

**TWIN ROLL CASTER, AND EQUIPMENT AND METHOD FOR OPERATING
THE SAME**

TECHNICAL FIELD

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This invention relates generally to twin roll casters, and more particularly to casting rolls for a twin roll caster.

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The twin roll method of continuous casting thin metal strip from molten metal between a pair of counter rotating casting rolls and through a nip between the rolls is known.

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Figures 14 and 15 show an example of a prior art continuous casting machine. With reference to the Figures, the casting rolls 2 are in contact with side dams 1 at the circumferential end surfaces of the casting rolls 2 and have hollow stub shafts 3 that axially engage the two ends of the casting rolls 2 (see for example U.S. Patent No. 6,241,002).

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The two end portions of the casting rolls 2 are smaller than the central portions and are shaped as to come into contact with the side dams 1. In the continuous casting machine, the casting rolls 2 are disposed lateral to each other in such a manner that the casting roll nip may be adjusted according to the thickness of the strip S that is to be manufactured. The side dams 1 are respectively in contact with end surfaces of central portions of greater diameter of the casting rolls 2. The arrangement is such that the casting rolls 2 and the side dams 1 contain the molten metal M. The speed and direction of revolution of the casting rolls are set such that the outer circumferential surfaces move towards the casting roll gap at the same speed.

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Radially below and spaced from the position of the side dams, the known casting rolls 2 have a plurality of axially extending, i.e. longitudinal, internal cooling passages 4 positioned equidistantly circumferentially, and
5 a plurality of radially extending cooling passages 5 connected with the ends of the longitudinal cooling passages 4. The cooling passages 4 extend from one end of the casting rolls to the other end of the casting rolls radially below the position of the side dams. Bolts 7 or
10 plugs 6 in the ends served as plugs to close the ends of the longitudinal cooling passages 4. The radial cooling passages 5 extend from an inner circumferential surface of the casting rolls at right angles to the longitudinal cooling passages 4.

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Radial cooling passages 8 pass through the hollow shaft 3 to allow cooling water W to flow through one hollow shaft 3 into radial cooling passages 5, then into longitudinal cooling passages 4, corresponding radial
20 cooling passages 8, 5 at the other end of the casting roll 2, and finally into the interior of the other hollow shaft 3.

In such a continuous casting machine, heat is
25 removed by cooling water W flowing through the radial cooling passages 5 and the longitudinal cooling passages 4 while molten metal M is poured into the space confined by the side dams 1 and the casting rolls 2 forming a pool of molten metal M above the nip between the casting rolls.

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As the casting rolls rotate, the metal that is being cooled on the outer circumferential surfaces of the casting rolls 2 forms solidified shells that form a strip S, and the strip S moves downwards from the casting roll
35 gap.

The rate of cooling of the molten metal is

however limited by the heat conductivity from the circumferential surfaces to the cooling passages.

Thus, it is apparent that it would be
5 advantageous to provide an alternative apparatus and method that provides more efficient casting of melt strip. Accordingly, a suitable alternative is provided including features more fully disclosed hereinafter.

10 DISCLOSURE OF THE INVENTION

An apparatus and a method are disclosed for casting metal strip having a pair of laterally positioned casting rolls forming a nip between them.

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A molten metal supply system delivers molten metal into the nip between the casting rolls and forms a casting pool of molten metal supported on the casting rolls immediately above the nip. A pair of side dams, one
20 at each end of the pair of casting rolls, confines the pool of molten metal and abuts axial end surfaces of the casting rolls.

Each casting roll comprises a cylindrical body.
25 In one embodiment the body is a stepped cylindrical body which comprises a cylindrical central portion of a larger outer diameter than adjacent cylindrical end portions that extend axially from each end of the central portion at an inwardly stepped shoulder that forms a radially extending
30 end surface.

Each casting roll also comprises a plurality of cooling passages extending through the central portion, typically between the radially extending end surfaces.
35 The cooling passages comprise longitudinal cooling passages. The cooling passages also comprise at least one bend in the cooling passages which requires cooling fluid

flowing through a cooling passage to undergo a change in direction.

Each casting roll also comprises a flow control
5 member positioned in the bend to control the flow of cooling fluid around the bend

Each casting roll may comprise radial cooling
10 passages extending from a casting roll inner periphery and connect to a longitudinal cooling passage, with the bend being formed where the longitudinal and radial cooling passages merge together.

In one embodiment each casting roll comprises at
15 least one circumferential section that interconnects adjacent longitudinal cooling passages so that cooling fluid can flow from one longitudinal cooling passage into and then along an adjacent longitudinal cooling passage, with the bend being formed in the circumferential section
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In one embodiment the flow control member comprises a baffle that is formed and positioned in the bend to change the flow of cooling fluid around the bend.

25 For example, the baffle is positioned to extend from an internal corner of the bend towards an external corner of the bend. This arrangement reduces the cross section of the bend and causes an increase in the velocity of the cooling fluid, such as water, and also directs the
30 cooling fluid towards the outer corner of the bend.

In one embodiment the flow control member is a plurality of fins that are formed and positioned in the bend to change the flow of cooling fluid around the bend.
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For example, the fins are aligned circumferentially and project from positions in the

vicinity of the radially extending end surfaces and extend in the direction of the longitudinal cooling passage, and cooling fluid, such as water, is caused to flow through the cooling passage. Thus, the fins reduce the cross
5 section of the bend and thereby increase the velocity of the cooling fluid, and also conduct the heat of the casting roll from the fins to the cooling fluid.

In one embodiment the flow control member is a
10 plurality of inserts positioned in the bend to change the flow of cooling fluid around the bend.

For example, the inserts fill in a portion of the bend and thereby reduce the cross-sectional area of the
15 bend and thereby increase the velocity of the cooling fluid, such as water, and also direct the cooling fluid to the vicinity of the outer circumferential surface of the roll in the bend.

20 The above-mentioned examples are not the only possible flow control members.

The foregoing and other aspects will become apparent from the following detailed description of the
25 invention when considered in conjunction with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

30 Figure 1 is a schematic drawing showing a vertical cross-section of one embodiment of a continuous casting machine;

Figure 2 is a schematic drawing showing one of
35 the baffles shown in Figure 1;

Figure 3 is a schematic drawing showing an axial

view of the casting rolls and the stub shafts shown in Figure 1;

5 Figure 4 is two diagrams comparing the flow velocity distribution of cooling water in the continuous casting machine shown in Figure 1, i.e. with internal baffles, and in an example of a continuous casting machine in which there are no internal baffles;

10 Figure 5 is two diagrams comparing the flow velocity distribution of cooling water in the continuous casting machine shown in Figure 1, i.e. with internal baffles, and in an example of a continuous casting machine in which there are no internal baffles;

15 Figure 6 is a schematic drawing showing a vertical cross-section of another embodiment of a continuous casting machine;

20 Figure 7 is a schematic drawing of the fins shown in Figure 6;

25 Figure 8 is two diagrams comparing the flow velocity distribution of cooling water in the continuous casting machine shown in Figure 6, i.e. with internal fins, and in an example of a continuous casting machine in which there are no internal baffles;

30 Figure 9 is two diagrams comparing the flow velocity distribution of cooling water in the continuous casting machine shown in Figure 6, i.e. with internal fins, and in an example of a continuous casting machine in which there are no internal baffles;

35 Figure 10 is a schematic drawing showing a vertical cross-section of another embodiment of a continuous casting machine;

Figure 11 is a schematic drawing showing a lateral cross-sectional view of the positions of the longitudinal cooling passages, circumferential cooling passages, and inserts of Figure 10;

Figure 12 is a schematic drawing showing a horizontal cross sectional view of the positions of the longitudinal cooling passages, circumferential cooling passages, and inserts of Figure 10;

Figure 13 is two diagrams comparing the flow velocity distribution of cooling water in the continuous casting machine shown in Figure 10 in which there are internal circumferential cooling passages and in an example of a continuous casting machine in which there are no circumferential cooling passages;

Figure 14 is a schematic drawing showing a vertical cross-section of a prior art continuous casting machine; and

Figure 15 is a schematic drawing showing an axial view of the casting rolls and the stub shafts shown in Figure 14.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In general terms, Figures 1 through 5 show cylindrical casting rolls with a central portion and shoulder portions adjacent side dams. The shoulder portions define radially extending end surfaces of the central portion. The casting rolls have longitudinal cooling passages extending through each of the central portions of the casting rolls from one shoulder portion to the other shoulder portion. Radial cooling passages pass through each of the casting rolls from inner

circumferential surfaces. The radial cooling passages are in positions that are close to the radially extending end surfaces. Cylindrical plugs, with closed base ends, engage the ends of longitudinal cooling passages. In use,
5 cooling water flows in sequence through a radial cooling channel, a longitudinal cooling channel, and another radial cooling channel at the opposite end of the casting roll.

10 In more specific terms, Figures 1 to 5 show a continuous casting machine with one embodiment of the disclosed casting rolls disclosed herein.

Such casting machines having casting rolls 12,
15 the outer diameters of which are greater at central portions 17 than at end portions 28 at the ends of the rolls. The central portions 17 comprise radially extending end surfaces. Side dams 11 contact the end surfaces of the central portions 17 in an operative
20 position of the casting machines. The casting rolls 12 also comprise hollow stub shafts 13 that axially engage the two end portions 28. The stub shafts 13 have diameters that are similar to the outer diameters of the two end portions 28 of the casting rolls 12.

25 Longitudinal cooling passages 14 pass through the casting rolls 12 between the radially extending end surfaces of the central portions 17 of the casting rolls 12. The longitudinal cooling passages 14 are disposed
30 substantially equidistantly circumferentially in the casting rolls 12. In this position, the longitudinal cooling passages 14 are in good heat transfer relationship with the outer surfaces of the rolls.

35 Radial cooling passages 15 extend radially through the casting rolls 12 from inner circumferential surfaces of the casting rolls near the end portions 28 of

the casting rolls 12 and connect with the longitudinal cooling passages 14. Consequently, the longitudinal and radial cooling passages 14, 15 form right angle bends at these locations.

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Furthermore, circular plate-shaped plugs 19 close both ends of the longitudinal cooling passages 14.

10 The plugs 19 are fixed to the casting rolls 12 by means of snap rings 20. Sealing materials, such as O-rings, are also used between the plugs 19 and the inner circumferential surfaces of the longitudinal cooling passages 14. As a consequence, cooling water W is caused to flow continuously in sequence into one of the radial
15 cooling passages 15 that communicates with the longitudinal cooling passages 14, that longitudinal cooling passage 14, and the other of the radial cooling passages 15 that communicates with that longitudinal cooling passage 14.

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In addition, cylindrical spacers 31 are positioned in each of the radial cooling passages 15 and define baffles 32 that extend partially into the longitudinal cooling passages 14.

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Baffles 32 are integrally provided in the leading end parts of the spacers 31. The baffles 32 are formed and positioned to project from an inner corner of the bends defined by the longitudinal cooling passages 14, 15
30 outwardly towards the outer corner of the bends, with the cross-sectional area of the passages being reduced by half before and after the baffles 32.

The stub shafts 13 are hollow and include radial
35 cooling passages 18 that extend radially through the stub shafts 13 so that the cooling water W can flow continuously in sequence into one of the radial cooling

passages 15 that communicates with the longitudinal cooling passages 14, that longitudinal cooling passage 14, and the other of the radial cooling passages 15, and rotary joints and the like in the radial cooling passages 18.

In operation of the continuous casting machine, the pair of casting rolls 12, the stub shafts 13 and the plugs 16 are positioned laterally to each other, and in such a manner that a casting roll nip can be adjusted according to the thickness of the strip S that is to be manufactured. In addition, the side dams 11 contact the radially extending end surfaces of the central portions 17 of the casting rolls 12.

In such a continuous casting machine, heat is removed from the casting rolls 12 by cooling water W flowing through the radial cooling passages 15 and the longitudinal cooling passages 14 while molten metal is poured into a space above the nip confined by the side dams 11 and the casting rolls 12 to form a casting pool of molten metal M. As the casting rolls rotate, the metal that has been cooled by the outer circumferential surfaces of the casting rolls 12 and has formed downwardly moving strip S at the nip.

As is mentioned above, the longitudinal cooling passages 14 extend between radially extending end surfaces of the central portions 17 of the casting rolls 12. The arrangement is such that there a small gap T3 only between the longitudinal cooling passages 14 and the outer circumferential surfaces of the casting rolls 12, while maintaining a spacing of T4 between the outer surfaces of the end portions 28 and the outer surfaces of the central portions 17.

Thus, in use, the cooling water W passes through

the longitudinal passages 14 of the casting rolls 12 can effectively cool the outer circumferential surfaces of the casting rolls 12.

5 Moreover, the baffles 32 reduce the cross-sectional area of the passages in the bends by approximately half when compared with the example illustrated in Figures 14 and 15 in which no baffles 32 are provided in the bends. Hence, the velocity of the
10 cooling water V is increased and moreover the cooling water W is directed towards the outer corners of the bends which results in more effective cooling of the ends parts of the casting rolls 12.

15 The beneficial impact of the baffles 32 in both flow directions is illustrated by the cooling water velocity profiles in Figures 4 and 5.

 Thus, the cooling effect upon the casting rolls
20 12 is increased in the casting rolls 12 described above, and it is therefore possible to increase the number of revolutions of the casting rolls 12, that is, to increase the casting speed and improve the production efficiency of the strip S.

25 Figures 6 to 9 show a continuous casting machine that comprises a second embodiment of the casting rolls 12, in which those parts represented by the same symbols as in Figures 1 to 5 refer to the same items.

30 In this casting roll 12 a plurality of integrally formed fins 33 that project into the longitudinal cooling passages 14 and straddle the outlets of the radial cooling passages 15 is provided in place of the spacers 31 and the
35 baffles 32 described above. Thus, the cross-sectional area of the passages in the bends defined by the intersections of the longitudinal and radial cooling

passages 14, 15 is reduced by approximately half.

5 The plurality of fins 33 is arranged circumferentially within the casting rolls 12 in such a manner as not to directly impede the flow of the cooling water W, and with leading ends of the fins being formed with acute angles and with the inner corners of the bends being lengthened.

10 In a continuous casting machine that employs such casting rolls, cooling water is caused to flow through the longitudinal cooling passages 14 and the radial cooling passages 15 and extract heat from the casting rolls 12 while molten metal is poured into a pool defined by the side dams 11 and the casting rolls 12.

20 The longitudinal cooling passages 14 extend between radially extending end surfaces of the central portions 17 of the casting rolls 12. The arrangement is such that there a small gap T3 only between the longitudinal cooling passages 14 and the outer circumferential surfaces of the casting rolls 12, while maintaining a spacing of T4 between the outer surfaces of the end portions 28 and the outer surfaces of the central portions 17.

30 Consequently, the cooling water W passes close to the outer circumferential surfaces of the casting rolls 12 and effectively cools these surfaces of the casting rolls 12.

35 Moreover, the velocity of the cooling water W increases because the cross-sectional area of the passages in the bends is reduced by approximately half when compared with the example in which fins 33 are not provided as shown in Figures 14 and 15 and, moreover, the heat received by the casting rolls 12 from the molten

metal is conveyed through the plugs 19 and the fins 33 to the cooling water W, with the result that the casting rolls 12 are efficiently cooled.

5 The beneficial impact of the fins 33 in both flow directions is illustrated by the cooling water velocity profiles in Figures 8 and 9.

10 Thus, the cooling effect of the casting rolls 12 is high in the casting rolls 12 described above, and hence it is possible to increase the rate of rotation of the casting rolls 12, that is, to increase the casting speed and to increase the production efficiency of the strip S.

15 Figures 10 to 13 show a continuous casting machine that employs a third, but not the only other possible, embodiment of the casting rolls, in which those parts represented by the same symbols as in Figures 1 to 5 refer to the same items.

20 This casting roll possesses circumferential cooling passages 34 that interconnect adjacent longitudinal cooling passages 14 and facilitate flow of cooling water W that has passed through the entire length of one longitudinal cooling passage 14 into an adjacent longitudinal cooling passage 14.

30 The circumferential cooling passages 34 are formed by cutting apertures from the inside towards the outside of the casting rolls 12 and by closing the apertures at positions in the vicinity of the rotational axis of the casting rolls 12 by means of plugs 35 in order to interconnect the two longitudinal cooling passages 14.

35 Moreover, inserts 36 are positioned in the longitudinal cooling passages 14, and the cross-sectional area of the passages is reduced by approximately half.

The leading ends of the inserts 36 are shaped to be at acute angles and are elongated along the rotational axis of the casting rolls 12.

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In the continuous casting machine employing the casting rolls 12 described above the heat is extracted from the casting rolls 12 by causing cooling water W to flow through the longitudinal cooling passages 14 and the radial cooling passages 15 while molten metal is poured into the space formed by the side weirs 11 and the roll bodies 12.

The longitudinal cooling passages 14 extend from one radially extending end surface at a position at which the outer radius of the casting rolls 12 is expanded and which is abutted by the side dam 11 to the other radially extending end surface at a position at which the outer radius of the casting rolls 12 is expanded and which is abutted by the side dam 11. Hence, the contact T4 between the side dam 11 and the radially extending end surface at that portion of the casting rolls 12 at which the outer radius is greater, while permitting the greatest possible reduction in the distance T3 between the longitudinal cooling passages 14 and the outer circumferential surface of the casting rolls 12.

Consequently, the cooling water W passes through the surface layer of the casting rolls 12 and effectively cools the outer circumferential surface of the casting rolls 12.

Moreover, the velocity of the cooling water W increases because the cross-sectional area of the passages in the bends is reduced by approximately half and, moreover, the cooling water W is directed to the vicinity of the outer circumferential surface of the casting rolls

12 in the bends, with the result that the casting rolls 12 are efficiently cooled.

5 The beneficial impact of the inserts 36 in one flow direction is illustrated by the cooling water velocity profiles in Figure 13.

10 Thus the casting rolls described above permit increases in the rate of rotation of the casting rolls 12, that is, increases in the casting speed and greater production efficiency for the strip S because the cooling effect of the casting rolls 12 is enhanced.

15 The casting rolls envisaged herein are not limited to modes of implementation described above and may of course be modified provided that such modifications do not violate the spirit of the invention.

20 The casting rolls envisaged herein may be employed for the continuous casting of steel and various other metals.

CLAIMS

1. An apparatus for casting metal strip comprising:
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 (a) a pair of laterally positioned casting rolls forming a nip between them, each casting roll comprising a cylindrical body with a central portion, and a plurality of cooling passages extending through the
10 central portion, the cooling passages comprising longitudinal cooling passages, the cooling passages also comprising at least one bend in the cooling passages which requires cooling fluid flowing through a cooling passage to undergo a change in direction, and a flow control
15 member positioned in the bend to control the flow of cooling fluid around the bend; and

 (b) a molten metal supply system to deliver molten metal above the nip between the casting rolls to
20 form a casting pool of molten metal supported on the casting rolls immediately above the nip.

2. The apparatus for casting metal strip of claim 1 where each casting roll comprises a radially extending end surface at each end of the central portion capable of
25 supporting a side dam, and the cooling passages extend through the central portion between the radially extending end surfaces.

30 3. The apparatus for casting metal strip of claim 1 or claim 2 where the cooling passages further comprise a plurality of radial cooling passages, each radial cooling passage extending from a casting roll inner periphery to one of the longitudinal cooling passages at one of the
35 ends of the central portion, with the bend being formed where the longitudinal and radial cooling passages merge together.

4. The apparatus for casting metal strip of claim 3 where the flow control member comprises a baffle extending from an inside corner of the bend towards an outer corner of the bend.

5. The apparatus for casting metal strip of claim 3 where the flow control member comprises a plurality of fins extending from the radially extending end surfaces in the direction of the longitudinal cooling passage.

6. The apparatus for casting metal strip of claim 1 or claim 2 where the cooling passages comprise at least one circumferential section that interconnects adjacent longitudinal cooling passages so that cooling fluid can flow from one longitudinal cooling passage into and then along an adjacent longitudinal cooling passage, with the bend being formed in the circumferential section.

7. The apparatus for casting metal strip of claim 6 where the flow control member comprises an insert that partially fills in the bend and reduces the cross-sectional area of the bend.

8. A casting roll comprising:

(a) a cylindrical body having a central portion; and

(b) a plurality of cooling passages extending through the central portion, the cooling passages comprising longitudinal cooling passages, the cooling passages also comprising at least one bend in the cooling passages which requires cooling fluid flowing through a cooling passage to undergo a change in direction, and a flow control member positioned in the bend to control the flow of cooling fluid around the bend.

9. The casting roll of claim 8 where the cylindrical body is a stepped cylindrical body having the central portion with a first outer diameter and an end portion
5 having a second outer diameter extending axially from each end of the central portion, and the second outer diameter being smaller than the first outer diameter.

10. The casting roll of claim 8 or claim 9 comprises
10 a radially extending end surface at each end of the central portion capable of supporting a side dam, and the cooling passages extend through the central portion between the radially extending end surfaces.

15 11. The casting roll of claim 10 where the cooling passages further comprise a plurality of radial cooling passages, each radial cooling passage extending from a casting roll inner periphery to one of the longitudinal cooling passages at one of the ends of the central
20 portion, with the bend being formed where the longitudinal and radial cooling passages merge together.

12. The casting roll of claim 11 where the flow control member comprises a baffle extending from an inside
25 corner of the bend towards an outer corner of the bend.

13. The casting roll of claim 11 where the flow control member comprises a plurality of fins extending from the radially extending end surfaces in the direction
30 of the longitudinal cooling passage.

14. The casting roll of any one of claims 10 to 13 where the cooling passages comprise at least one circumferential section that interconnects adjacent
35 longitudinal cooling passages so that cooling fluid can flow from one longitudinal cooling passage into and then along an adjacent longitudinal cooling passage, with the

bend being formed in the circumferential section.

15. The casting roll of claim 14 where the flow
control member comprises an insert that partially fills in
5 the bend and reduces the cross-sectional area of the bend.

16. A method of continuously casting thin metal strip
comprising the steps of:

10 (a) assembling a pair of laterally positioned
casting rolls forming a nip between them, each casting
roll comprising a cylindrical body with a central portion,
and a plurality of cooling passages extending through the
central portion, the cooling passages comprising
15 longitudinal cooling passages, the cooling passages also
comprising at least one bend in the cooling passages which
requires cooling fluid flowing through a cooling passage
to undergo a change in direction, and a flow control
member positioned in the bend to control the flow of
20 cooling fluid around the bend;

 (b) delivering molten through a metal supply
system above the nip between the casting rolls to form a
casting pool of molten metal supported on the casting
25 rolls immediately above the nip between the casting rolls;
and

 (c) counter rotating the casting rolls to form
shells from the casting pool on the cylindrical surfaces
30 of the casting rolls and form thin cast strip at the nip
between the casting rolls delivered downwardly.

17. An apparatus for casting metal strip comprising:

35 (a) a pair of laterally positioned casting
rolls forming a nip between them, each casting roll
comprising a cylindrical body with a central portion and a

radially extending end surface at each end of the central portion capable of supporting a side dam, and a plurality of cooling passages extending through the central portion between the radially extending end surfaces, the cooling
5 passages comprising longitudinal cooling passages, the cooling passages also comprising at least one bend in the cooling passages which requires cooling fluid flowing through a cooling passage to undergo a change in
10 direction, and a flow control member positioned in the bend to control the flow of cooling fluid around the bend;
and

(b) a molten metal supply system to deliver molten metal above the nip between the casting rolls to
15 form a casting pool of molten metal supported on the casting rolls immediately above the nip confined by side dams positioned adjacent the radially extending end surfaces.