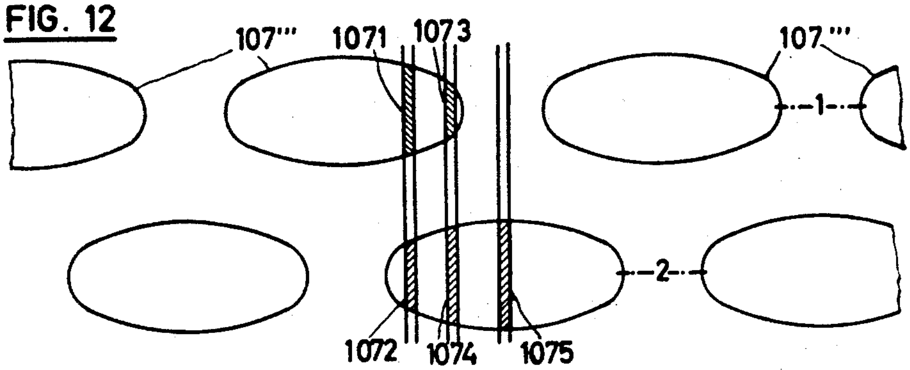

FIG. 13

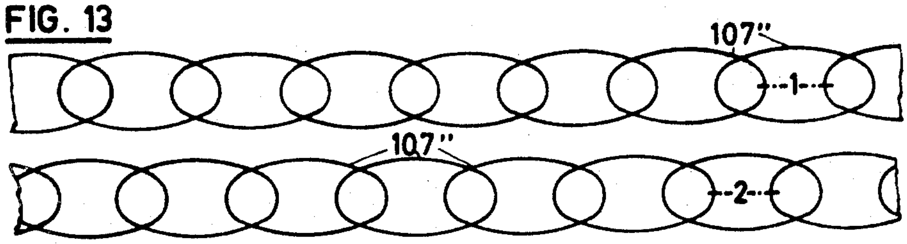

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FIG. 14

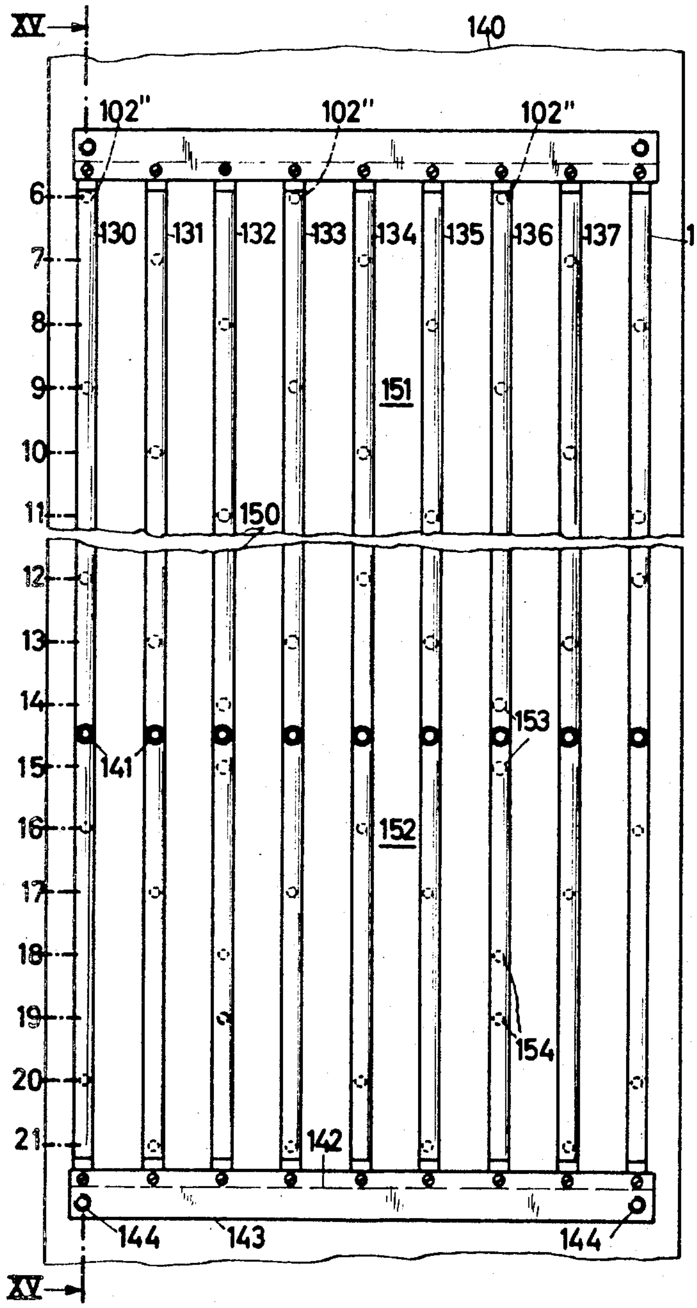
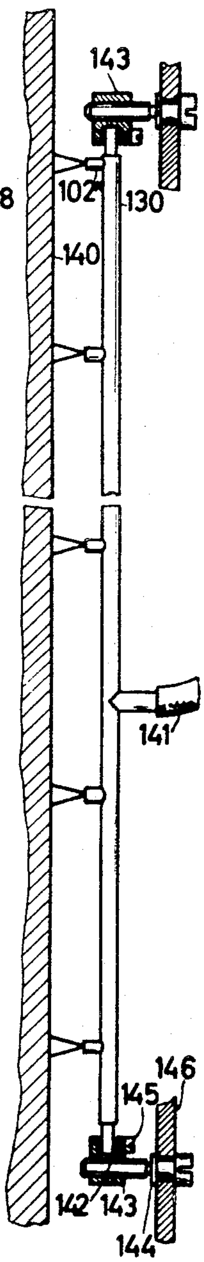


FIG. 15



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METHOD OF COOLING CAST MEMBERS FROM A CONTINUOUS CASTING OPERATION

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Claims priority, application Switzerland, May 31, 1966, 7,880/66
Int. Cl. B22d *11/12;* B05b *1/20*
U.S. Cl. 164—89 7 Claims

ABSTRACT OF THE DISCLOSURE

A method of cooling a cast member from a continuous casting operation including the steps of moving the cast member along a path of travel, arranging a multiplicity of spray locations in a plurality of rows disposed across the path of travel, positioning the spray locations in adjacent rows in staggered relationship in the direction of the path of travel, and spraying coolant fluid onto the surface of the cast member whereby the spray from each location is deposited in an individual area on the surface and the distribution of the coolant fluid in the areas in each row is non-uniform and the sum of the distribution of the coolant fluid in a selected number of rows having the staggered spray locations provides a uniform distribution of the coolant fluid across the surface of the cast member for achieving a uniform cooling effect for the cast member.

Summary of the invention

The present invention is directed to a method of and apparatus for cooling a cast member from a continuous casting operation in a secondary cooling zone, and more particularly, it is directed to an arrangement of spray nozzles disposed across the path of travel of the cast member in the cooling zone wherein the coolant fluid is non-uniformly distributed across the surface of the cast member in each row of nozzles but is uniformly distributed by the sum of the coolant fluid from a selected number of rows of the nozzles.

In continuous casting operations after the cast member has been removed from the cooled mold it still has not been completely solidified and requires additional heat removal in a secondary cooling zone. The manner in which the heat is removed from the cast member in the secondary cooling zone is of considerable importance, not only to the quality of the member but also to the efficiency of the continuous casting operation. For effective cooling of the cast member, finely atomized water is sprayed from specially constructed nozzles onto its surface. Since the cast members vary in size and in other characteristics the disposition of the spray nozzles in relation to the surface of the member is important because of the following: the interaction of adjacent spray nozzles, the angle of the spray cone, the spraying characteristics of the nozzles, the shape of the area of coolant fluid contact on the surface of the cast member, and the pressure of the coolant fluid. These are all variable parameters which may have a considerably effect on the quality of the cast member after it has been completely cooled.

In the past, spray nozzles have been arranged in rows which are substantially perpendicular to the direction of the path of travel of the cast members through the cooling zone and the coolant fluid is supplied from a common supply. However, a serious shortcoming of this arrangement is the non-uniform distribution of the coolant fluid striking the surface of the casting member in the direction transverse to the path of travel of the casting member.

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This non-uniformity in the cooling has been avoided in another method by providing the nozzles with a flat characteristic, that is a uniform distribution of the coolant spray across the surface of the cast member. In such an arrangement the nozzles are adjusted so that an even concentration of coolant fluid is deposited across the surface. In such an arrangement, however, due to the varying sizes of the cast members, particularly wide slabs, a considerable amount of adjustment is required to locate the spray nozzles in relationship to one another and to the surface of the cast member so that uniform distribution is achieved. Another problem in this particular arrangement is in achieving a flat distribution where a certain amount of overlap occurs in the spray from adjacent nozzles. Such overlap results in a loss of momentum of the spray particles due to their collision and causes a decrease in the cooling effect in the region of the overlap. Accordingly, less heat is removed from the cast member by the same volume of coolant and the temperature in the area of the overlap is higher than that in the adjacent areas receiving the coolant fluid.

Another method of controlling the cooling effect is to vary the pressure of the coolant fluid, however, this is possible only within rather narrow limits because any change in pressure involves a change in the overlap of the spray distribution from adjacent nozzles. As indicated above, this overlap causes an imbalance in the temperature distribution on the surface of the cast member. Accordingly, attempts at adjusting the cooling effect by varying pressure has a tendency to be self-defeating. Further, while these changes in pressure may be purposeful, they may also develop unintentionally in the course of the spraying operation and, as a result, they tend to unbalance the uniform distribution of the coolant.

Another cooling arrangement involves the disposition of the nozzles into a number of groups with each group being selectively provided, in cyclic rotation, with the coolant fluid. In this arrangement the cooling effect varies depending upon the rotation of the coolant to the various groups of nozzles. Adjustment of the nozzle spacing in such an arrangement does not afford uniform cooling across the width of the cast member because areas are developed which do not receive any coolant spray and the positions of the nozzles are not matched. This is a particular problem if the cast member is one that is prone to cracking. In this cooling system, if the width of the castings does not vary except within a limited range, its use is not particularly economical because of both the large number of nozzles required, and the complicated control means needed for cyclic operation. Additionally, due to the cyclic distribution of coolant through the nozzles, at times a considerable number of nozzles do not issue any spray coolant and as a result the number of nozzles needed is very considerable to achieve the desired effect.

Accordingly, the primary object of the invention is to provide both a method of and apparatus for cooling a cast member where spray nozzles are used in a number of transverse rows so that the multiple effect of the spray from several rows provides an uniform cooling distribution of the coolant fluid on the surface of the cast member.

Another object of the invention is to provide a means for adjusting the distribution of coolant spray onto the surface of the cast member.

Still another object of the invention is to arrange the spray nozzles in adjacent transverse rows so that they are in offset relationship to one another.

A still further object of the invention is to supply a support structure for the nozzles which can be adjusted for the transverse spacing of the nozzles from one another and for spacing the nozzles perpendicularly to the surface of the cast member.

Moreover, another object of the invention is to dispose the nozzles in staggered relationships so that the cooling distribution may be uniformly effected.

Yet another object is to afford an effective and efficient cooling operation which overcomes the problems of the prior art and improves the efficiency of the overall continuous casting operation.

Therefore the present invention affords a method of cooling a cast member from a continuous casting operation including the steps of moving the cast member along a path of travel, and adjustably spraying a coolant fluid from a multiplicity of spray locations whereby a plurality of rows of areas of coolant fluid contact are formed on the surface of the cast member, the rows of areas aligned across the path of travel, and in adjacent rows the areas are staggered in the direction of the path of travel. In this way, though each row of areas has a non-uniform distribution across the surface of the cast member, the multiple effect or sum of the distribution of the coolant fluid in a number of selected staggered rows provides a substantially uniform cooling effect.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated and described preferred embodiments of the invention.

Description of the drawings

In the drawings:

FIG. 1 is a view of a surface of a cast member and a cooling system embodying the present invention;

FIG. 2 is a side view of the embodiment shown in FIG. 1;

FIG. 3 is a transverse view, partly in section, taken along line III—III in FIG. 1;

FIG. 4 is a partial view of the areas of coolant fluid contact on the surface of a cast member provided by two rows of nozzles shown in FIG. 1;

FIG. 5 illustrates the characteristics of the spray distribution on the surface of the cast member in one of the rows of areas shown in FIG. 4;

FIG. 6 demonstrates the temperature distribution across the surface of the cast member for the spray characteristic shown in FIG.5;

FIG. 7 displays the spray characteristic of the other row of areas of coolant fluid contact shown in FIG. 4;

FIG. 8 shows the temperature distribution across the surface of the cast member for the spray characteristic shown in FIG. 7;

FIG. 9 is the sum of the temperature distributions shown in FIGS. 6 and 8 for the two rows of areas illustrated in FIG. 4;

FIG. 10 is a view of another arrangement of the areas of coolant fluid contact with the cast member;

FIG. 11 discloses the temperature distribution across the surface of the cast member represented by the areas in FIG. 10;

FIG. 12 illustrates the arrangement of the areas of coolant fluid contact for nozzles having an ogival or pointed arch pattern of spray on the surface of the cast member;

FIG. 13 discloses an arrangement of overlapping areas of coolant fluid contact on the surface of a cast member;

FIG. 14 is another embodiment of a cooling system, generally similar to the one shown in FIG. 1, but with the orientation of the supply pipes changed; and

FIG. 15 is a side view, partly in section, taken along line XV—XV in FIG. 14.

Detailed description

In FIG. 1 rollers **101** provide a path of travel for a cast member **105** from a continuous casting operation where the member has been removed from its mold and is being passed through a secondary cooling zone. For clarity in the illustration of the invention, the manner in which the rollers are mounted and the general arrangement of the plant are not shown. Positioned across the path of travel of the cast member **105** and in parallel relationship with the rollers **101** are a number of supply pipes **103, 103'**. Each of the pipes **103, 103'** is provided with a number of nozzles **102, 102'** for spraying a coolant fluid onto the surface **106** of the cast member **105**. The coolant fluid is supplied to the pipes **103, 103'** by a feeder pipe **104** from a common source, not shown.

On the surface **106** of the cast member **105** the areas **107, 107'** of contact of the spray coolant are shown having a closed curved shape elongated in the direction of the pipes **103, 103'**. The nozzles positioned in each of the supply pipes are identified as rows **1, 2, 3, 4** and **5**. It will be noted that the spray nozzles in rows **1, 3** and **5** are in alignment in the direction of the path of travel as are the nozzles in rows **2** and **4**, however, the nozzles in rows **1** and **2** are staggered in relationship to one another whereby the nozzles **102'** are positioned midway between the nozzles **102**.

In FIG. 2 the spray cone **102A** displays the distribution of the coolant fluid from the nozzles **102** to the surface **106** of the cast member **105**. In FIG. 3 the angle of spray, α, from the nozzle **102** to the surface **106**, is shown. The angle α is the same for each of the nozzles across the pipe **103** and also for the nozzles in pipes **103'**, as is shown by the dotted lines in FIG. 3.

The coolant fluid spray from each of the nozzles **102, 102'** has a flat characteristic **110** in the areas of contact with the surface of the **106** of the cast member **105** as shown in FIGS. 5 and 7 for the rows **1** and **2**, see FIG. 1. By a flat characteristic is meant that within the area of contact of the spray with the cast member each portion of the area receives substantially the same amount of coolant fluid. In describing the distribution of the coolant on the cast member only two rows of areas **107, 107'** are shown in FIGS. 4 through 13. In FIG. 4 a portion of the areas **107, 107'** in rows **1** and **2** are shown, both rows of areas are aligned across the path of travel of the cast member and are staggered in the direction of the path of travel. Further, it can be seen in FIG. 4 that the ends of the areas **107, 107'** are arranged so that they overlap or cover similar sections of the surfaces of the cast member. In FIGS. 5 and 7 the areas **110** represent the distribution of coolant fluid in the areas **107, 107'** on the surface of the cast member **105**. Due to the spacing of the nozzles in each of the rows **1** through **5** an non-uniform distribution of coolant fluid is provided across each row. In FIGS. 6 and 8 a representation of the temperature distribution is shown for the surface **106** across rows **1** and **2** respectively, the vertical axis, identified as t, indicating the relative temperature of the surface **106** and the horizontal axis, marked B, signifies the transverse dimension of the surface **106**. As can be seen in both FIGS. 6 and 8 the temperature distribution across the surface of the cast member varies both because of the spacing of the nozzles **102, 102'** and because the coolant impinges only on a restricted portion of the surface.

In the system illustrated in FIG. 1 the sum of the cooling effect on the surface **106** due to the spray from the nozzles **102, 102'** in adjacent rows affords a uniform heat removal distribution for a given set of parameters, such as the coolant pressure, nozzle characteristics, spray angle, nozzle spacing, and the characteristics of the cast member itself. FIG. 9 illustrates the combination of the temperature distributions shown in FIGS. 6 and 8 indicating that a uniform surface temperature is provided.

If, for a given set of parameters the cooling effect proves to be non-uniform then an adjustment can be made by changing the distance of the nozzles from the surface of the casting. For instance, if the nozzles are too close to the surface of the cast member **105** the area of contact or the spray cone will be relatively small and the coolant fluid will be concentrated on a smaller area. This condition is illustrated in FIG. 10 where the areas of coolant fluid contact **107A** in rows **1** and **2** are disposed so that there is a portion **120** of the surface of the cast member which does not receive any of the spray. Unlike the combined cooling effect obtained from the arrangement shown in FIGS. 4 to 9, in FIG. 11 the combined effect of the rows **1** and **2** disclosed in FIG. 10 still results in a non-uniform distribution. By changing the distance from the spray nozzle to the surface of the cast member the area **107A** can be increased and the corresponding surface **120** reduced or eliminated whereby uniform cooling is attained across the entire transverse surface of the cast member.

An alternative manner of controlling the cooling effect on the surface of the cast member is to vary the spacing of the nozzles from one another. Instead of positioning the nozzles in pipes running across the path of travel of the cast member the nozzles are located in pipes running in the direction of the path of travel, but with the nozzles still aligned in transverse rows. Accordingly, by changing the spacing of the pipes the spacing of the nozzles can be varied to obtain a particular spray distribution, for example note the areas **107″** in rows **1** and **2** shown in FIG. 13. If the pipes are moved close enough the areas **107″** overlap one another. Preferably such an adjustment is made where the coolant pressure fluid is at a maximum and, hence, the spray angle is also at its maximum. If the pressure is then reduced the spray angle will also be reduced and the area **107″** will become smaller with less or no overlap. Though the pressure is varied it does not alter the cooling effect across the surface of the cast member. Accordingly, during operation the pressure of the coolant fluid can be varied through its normal range without substantially effecting the uniformity of the temperature distribution on the surface of the cast member. The coolant pressure depends primarily upon the casting conditions such as the quality of material, casting rate, temperature of steel, and should not significantly affect the cooling effect. In view of this the nozzles used in the cooling operation should be selected to maintain the spray angle, α, as constant as possible within the range of the pressures conventionally used in continuous casting operations.

Still another means for regulating the cooling effect of the cast member involves changing the nozzles so that a different spray angle or different spray characteristics are obtained so that the area of coolant fluid contact is regulated to provide the optimum cooling effect.

In the present invention it is also possible to use nozzles which do not have the flat distribution characteristic shown in FIGS. 5 and 7 but which have what is known as an ogival characteristic. The area **107‴**, see FIG. 12, illustrates the coolant fluid distribution obtained from a nozzle having an ogival characteristic, the areas are disposed in transverse rows across the surface of a cast member. Similar to the arrangement of areas in FIG. 4 the areas **107‴** in FIG. 12 are offset in row **2** with relationship to row **1**, that is they are spaced midway between the areas in the adjacent row. The parameters of the spray angle, nozzle spacing in each row, and the distance of the nozzles from the surface of the cast member are chosen so that the cumulative amount of the coolant fluid sprayed on the aligned sections **1071** and **1072** or **1073** and **1074** are equal to that in section **1075** for the adjacent rows **1** and **2**. Accordingly, though the nozzle does not have a flat characteristic the distribution of coolant is such that the sum of the distributions for the two rows provide a uniform cooling effect across the transverse surface of the cast member.

Another embodiment of the present invention is shown in FIGS. 14 and 15 where the nozzles **102″** are supported in pipes **130** to **138** which extend in the direction of the path of travel of the cast member. However, the nozzles **102″** are disposed in a number of rows **6** to **21** which extend transversely of the path of travel. The pipes **130** to **138** are clamped between guide ways **142** in rails **143**. In this arrangement the pipes can be moved across the path of travel and the spacing between the nozzles will be either decreased or increased for the rows **6** to **21**. Since the pipes are movable the supply of coolant to them is made by a flexible hose connection **141**. In addition to providing spacing between the nozzles the screws **144** in the pipe support arrangement are held in a beam **146** so that the guide rails can be positioned relative to the surface **140** of the cast member and the distance of the nozzles from the surface **140** can be adjusted as required.

Compared to the arrangement shown in FIG. 1 where the cumulative effect of the coolant fluid in adjacent transverse rows achieves uniform distribution, in the system shown in FIG. 14 more than two rows of the nozzles **102″** may be used to obtain the uniform cooling effect. The apparatus in FIG. 14 is divided by the parting lines **150** into two secondary cooling zone sections **151, 152.** In the upper section **151** the nozzles are arranged with every three rows providing the overlapping arrangement needed to achieve the uniform cooling effect. It will be noted that rows **6, 7,** and **8** are repeated by rows **9, 10,** and **11** so that the sum of the cooling effect of each set of rows provides a uniform heat removal operation from the surface of the cast member.

In the lower section **152** shown in FIG. 14 the cooperating nozzles are distributed in alternating rows and in determining the cooling effect rows **12** and **14, 16** and **18, 13** and **15,** and **17** and **19** are considered together.

The rows of nozzles **102″** in sections **151** and **152** are arranged in a recurrent patterns. However, other arrangements in which the nozzles are not disposed in this recurrent fashion would also be feasible.

Alternatively, the embodiment shown in FIGS. 14 and 15 could be arranged into a number of groups with each group being provided, selectively and in cyclic rotation, with the coolant fluid for achieving uniform cooling by varying the pattern of flow from the various spray nozzles. The variation of flow pattern can be achieved, for example, by an oscillating or rotating valve connected with two water pumps which are generating different fluid pressures.

It would be appreciated that the arrangements shown in the drawings, while illustrating the basic concept of the present invention, are by no way limiting in the manner in which the nozzles can be positioned to provide the desired uniform distribution of the coolant. As an example, an increase in the cooling fluid pressure or the use of larger nozzles in the pipes **132** and **136** of FIG. 14 would permit the number of nozzles associated with the pipes to be reduced without altering the uniformity of the cooling effect. Specifically the nozzles **153** or **154** could be replaced by a single nozzle having the same cooling effect.

It is not essential that the supply pipes **103, 103′** and **130** to **138** be disposed transversely to the path of travel as shown in FIG. 1 or along the direction of the path of travel as shown in FIG. 14. Alternatively, the pipes could be positioned obliquely to the direction of travel. As an example, referring to FIG. 1, if the first nozzles in rows **1** and **2** and the second nozzles in rows **1** and **2** are grouped together the supply pipes would be positioned obliquely to the path of travel, though the nozzles would still be disposed in a transverse rows. The supply pipes could extend in this oblique direction and would have a multiplicity of nozzles similar to the pipes **103, 103′** and **130** to **138**.

In another arrangement the nozzles could be aligned in rows extending parallel to the path of travel of the cast member without being displaced relative to one another in a transverse direction. In such a pattern, however, adjacent nozzles in the direction of the path of travel would have different spray distributions. The effect of this would be to offset the areas of contact of the coolant fluid in each succeeding row of nozzles and would, thereby operate in the same manner as the arrangement shown in FIGS. 1 and 14.

In practicing the present invention the various arrangements which have been discussed and illustrated may not immediately achieve the desired uniform cooling distribution. Any unevenness may be due to the cooling effects of adjacent faces at corners, the qualities of the steel involved, or other causes which bring about the imbalance. However, the presence of these factors is observable during the cooling operation because of the appearance of darker bands on the surface of the cast member in its direction of travel. These irregularities can be compensated by additional adjustments in the nozzles as hereinbefore described.

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

What is claimed is:

1. A method of cooling cast members in a secondary cooling zone of a continuous casting operation comprising moving a cast member along a longitudinal path of travel in the secondary cooling zone, arranging a multiplicity of coolant spray nozzle locations in the secondary cooling zone in spaced relationship to the surface of the cast member to be cooled, spacing the spray nozzle locations in a uniform manner in a plurality of spaced rows extending transversely of the longitudinal path of travel of the cast member for forming a plurality of rows of substantially similar coolant fluid contact areas extending transversely across the surface of the cast member, staggering the position of the spray nozzle locations in at least two adjacent rows with the spray nozzle locations in one of the adjacent rows being offset in a regular pattern in the transverse direction to the spray nozzle locations in the other adjacent row so that the coolant fluid contact areas for each row are similarly offset, arranging the distribution of coolant fluid from the spray nozzle locations to the coolant fluid contact areas in each of the adjacent rows having the offset relationship of the spray nozzle locations for forming both a transversely extending non-uniform distribution of coolant fluid on the surface of the cast members across each adjacent row

and a substantially uniform distribution of coolant fluid in the combined adjacent rows for uniformly cooling the cast member across its transverse dimension.

2. A method of cooling cast members as set forth in claim 1, comprising the step of varying the distance of the spray nozzle locations from the surface of the cast member for adjusting the area of contact of the coolant fluid on the surface of the cast members.

3. A method of cooling cast members as set forth in claim 1, comprising the step of varying the spacing of the spray nozzles across the path of travel of the cast member for adjusting the position of the areas of contact of the coolant fluid on the surface of the cast members.

4. A method of cooling cast members as set forth in claim 1, comprising the step of varying the spray angle of the spray nozzles for adjusting the area of contact of the coolant fluid on the surface of the cast members.

5. A method of cooling cast members as set forth in claim 1, comprising the step of varying the spray characteristics of the spray nozzle for adjusting the flow of coolant fluid from the spray nozzle to the surface of the cast member.

6. A method of cooling cast members as set forth in claim 1, comprising the step of supplying coolant fluid from a common source to the spray nozzles.

7. A method of cooling cast members as set forth in claim 1, comprising the step of cyclically routing coolant fluid to a selected number of spray nozzle locations for achieving uniform cooling by varying the pattern of flow from the various spray nozzles.

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U.S. Cl. X.R.

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