

Oct. 5, 1948.

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2,450,428

STRIP FORMING APPARATUS

Filed March 23, 1944

3 Sheets-Sheet 1

Fig. 1.

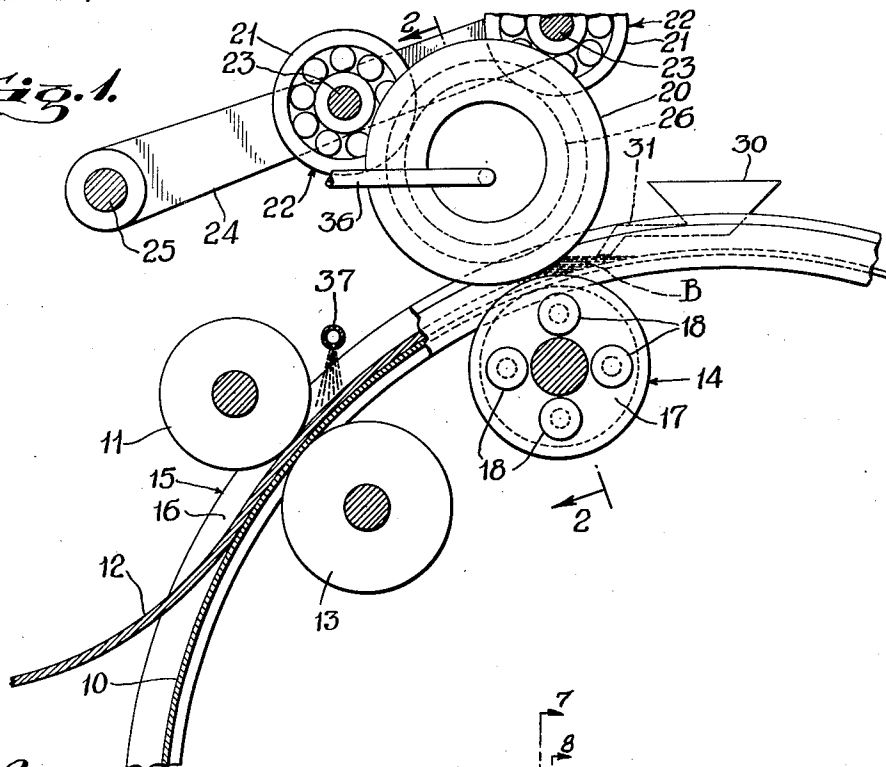
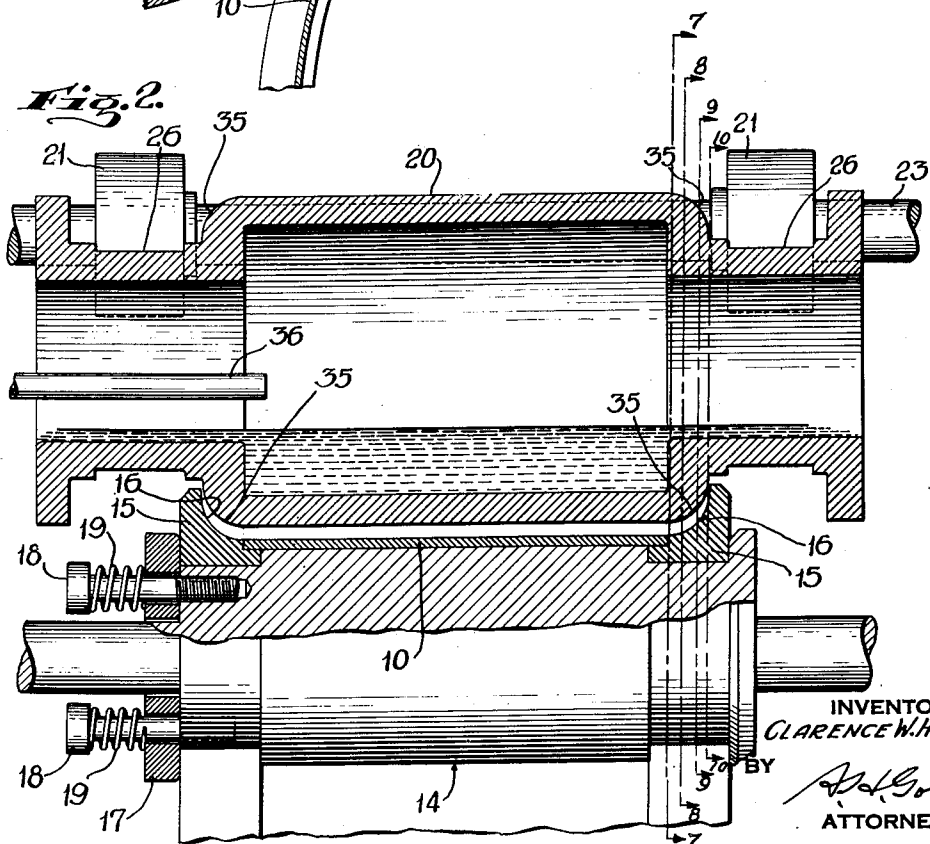


Fig. 2.



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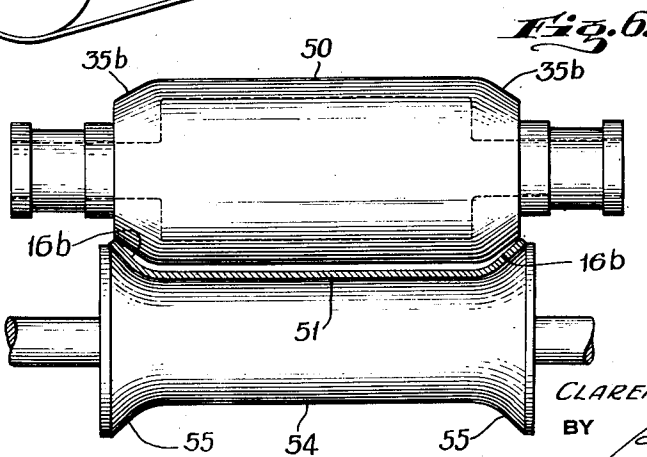
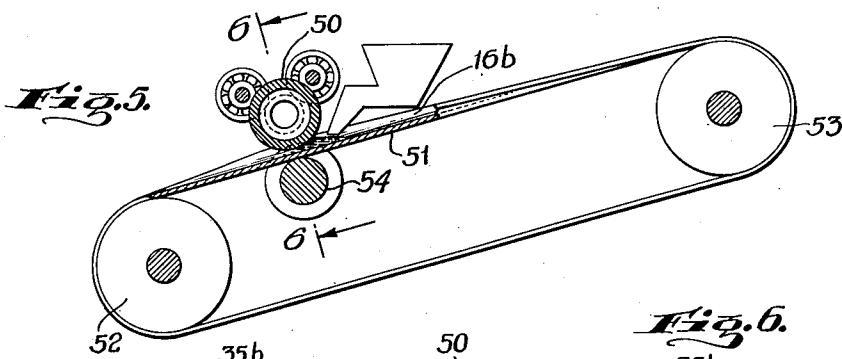
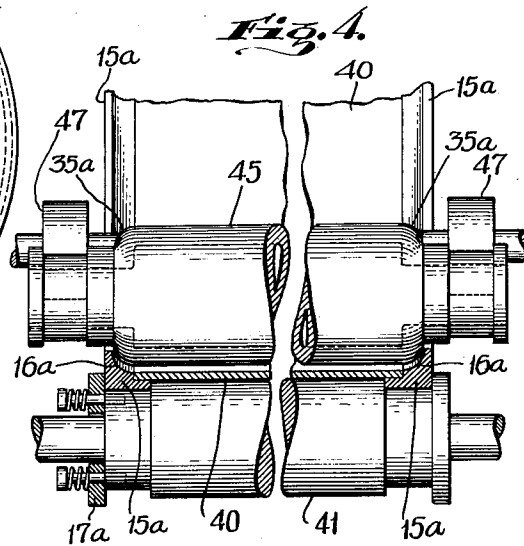
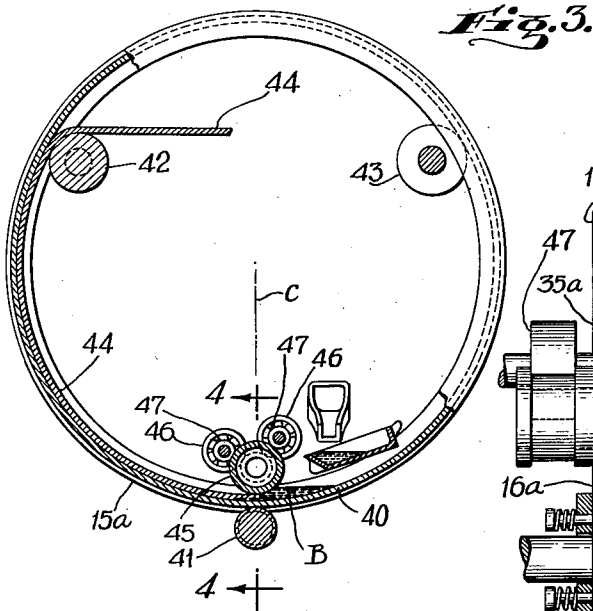
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3 Sheets-Sheet 2



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Fig. 7.

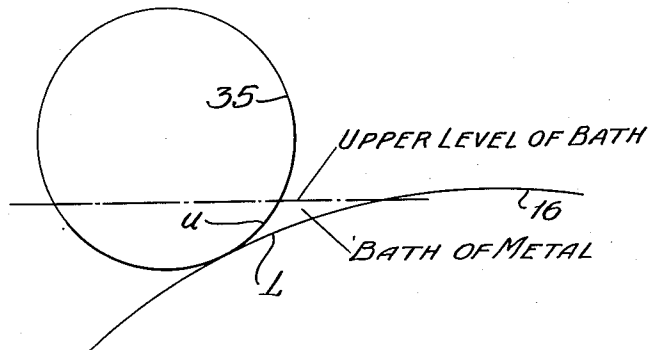


Fig. 8.

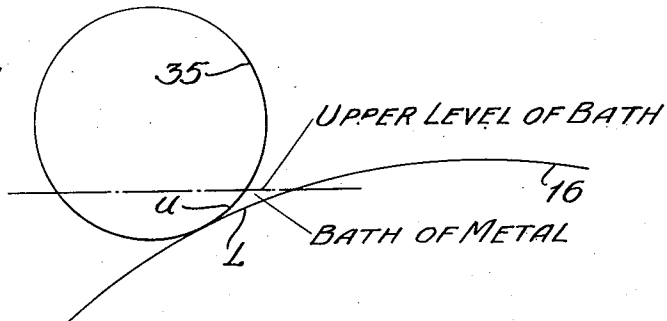


Fig. 9.

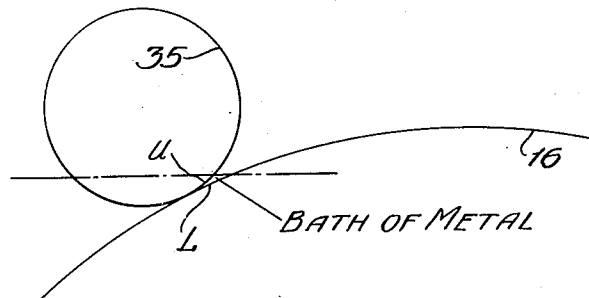
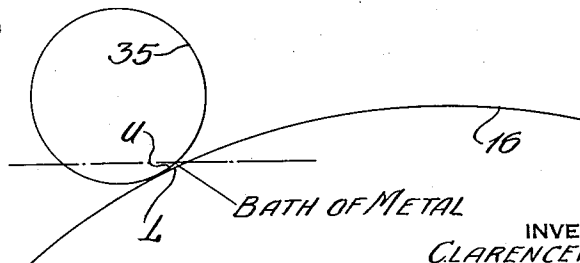


Fig. 10.



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UNITED STATES PATENT OFFICE

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STRIP FORMING APPARATUS

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Application March 23, 1944, Serial No. 527,704

13 Claims. (Cl. 22—57.3)

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This invention relates to a metal working apparatus for the production of metal strip directly from molten metal. In brief, the formation of metal strip directly from molten metal is usually accomplished by the passage of molten metal between a cooperating pair of moving cooling surfaces. These cooling surfaces may comprise a pair of rolls or rings between the peripheries of which the metal passes. On the other hand, the cooling surfaces may comprise a ring toward the inner periphery of which presses a roll or ring for forming metal strip therebetween. Still further, the cooling surfaces may comprise an endless belt adapted for cooperation with a roll and with means being provided for backing up the endless belt where it cooperates with the roll. Since rings and rolls function alike in apparatus of the general class described, I shall hereinafter use the term "roll" as inclusive of both rings and rolls; in other words, the term "roll" will be used here in its generic sense, thereby simplifying and shortening the specification.

It has been found, especially when forming thin metal strip, that it is best to feed the metal between the cooling surfaces from a bath of metal maintained between the said cooling surfaces. For containing the ends of the bath of metal, the lower cooling surface is formed with end damming means such as flanges. Those skilled in the art know that the damming means cause excess cooling of the metal and the building up of solid masses of metal that frequently seriously damage the apparatus. Even where such damage is avoided, excess pressures will develop due to the excess cooling, thereby preventing the use of non-working strip forming apparatus such as set forth in my Patent No. 2,383,310, issued August 21, 1945. Thus, where light pressures are maintained between the cooling surfaces for the passage of metal therebetween, the excess cooling of the metal at the ends of the bath will separate the cooling surfaces, spilling the molten metal from the bath of metal, and stopping the mill. This condition prevents the use of cooling surfaces maintained under the light pressures that are necessary to fabricate an un-worked metal strip of the type in which upper and lower chilled films are welded together, in effect, for the formation of metal strip.

At this point, it may be well to indicate that the invention to be described hereinafter has actually been used by me in the manufacture of metal strip, and has been found extremely successful. In describing my invention, I shall, of necessity, outline certain theories of operation

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that I now believe to be true from those studies of my invention that I have made. However, I do not wish the patent claims to be granted to me to be limited by the theories I shall set forth, since those theories may not be entirely correct or complete as later developments may prove. It will also be well to consider that the apparatus I shall outline hereinafter is merely exemplary of preferred means whereby my invention may be utilized, and that other arrangements of the apparatus may be successfully used following my teachings to the prior art.

Efforts have been made, as witnessed by prior art patents, to overcome the difficulties inherent in the use of damming means for baths of metal. Thus, the flanges or end dams of the cooling means have been heated, it being thought that by this method the excess cooling at the ends of the bath of metal might be obviated. Similarly, attempts have been made to apply more heat at the ends of the bath whereby to yield uniform cooling of the metal passing between the cooling surfaces. These expedients have not been entirely satisfactory.

In my application supra, I eliminate the bath of metal entirely, but as I have already indicated, it is not always possible or desirable to form strip without a bath of metal. The problem I have thus outlined, and which for many years has confronted the art, thus remains unsolved.

It is the object of my invention to contribute an apparatus in which a bath of metal is contained by cooling surfaces for feeding between the cooling surfaces for the forming of metal strip, while eliminating excess cooling of the metal at the ends of the bath. It is a further object of my invention to contribute an apparatus in which the metal strip can be cooled uniformly throughout its width, and under uniform pressures throughout its width. While the contribution of my invention is particularly valuable in making possible the use of non-working cooling surfaces of the class outlined, with but light pressures yieldingly holding the cooling surfaces in operative relation, my invention is useful also with other types of processes and apparatus as will be readily apparent to those skilled in the art.

Those skilled in the art will further appreciate, upon a review of my invention, that I have solved the long standing problem relating to the utilization of a bath of metal, by eliminating the excess cooling at the ends of the metal bath, now inherent in all strip forming mills utilizing a bath of metal.

Those skilled in the art will of course appreciate

that my invention is most effective under preferred conditions. Thus, the cooling surfaces should be degassed, and they should not scale under operating temperatures. Also, where the cooling surfaces are maintained under yielding pressure, the speed of operation of the apparatus should be controlled to yield a product of uniform thickness, all in a manner similar to that taught in my prior application supra. I do not believe it is necessary to further lengthen and complicate this specification by setting forth other conditions under which my process will best operate, since those skilled in the art will readily appreciate the manner in which the basic contribution of my invention should be employed.

One feature of my invention whereby the objects thereof are achieved, resides in the utilization of strip forming portions of the cooling surfaces as containing surfaces for the bath of metal. A further feature of my invention resides in the utilization of the ends of the cooling surfaces as containing surfaces for the bath of metal, the said ends functioning simultaneously as portions of the cooling surfaces actually forming the metal strip through the passage of metal therebetween from the bath of metal. As illustrative of the broad nature of my invention, I shall first describe its utilization in an apparatus in which the outer peripheral surfaces of a pair of rolls function as the cooling members. Thereafter, I shall describe the invention embodied in an apparatus in which the outer peripheral surface of a roll forms one cooling surface and cooperates with another cooling surface that is the inner peripheral surface of a ring. My invention shall then be described as embodied in an apparatus in which one cooling surface is the outer periphery of a roll while the other cooling surface is a continuously moving metal belt.

I have thus outlined generally my invention in order that my contribution to the art may be better understood. However, additional features of my invention will be presented in the specification that follows, and it is intended that those additional features be included in the protection afforded by the patent claims to be granted me.

Referring now to the drawings, Fig. 1 is a vertical schematic view of a mill utilizing my invention. Fig. 2 is a section taken along lines 2—2 of Fig. 1. Fig. 3 is a schematic vertical section through the second modification of my invention hereinabove outlined. Fig. 4 is a section taken along lines 4—4 of Fig. 3. Fig. 5 is a schematic vertical section through the third modification of my invention hereinabove outlined. Fig. 6 is a section taken along lines 6—6 of Fig. 5. Fig. 7 is a vertical section through the bath of metal taken substantially in the same vertical plane as Fig. 1 and substantially along lines 7—7 of Fig. 2. Figs. 8, 9, and 10 are vertical sections similar to Fig. 7 but taken in planes displaced laterally from that of Fig. 7 toward one end of the bath of metal as indicated by lines 8—8, 9—9, and 10—10 of Fig. 2.

Referring now more particularly to the drawings, and especially Figs. 1 and 2, the lower cooling member of my apparatus is in the form of a ring 10. It is preferably rotated by a power roll 11 that is pressed yieldingly against the outer periphery of the ring 10 through the intermediary of the metal strip 12 formed on the said outer periphery. The ring 10 is backed up by a back up roller 13 located diametrically opposite the power roll 11 and supported in a conventional manner.

A further back up roll 14 is utilized for the ring

10, and this back up roll serves to support the rather novel margin members 15, whose surfaces 16 form, in effect, part of the lower cooling surface, as continuations of the peripheral surface of the ring 10. Endwise expansion of the ring 10 will naturally tend to separate the margin members 15, and for that reason the left margin member 15 in Fig. 2, is maintained yieldingly against the ring 10 through a pressure ring 17 carried by roll 14. The pressure exerted by the ring 17 is controlled through threaded bolts 18 and springs 19 maintained in pressing relation to the ring 17 by the said bolts 18.

The upper cooling member of my invention is designated by reference numeral 20, and is in the form of a hollow roll backed up by the outer races 21 of ball bearings 22 rotating about shafts 23. The shafts 23 are supported by some suitable member such as the lever 24 pivoted at 25. By determining the pressure to be exerted by the races 21 against the surfaces 26 of the roller 20, the pressure of the roller 20 relatively to the ring 10 may be determined. In accordance with the preferred operation of my invention, this pressure will be extremely light, in order that the metal strip shall be formed without appreciable pressure, thus avoiding folding, segregation, and other difficulties that need not here be discussed, and which are inherent in mills using fixed or high pressure cooling surfaces. However, my invention to be hereinafter more particularly described, is of course applicable to other arrangements of apparatus as is apparent to those skilled in the art.

Metal is deposited on the lower cooling surfaces or ring 10, through a suitable distributor 30 and its chute 31. It is quite apparent that the metal will be deposited to form a bath B as best illustrated in Fig. 1. The upper containing surface of this bath will of course be the upper roll 20 and the surfaces 35 of its inwardly tapering ends, as is clearly apparent from an examination of Fig. 2. The lower containing surface for the bath of metal will of course be the peripheral surface of the ring 10, and the peripheral surfaces 16 of margin members 15.

It may be well to consider at this point that the margin surfaces 16 may conceivably be integral extensions of the peripheral surface of the ring 10, with the said ring being formed integrally with margin members 15. It will now be noted also that the ends of the bath of metal B will be contained particularly by the margin surfaces 16 and by the surfaces 35 of the roll 20. So long as the bath B is maintained sufficiently low so that it does not rise to the point where it can not be contained by the surfaces 16 and 35, the said surfaces will be quite effective in holding the metal bath against spilling at its ends. It seems rather apparent now that surfaces 16 and 35 act not only to contain the ends of the metal bath B, but they are part of the surfaces used to form the metal strip by the passage of metal therebetween from said bath.

Thus, in Figs. 1 and 7 the metal of the bath is shown in contact with the surface L of the lower roll and the surface U of the upper roll. In Fig. 8, taken in a plane in which the lower surface has tapered upwardly relatively to the upwardly tapered surface of the upper roll, the length of surface L has decreased materially and so has the surface U. Of course, the amount of metal in the bath is also smaller.

In Figs. 9 and 10 the surfaces L and U have further decreased and the bath of metal has also

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decreased in volume. It can now be said that the lower roll so tapers relatively to the upper roll as to decrease progressively the amount of metal to be cooled at the ends of the bath. It can also be said that the application of cooling surfaces to the bath of metal decreases toward the ends of the bath. It is further important to consider that no cooling surface is in contact with an end of the bath of metal, so that my bath of metal is contained at its ends without end dams.

In other words, the time of contact of the molten bath with the cooling surfaces is thus progressively less towards the ends of the bath, resulting in progressively less cooling of the ends of bath of metal. Because the actual metal at the ends of the bath is progressively smaller also, the decrease in the cooling rate is partially compensated for, in order that the cooling rate in the entire bath remain fairly uniform. I can however, actually effect less cooling at the ends of the bath, if I so desire, as distinguished from the prior art where the cooling rate at the ends of the bath is so great as to have a deleterious effect.

It is also important to note that because there is less metal available at the ends of the bath of metal, the metal strip that is formed by the cooling surfaces may have edges of decreasing thickness.

The apparatus thus far described will of course have the usual cooling apparatus, a pipe 36 being utilized for cooling the upper cooling member 20 while a pipe 37 supplies water for cooling the lower cooling member and the strip metal 12. I believe it unnecessary to describe my invention in further detail since the basic contribution thereof is now rather apparent.

In Figs. 3 and 4, a modification of my invention is shown, in which the equivalent of the lower cooling member of the first modification is a ring 40 that is rotated in any suitable way and is backed up by a roller 41 and further rollers 42 and 43, the strip metal 44 formed being drawn off as shown. The upper cooling member is designated by reference numeral 45 and is of the same character, substantially, as the cooling member 20 of the first modification. As in the first modification, it is backed up by the races 46 of a pair of ball bearings 47.

In sectional Figure 4, it is well noted that the relationship of the several parts of Fig. 3 is exactly the same as the same parts in Figs. 1 and 2. Thus, the lower cooling ring 40 is fitted with margin members 15a similar to the members 15 of the first modification. A pressure ring 17a on roller 41 has also the same function as the pressure ring 17 of the first modification. The upper cooling member 45 is tapered as at 35a in the same manner as the cooling roll 20 is tapered at 35 in the first modification. It is the function of the surfaces 16a of the margin members 15a to contain with the surfaces 35a the ends of the bath of metal B shown in Fig. 3. In functional operation, the apparatus of Figs. 3 and 4, is exactly the same as that of Figs. 1 and 2. It is of course possible, to move the roll 45 to one side of the center line C if a deeper bath of metal is required, all of which will be quite apparent to those skilled in the art.

In Figs. 5 and 6, I illustrate a further modification of my invention. There, the upper cooling member 50 is exactly the same as the upper cooling member 45 of the second modification, and the cooling member 20 of the first modification. This is most clearly apparent from an examination of Fig. 6. The lower cooling member takes

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the form of a metal belt 51 running between rollers 52 and 53. The side edges of the belt are controlled by a backing roller 54 that is formed with tapering ends 55. It is the function of these ends 55 to so deform the belt 51 that along the section 6-6 of Fig. 5 and thereabove, it will assume that shape shown in Fig. 6. The shape so assumed by the belt is approximately the shape of the cooling member 10 taken together with surfaces 16 in Fig. 2, or the cooling member 40 taken together with cooling surfaces 16a in Fig. 4. The tapered margins of belt 51 are designated by reference numeral 16b in order to clarify the relation of this modification to the two earlier modifications. The belt 51 and margins 16b will of course cooperate with the cooling surfaces of the roller 20, comprising the tapering portions 35b, in exactly the same manner as the cooling surfaces of the first two modifications cooperate.

It will now be apparent that my invention is such that it may be readily utilized in many different types of apparatus for contributing the results set forth. Thus, as is quite clearly apparent from an inspection of Figs. 2, 4 and 6, the cooling surfaces in each of the several modifications have substantially the same operation and contribute substantially the same type of metal strip.

I now claim:

1. In a combination of the class described, a pair of cooling members each having a cooling surface of circular cross section, means mounting said cooling members for rotation about parallel horizontal axes whereby said surfaces approach one another along a horizontal line for the passage of metal therebetween to form continuous metal strip, said metal moving from a bath of metal contained by said surfaces, and the margins of said cooling surfaces tapering upwardly at said line of approach for containing the ends of said bath of metal, the taper of the margins on one of said surfaces being such relatively to the taper of the margins of the other surface as to decrease progressively the amount of metal to be cooled at the ends of said bath of metal and the area of the cooling surfaces applied to the ends of said bath of metal.

2. In a combination of the class described, a pair of rolls having peripheral cooling surfaces, means mounting said rolls for rotation with their cooling surfaces positioned so as to form the upper and lower containing surfaces of a bath of metal, the metal passing from said bath of metal and between said cooling surfaces, the ends of the cooling surface of the lower of said pair of rolls tapering outwardly relatively to the axis of rotation thereof, the ends of the cooling surface of the upper of said rolls tapering inwardly relatively to the axis of rotation thereof, whereby said end surfaces form end dams, in effect, of said cooling surfaces for containing the ends of the bath of metal between the cooling surfaces of said rolls, and the ends of the lower roll so tapering relatively to the ends of the upper roll as to decrease progressively the amount of metal to be cooled at the ends of said bath and the area of the cooling surfaces applied to the ends of said bath of metal.

3. In a combination of the class described, a pair of cooling members having cooling surfaces, means mounting said cooling members for movement whereby said surfaces approach one another for the passage of metal therebetween to form continuous metal strip, said metal moving from a bath of metal contained by said surfaces, the

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ends of said cooling members tapering upwardly and toward one another while remaining out of contact so that the cooling surfaces thereof contain the side ends of the bath of metal through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, the said cooling surfaces including said upwardly tapering ends functioning as complementary opposed cooling surfaces for the opposed upper and lower surfaces of the metal strip passing therebetween from said bath as well as the containing surfaces for said bath.

4. In a combination of the class described, a pair of continuous cooling surfaces, means mounting said cooling surfaces for movement whereby said surfaces approach one another along a horizontal line for the passage of metal therebetween to form continuous metal strip, said metal moving from a bath of metal contained by said surfaces, the lower of said surfaces being upwardly inclined from the line of approach of said surfaces whereby to form the lower containing surface of said bath of metal, the ends of said surfaces being upwardly tapered relatively to one another from the line of approach of said surfaces while remaining out of contact whereby to contain the side ends of said bath of metal through said upward tapering rather than by end dams, and with the corresponding ends of the bath of metal out of contact with an end cooling or containing surface, and the rate of taper of said cooling surfaces being such as to decrease progressively the amount of metal to be cooled at the side ends of said bath of metal and the area of the cooling surfaces applied to the ends of said bath of metal.

5. In a combination of the class described, an upper cooling member having a continuous cooling surface and a lower cooling member having a continuous cooling surface, means mounting said cooling members for movement whereby said surfaces approach one another along a horizontal line for the passage of metal therebetween to form a continuous metal strip, the ends of said surfaces being upwardly tapered from said line of approach while remaining out of contact whereby to form the containing surfaces for a bath of metal to be fed between said surfaces and contained between said surfaces through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, and the said upper and lower surfaces tapering upwardly at said line of approach substantially as described for progressively decreasing the amount of metal to be cooled at the side ends of said bath of metal and the areas of the cooling surfaces applied to the ends of said bath of metal.

6. In a combination of the class described, an upper cooling member having a continuous cooling surface and a lower cooling member having a continuous cooling surface, means mounting said members for movement whereby said surfaces approach one another along a horizontal line for the passage of metal therebetween to form a continuous metal strip, the lower of said surfaces being upwardly inclined from said line of approach whereby to form the lower containing surface of a bath of metal to be fed between said surfaces and contained between said surfaces, and the ends of said upper and lower surfaces tapering upwardly from said line of approach and toward one another while remaining

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out of contact whereby to contain the side ends of said bath of metal therebetween through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, said surfaces functioning therefore simultaneously as cooling surfaces for the opposed surfaces of the metal strip passing therebetween from said bath as well as containing surfaces, the taper of the ends of said surfaces being such relatively to one another as to decrease progressively the amount of metal to be cooled at the side ends of said bath of metal and the area of the cooling surfaces applied to the ends of said bath of metal.

7. In a combination of the class described, a pair of cooling members having cooling surfaces, means mounting said cooling members for movement whereby said surfaces approach one another along a horizontal line for the passage of metal therebetween to form continuous metal strip, said metal moving from a bath of metal contained by said surfaces, one of said surfaces being upwardly inclined from said line of approach whereby to form the lower containing surface of said bath of metal, and the ends of said surfaces tapering upwardly at said line of approach and relatively to one another while remaining out of contact whereby to contain the side ends of said bath of metal through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, the taper of the ends of the lower surface being such relatively to the taper of the ends of the other surface as to decrease progressively the amount of metal to be cooled at the side ends of said bath of metal and the area of the cooling surfaces applied to the ends of said bath of metal.

8. In a combination of the class described, a pair of cooling members each having a cooling surface of circular cross section, means mounting said cooling members for rotation about parallel horizontal axes whereby said surfaces approach one another for the passage of metal therebetween to form continuous metal strip, said metal moving from a bath of metal contained by said surfaces, one of said surfaces being below the other surface at said line of approach whereby to form the lower containing surface of said bath of metal, and the ends of said cooling surfaces tapering upwardly and toward one another while remaining out of contact whereby to contain the ends of said bath of metal through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, said tapering ends forming simultaneously the upper and lower cooling surfaces of the metal strip passing between said cooling members from said bath.

9. In a combination of the class described, a pair of rolls having peripheral cooling surfaces, means mounting said rolls for rotation about parallel horizontal axes offset vertically and horizontally from one another and with the line of nearest approach of said peripheral surfaces below the plane of the uppermost portion of the peripheral surface of the lower roll whereby said peripheral surfaces form the upper and lower containing surfaces for a bath of metal, the metal passing from said bath between said cooling surfaces to form continuous metal strip, the ends of said rolls so tapering upwardly at their line of

approach while remaining out of contact as to contain the bath of metal through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, the peripheral surfaces of the tapered ends of said rolls thus forming cooling surfaces for the metal strip formed by the passage of metal between said rolls from said bath of metal and containing surfaces for said bath of metal.

10. In a combination of the class described, a pair of rolls having cooling surfaces for forming metal strip fed between said rolls from a bath of metal contained between the cooling surfaces of the rolls, means mounting said rolls for rotation about parallel vertically and horizontally offset horizontal axes with the cooling surfaces of the rolls positioned so as to form the upper and lower containing surfaces of a bath of metal, the ends of the cooling surface of the lower of said pair of rolls tapering outwardly relatively to the axis of rotation thereof and the ends of the cooling surface of the upper of said rolls tapering inwardly relatively to the axis of rotation thereof, the rate of taper being such that said end surfaces remain in spaced relation while forming end dams, in effect, of said cooling surfaces for containing the ends of the bath of metal between the cooling surfaces of said rolls through said tapering rather than by end dams, and with the side ends of the bath of metal and the strip moving between said rolls out of contact with an end cooling or containing surface.

11. In a combination of the class described, an outer roll having an inner peripheral cooling surface, an inner roll having an outer peripheral cooling surface, means mounting said rolls for rotation about parallel horizontal axes and said inner roll within said outer roll, the cooling surfaces of said rolls being adapted for the passage of metal therebetween at their line of nearest approach, said metal moving from a bath of metal contained between said surfaces with the inner peripheral surface of the outer roll forming the lower containing surface for said bath of metal, the ends of said rolls so tapering upwardly at their line of approach while remaining out of contact as to contain the bath of metal through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, the surfaces of the tapered ends of said rolls thus forming cooling surfaces for the metal strip formed by the passage of metal between said rolls from said bath of metal and containing surfaces for said bath of metal.

12. In a combination of the class described, an outer roll having an interior cooling surface, an inner roll having an outer peripheral cooling surface, means mounting said rolls for rotation about parallel horizontal axes with the peripheral cooling surface of the inner roll adapted for spacing from the inner surface of the outer roll at their line of nearest approach for the passage of metal

therebetween to form continuous metal strip, said metal moving from a bath of metal contained by said surfaces, the cooling surface of said outer roll forming the lower containing surface for said bath of metal, the ends of said rolls so tapering upwardly at their line of approach while remaining out of contact as to contain the bath of metal through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, the surfaces of the tapered ends of said rolls thus forming cooling surfaces for the metal strip formed by the passage of metal between said rolls from said bath of metal and containing surfaces for said bath of metal, and the tapering of the ends of the lower cooling surface being such relatively to the tapering of the ends of the inner surface so as to decrease progressively the amount of metal to be cooled at the ends of said bath of metal, and the area of the cooling surfaces applied to the ends of said bath of metal.

13. In a combination of the class described, a cooling roll having a peripheral cooling surface, a continuous belt-like member having a cooling surface adapted to approach the peripheral surface of said cooling roll in a downwardly inclined path, means for rotating said roll and moving said belt-like member, said cooling surfaces being adapted for the passage of metal therebetween at their line of nearest approach to form continuous metal strip, said metal flowing from a bath of metal contained between said roll and the cooling surface of said belt-like member above said line of nearest approach, the ends of said roll tapering inwardly relatively to the axis of rotation thereof and the ends of the surface of said belt-like member tapering upwardly at and above said line of approach while remaining out of contact with said roll, whereby to contain the ends of said bath of metal through said upward tapering rather than by end dams, and with the edges of the side ends of the bath of metal and the strip out of contact with an end cooling or containing surface, said tapering ends forming simultaneously the upper and lower cooling surfaces of the metal strip passing between said cooling members from said bath.

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