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T. SENDZIMIR

2,597,046

METHOD OF PRODUCING TUBULAR AND SHEET METALS

Filed June 25, 1948

4 Sheets-Sheet 1

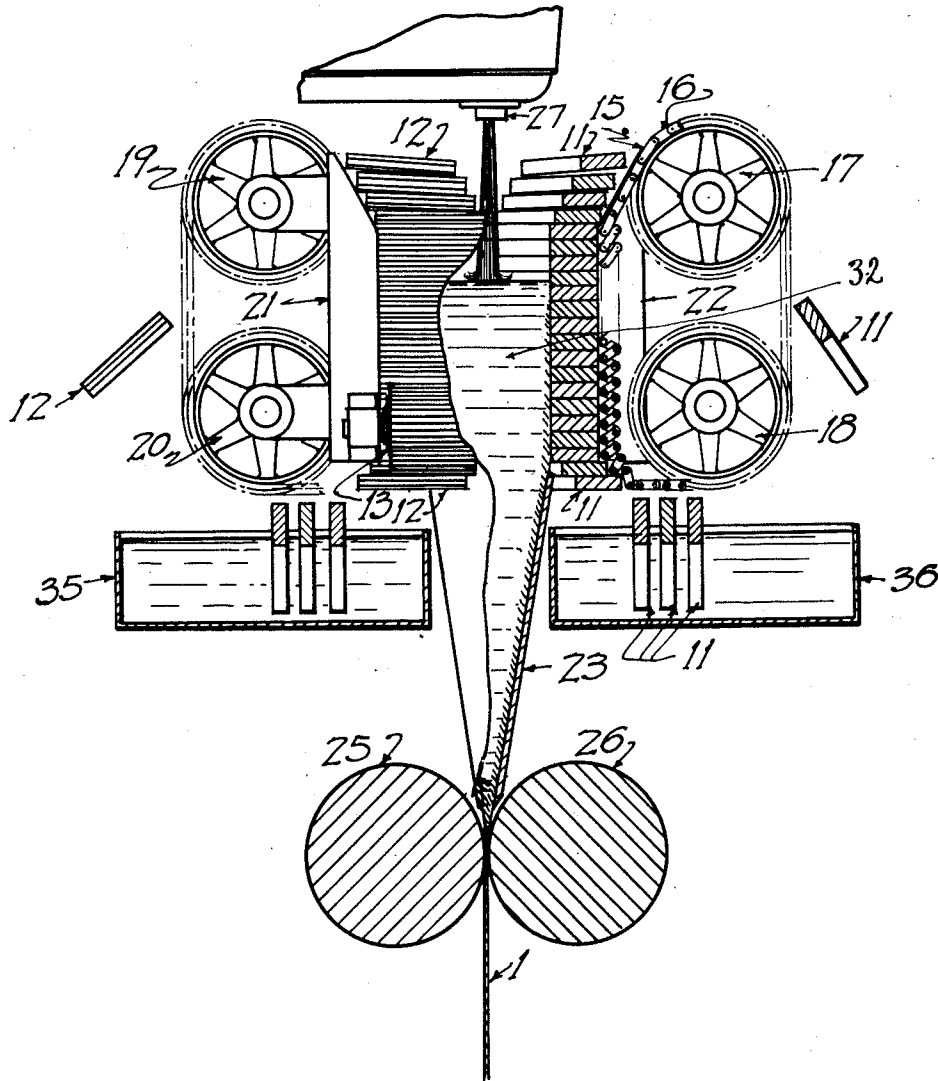


FIG. 1.

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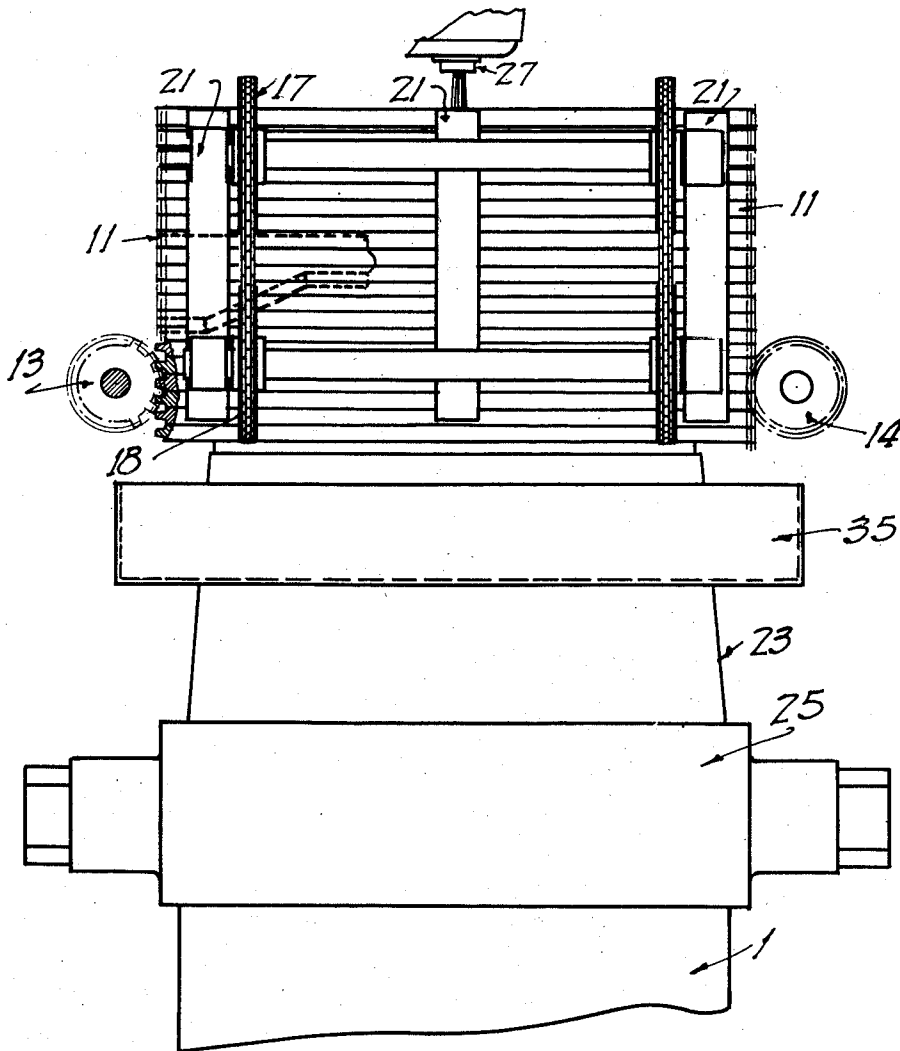


FIG. 2.

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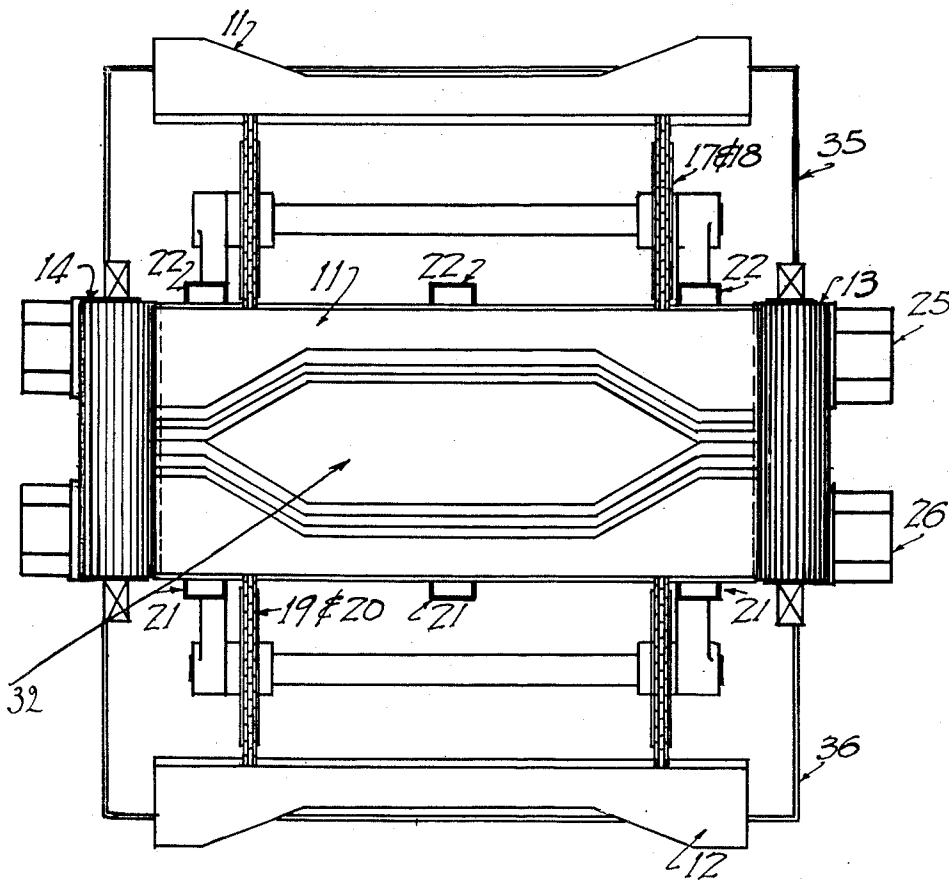
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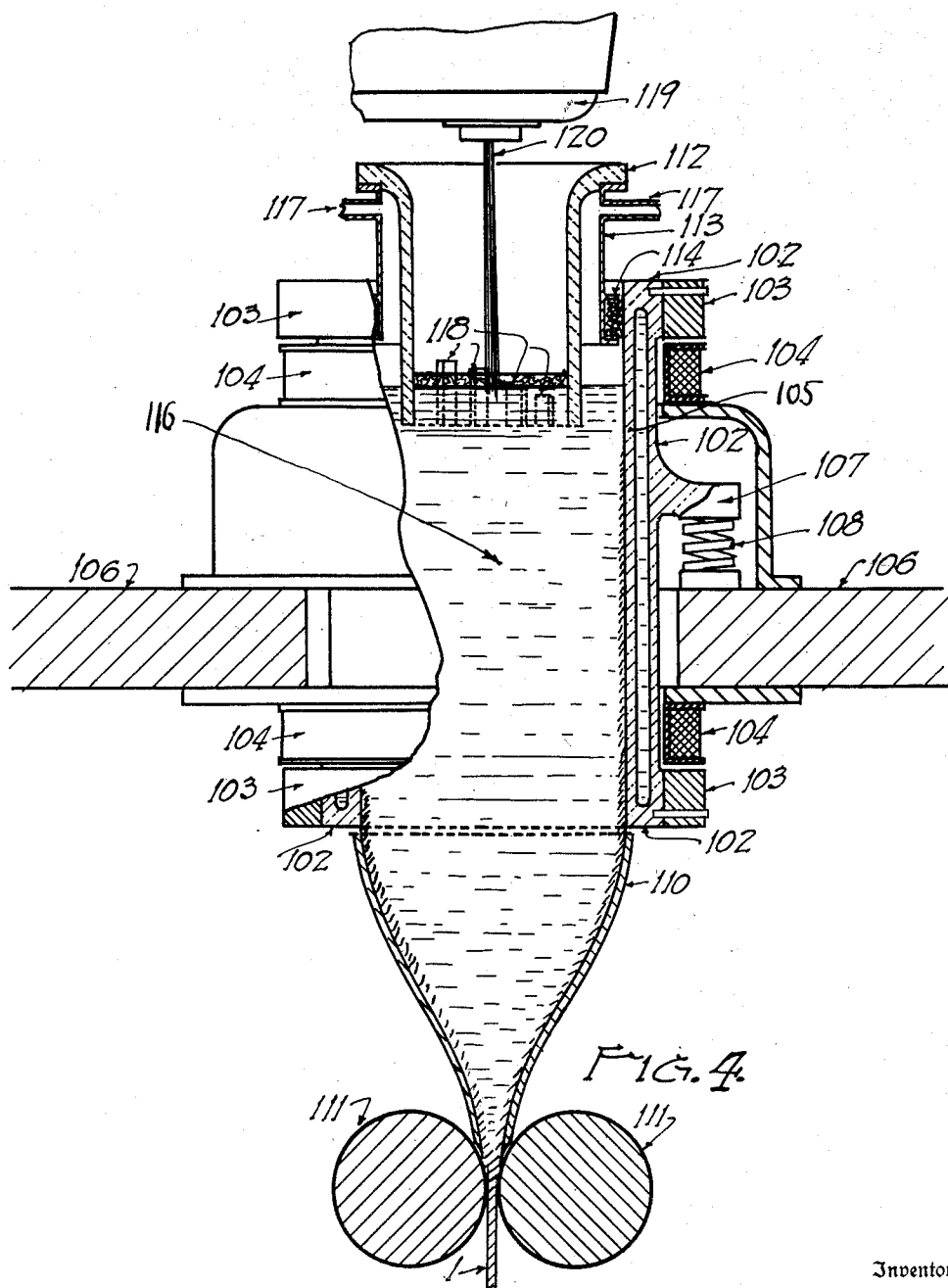
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METHOD OF PRODUCING TUBULAR AND SHEET METALS

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4 Sheets-Sheet 4



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METHOD OF PRODUCING TUBULAR AND SHEET METALS

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9 Claims. (Cl. 22—200.1)

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The present invention shows the improvements over my Patent 2,074,812, in which an internally cooled rotating body was partially submerged in a bath of molten metal, so that a crust of solidified metal was continuously formed on the surface of said rotating body, and withdrawn in the form of a strip.

This method, especially when applied to metals with a high melting point, presented certain difficulties, in that it was very difficult to operate a unit in which a rotating metallic body had to be kept inside of a high temperature furnace containing a molten metal bath.

The second difficulty was with keeping off the slag which readily assembled on the surface of metal, and interfered with the quality and surface of the obtained strip.

The third difficulty was the condition of solidifying the metal crust at and around the edge of the strip. It was difficult to obtain a clean edge and a uniform width of the strip because the conditions of heat transfer near the edge of the strip were different than in other parts of the strip.

I now developed a method where instead of an internally cooled rotating body partially immersed in a molten metal bath, and capable of solidifying a metallic crust on its outer surface, I am using a body, the inner surface of which serves for solidification of a metallic crust out of the molten metal, and is either externally cooled or the cooling takes place outside of the working zone. Such heat-absorbing body may have the form of a conveyor, the members of which meet on that portion of their travel where they face each other, so that they form a liquid-tight, tubular body, on the surface of which a metallic crust solidifies, and also forms a metallic tube; that is, it has no free edges, like in the case of my previous patent, above cited, and is further conveyed towards the rolling mill by the movement of said conveyor members.

Or, such heat-absorbing body may have the form of a vertical tube which contains the liquid metal bath, and on the walls of which such tubular-shaped metallic crust continually solidifies. This heat-absorbing tubular body may be caused to vibrate in order to prevent any sticking or frictional contact of the newly formed metallic crust with its internal surface.

In order to make my invention clearly understood, I will now explain it on hand of the following figures:

Figs. 1, 2, and 3 represent the first embodiment of my invention.

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Fig. 1 shows a side elevation and, partially, a vertical section of the apparatus.

Fig. 2 shows the front elevation and

Fig. 3 the top view of it.

Fig. 4 is a view, in vertical section, of another form of apparatus that may be used in practicing the invention.

Referring to Figs. 1, 2, and 3, representing the first embodiment of my invention, conveyor plates 11 and 12, preferably made of copper or some other highly heat conductive metal, are caused to stand one on top of another by two pinions engaging teeth provided at the ends of such plates, said pinions 13 and 14 turning with a uniform but adjustable velocity. The conveyor plates 11 and 12 are preferably joined together by knee-action chain links 15 and 16 so that while on their downward movement they stand one on the top of the other in close contact, thus forming between the two conveyors a closed tubular cavity. Such chain links permit them to stand apart of one another during the rest of their cycle for the purpose of better cooling. Said chain links are engaged by idle sprockets 17, 18, 19, and 20, and in addition to this, the conveyor plates 11 and 12 are supported directly on their downward travel, where they contain the molten metal bath, by solid rails 21 and 22, which not only guide the vertical movement of such conveyor plates, but also take up the forces of the hydrostatic metallic bath pressure which would tend to separate the two conveyors.

As each conveyor plate 11 or 12 passes beyond the tooth contact with pinion 13 or 14, it is rapidly pulled out by the weight of the chain and its load in the direction parallel to the tooth and away from the reciprocal plate of the other conveyor, at the moment it is relieved from the pressure of the stacked up conveyor plates 11 and 12. The funnel 23 is so located that its upper edge just clears the receding conveyor plates, and its lower edge terminates close to the bite of the rolls 25 and 26 or even touches the surface of such reducing rolls.

It will be clear that when the inside cavity formed by the two conveyors as described, enclosed on the bottom by the funnel 23 and the bite of the rolls 25 and 26 is filled with a molten metal, a crust of such metal immediately solidifies on the inner surface of such conveyor plates because the heat of fusion of such crust is rapidly taken away by the relatively cool conveyor plates. A steep temperature gradient is immediately formed within such solidifying crust, the tem-

perature of the layer immediately adjacent to the surface of the conveyor plates being quite low. It is a known fact that a solidified metal crust has a much lower heat conductivity than a molten metal, which makes this temperature gradient quite pronounced.

A freshly solidified crust has an almost negligible resistance to tension, but in this case that portion of the solidified metal layer which contacts the conveyor plates has a relatively low temperature, and, therefore, is mechanically quite solid. This fact is made use of in the short transition period where the conveyor plates recede when getting out of contact with the two pinions 13 and 14 and before the solidifying crust can touch the funnel 23. That short space, usually not over three-quarters of an inch, is unsupported, and, therefore, the thin crust must be strong enough to resist the hydrostatic metallic bath pressure for a short period of time. I am, therefore, in certain cases, using additional external cooling means, like blowers or a liquid spray, to prevent such crust from being heated through from the side of the liquid bath, when it is no more in contact with the heat-absorbing conveyor plates.

The metallic bath is constantly replenished, for instance, by means of a tube 112, omitted on Fig. 1 for the sake of clearness, but shown on Fig. 4, preferably made of a refractory material, the lower end of which reaches below the surface of the molten metal. A certain amount of slag may form on the surface of the molten metal bath within this tube, but a strictly reducing atmosphere is maintained over the free surface of the metallic bath outside of said tube 112, over the surface of molten metal. For this purpose the space between said tube and the conveyor plates may be sealed by the seal 114 and a reducing or neutral gas may be admitted and circulated, as by the tubes 117.

For starting a unit like this, a metallic sheet folded to form a tube may first be inserted into the bite of the rolls covering the funnel 23, and reaching back partly into the conveyor cavity. Thereupon, said conveyor cavity 32 is filled with molten metal under a protective atmosphere so that during filling no appreciable amount of slag is formed. Simultaneously, the conveyors and the rolls are started. The metallic crust forms immediately on the surface of the conveyor plates, and partly on the metallic sheet which has been inserted, and the working rolls 25 and 26 move it out of the unit, that is first the inserted sheet with some solidified metal on it, and later the solidified tubular crust which in the bite of the rolls is welded into one solid strip and reduced in thickness to the desired gauge, usually corresponding to a hot rolled strip which may later be cold reduced to a final gauge. On the other hand, if a greater amount of hot working of this solidified strip is deemed necessary, a thicker crust may be produced and may be continuously reduced while hot by more than one pair of reducing rolls working in succession. In other cases, where this condition is immaterial, the usual factors which prevent the rolling of hot strip on continuous mills below a certain gauge do not exist here, because conditions of a high degree of uniformity in temperature of the solidified strip can be maintained indefinitely, and in this way a hot rolled strip of half or one-quarter the gauge today produced by hot strip mills can easily and accurately be rolled if desired. For

the same reason, the usual limits to the maximum weight of a coil do not exist in this instance, and coils as heavy as desired, or as can be handled, can be produced.

As the strip leaves the bite of the one or more pairs of reducing rolls, I prefer to let it cool down under a hood containing reducing gases, so it may cool down without any oxide layer, so it can be further cold reduced or treated without the necessity of first cleaning or pickling its surface. Under such circumstances, the strip is finally coiled while fairly cool, and very much heavier coils can be produced because the danger of individual layers sticking or welding together does not exist.

The operation of this double conveyor does not need much comment. The conveyor plates 11, 12 after they have left the stacks in their bottom position, have ample opportunity to be completely cooled by natural radiation, artificial draft, and if necessary sprinkling or bathing in a cooling liquid before they again come in contact with the hot metal bath. A liquid, for instance, water cooling bath, can conveniently be arranged in the form of troughs 35 and 36, in which the plates bathe while on the bottom portion of their travel.

Whenever it is necessary to either periodically or constantly redress that portion of conveyor plates 11 and 12 which comes in contact with molten metal, or in fact any other parts of their surface which may be subject to wear or deterioration, suitable polishing or grinding apparatus are simply placed in the path of their travel, as, for instance, a grinding wheel. In certain cases, I prefer to plate said surface of the conveyors which comes in contact with molten metal with another metal, for instance, chromium, to give it a high polish and a better resistance. In such case, said plating may be periodically stripped and replaced by a new one, or simply some more plating metal, which may be the same or different from the metal of the conveyor plates, may be added to it continuously while the unit is in operation. For this purpose, for instance, the troughs 35 and 36 can be arranged as plating baths and still perform the cooling function, at the same time.

While the solidified tubular crust slides past the inner surface of the funnel 23 it also is cooled, to a certain extent, by artificial means, but the temperature of the outer layer of such crust slightly increases, if heat is not taken away by the funnel 23 as rapidly as it is by the cold conveyor plates 11 and 12. In such cases, I prefer to face the inside of said funnel with a wear- and heat-resisting material. In any case, I prefer to so face the last or lowest portion of said funnel 23, where I purposely allow the temperature of the outer layer of the solidified crust to go up, in order to make it easier to hot reduce it in the bite of the rolls 25 and 26, and to reduce the difference in temperature between the surface layer and the inside portion of the solidified tube now pressed by the rolls into a flat strip.

The molten metal contained within the funnel 23 remains substantially at the same temperature as the rest of the metallic bath, but some of it may solidify in the lowest portion of it, and such solidified metal particles are entrained by the tubular solidified crust into the bite of the rolls, and are reduced into the strip together with said crust.

This process of producing strip out of molten metal is, to a certain extent, less delicate, and

does not require to keep such exact pouring temperatures as pouring ordinary ingots. This is accounted for by the fact that the greatest portion of the thin crust which usually does not exceed in thickness about $\frac{1}{8}$ or $\frac{3}{16}$ of an inch, for most metals, is chilled almost instantaneously on the first contact with the conveyor plates, and the usual process of gradual growth of crystals with partial evolution of gases and segregation, etc., peculiar to the solidifying of an ingot is present to a far lesser extent, with this process. In fact, the best operation of such unit consists in placing a full ladle of molten metal with its spout over the tube 27 and pouring the molten metal continuously, while the unit operates, and controlling the speed of pouring so that the upper level of the metal within the conveyor cavity is kept uniform, within fairly narrow limits. In the case of steel, such unit may be conveniently operated, say, between 50 and 100 tons an hour to produce strip, say 40 or 50 inches wide, by .100 inch thick. A 75-ton ladle of molten steel may be poured until about half the metal is gone, which would take anything between 20 and 40 minutes. At this moment molten metal of a higher temperature may be added to it from another ladle without interrupting the process of pouring, as long as the spout will stand, thereby preserving the molten metal temperature within the required limits.

The shape of the cavity left between conveyor plates 11 and 12 is in this instance preferably flat, as shown in Fig. 3, with the portions corresponding to the edges of the strip converging at a sharp angle. With such shape, there is room enough for a pouring funnel, like 112, Fig. 4, and enough weight of metal in the bath to easily maintain its upper surface within narrow limits, but at the same time the bottom funnel 23, where the profile changes from a tubular one into a flat strip is relatively short, and there is no danger of tearing the solidified crust at any place.

The embodiment shown in Fig. 4 discloses a different type of a heat-absorbing body. It is in a form of a tube 105 made of a metal of a high heat conductivity like copper, preferably work-hardened, polished, and even plated with chromium or other suitable metal inside, and fitted with some apparatus to cause it to vibrate with a very high frequency. When a crust of solidifying metal formed on contact of the inner surface of such tube with molten metal is formed, such crust will never adhere to such tubular body if its surface is sufficiently highly polished, and if it is subject to such high frequency vibration. On the contrary, it will slide freely on such surface, and the crust may be continuously moved as through funnel 110, and then may go through reducing rolls 111.

As one means of causing such tubular mold 105 to vibrate, I may affix to it, at its both ends, two rings 103 of a magnetic material, and dispose, in closest proximity of those rings, but with a definite air gap, two electro-magnetic coils 104 mounted on a common structure independent of the support 107 of the heat-absorbing tube 105 and its water jacket 102, the latter structure being preferably mounted on springs 108 located on a suitable foundation 106.

If alternating current of a suitable frequency is passed through the electro-magnetic coils 104 a certain force is created, having a tendency to attract towards each other the two magnetic rings 103 situated at the two ends of the heat-absorbing tube 105, thereby elastically compress-

ing such tube. As the current decreases to zero, during each cycle, such force disappears, and the tube which is no more compressed expands to its original length. The frequency of the alternating current should be preferably so chosen as to coincide with the natural swing cycle of such tube 105 considered as one elastic system, together with its tube magnetic rings 103 as in such case the high vibration effect will be obtained with a relatively low consumption of electric energy.

I have disclosed here one preferred system of causing the heat-absorbing mold 105 to vibrate longitudinally, but evidently torsional or even oval vibrations could be used with the same effect, that is, insuring a free sliding of a newly formed fragile metal crust on the inside of such heat-absorbing mold. In many cases, a suitably polished mold, without any vibrating apparatus, is sufficient, to insure an easy gliding of the solidified crust. As the crust cools down further, when descending through the mold 105, I prefer to make the diameter of said mold slightly tapering, to insure continuous contact and support of such tubular crust.

Aside from its extreme simplicity and relatively low cost, this type of mold possesses an advantage of having a very small clearance between its lower end and the funnel 110, so that the danger of a rupture and bleeding at this point when the mold is filled with molten metal 116 is not present.

In such case, that is, when the inside of the mold and funnel are filled with molten metal, the cross section of the tube 105 does not necessarily have to be round, but may also be oval or flat, as in Figs. 1, 2, and 3. Funnel 110 may, in some cases, be omitted altogether, mold 105 extending right down to the rolls.

For the purpose of continuously filling such mold with molten metal, and keeping the upper surface of the metal bath in the vicinity of the inner surface of the mold 105 free from slag by preventing its contact with oxygen, I may use a funnel 112, preferably made of a refractory material and fitted with a seal 114 placed in a metallic tube 113, and having gas inlets and outlets 117. The upper surface of the metal bath 116, with a thin layer of slag on the top of it, is visible to the operator from the outside, and if a number of notches 118 disposed at varying heights are provided on the inside of such funnel, the operator can very conveniently estimate the level of his metal bath 116 by watching which notches are submerged.

In the further treatment of the solidifying strip 1, that is, its gradual flattening in the funnel 110, and its reduction in the bite of rolls 111, this embodiment hardly differs from the one described in Figs. 1, 2, and 3.

I claim:

1. The method for continuously producing strip material directly from a mass of molten metal, which method comprises: laterally supporting a mass of molten metal and progressively solidifying a tubular skin thereon against its lateral support by extracting heat from the exterior of the said mass of molten metal substantially uniformly around its entire perimeter; coincidentally withdrawing the said skin in an axial direction away from its initial zone-of-formation while continuing the said solidification and supporting the said skin free of frictional sliding movement relative to its support at least until the said skin has sufficient thickness and strength

to withstand such frictional sliding engagement; maintaining the perimetrical dimension of the said skin substantially unaltered during its said solidification to thereby avoid breaks or the formation of corrugations therein during its said axial movement; and continuously flattening the said tubular skin in substantial synchronism with its axial movement by bringing its opposite inner surfaces substantially into contact with each other while the same are sufficiently hot to weld together and maintaining substantially unaltered the perimetrical dimension of the said skin to thereby avoid breaks or the formation of corrugations therein.

2. The method as defined in claim 1 and in which the means for supporting the tubular skin during its initial formation is caused to move in a direction substantially parallel with the path of movement of the said tubular skin and at substantially the space speed.

3. The method as defined in claim 1 and in which the solidifying of the said tubular skin is accomplished by the relatively-rapid extraction of heat therefrom in a first zone and in a second zone the heat extraction is made at a relatively-slower rate to provide a high gradient of temperature in the said skin in the said first zone and a relatively-low gradient of temperature in the said second zone.

4. The method as defined in claim 1 and in which the skin, after becoming sufficiently thick and strong to be self-supporting, is caused to move substantially unsupported across a gap before having its opposite inner surfaces brought substantially into contact as set forth.

5. The method for continuously producing strip material directly from a mass of molten metal, which method comprises: laterally supporting a mass of molten metal and progressively solidifying a tubular skin thereon against its lateral support by extracting heat from the exterior of the said mass of molten metal substantially uniformly around its entire perimeter; coincidentally withdrawing the said skin in an axial direction away from its initial zone-of-formation while continuing the said solidification and supporting the said skin free of frictional sliding movement relative to its support at least until the said skin has sufficient thickness and strength to withstand such frictional sliding engagement; maintaining the perimetrical dimension of the said skin substantially unaltered during its said solidification to thereby avoid breaks or the formation of corrugations therein during its said axial movement; and continuously flattening the said tubular skin in substantial synchronism with its axial movement by bringing its opposite inner surfaces substantially into contact with each other in the presence of molten metal and while maintaining substantially unaltered the perimetrical dimension of the said skin to thereby avoid breaks or the formation of corrugations therein as brought into contact.

6. The method as defined in claim 5 and in which the two layers of skin resulting from the bringing of opposite inner skin-surfaces to-

gether, are simultaneously forcibly reduced in thickness to positively exclude molten metal from between the said surfaces.

7. The method for continuously producing strip material directly from a mass of molten metal, which method comprises: supporting a mass of molten metal by means of an axially-movable support which extends completely around the perimeter of the said molten metal and progressively solidifying a tubular skin thereon against the said support while the latter is moving axially, the said solidification being done by extracting heat from the exterior of the said mass of molten metal substantially uniformly around its entire perimeter; coincidentally withdrawing the said skin in an axial direction away from its initial zone-of-formation while continuing the said solidification and supporting the said skin free of frictional sliding movement relative to its support until the said skin has sufficient thickness and strength to withstand frictional sliding engagement with the hereinafter-mentioned second support; maintaining the perimetrical dimension of the said skin substantially unaltered during its said solidification to thereby avoid breaks or the formation of corrugations therein during its said axial movement; sliding the said skin relative to a second support and meanwhile again maintaining the perimetrical dimension of the said skin substantially unaltered; and thereafter continuously flattening the said tubular skin in substantial synchronism with its axial movement by bringing its opposite inner surfaces substantially into contact with each other while the same are sufficiently hot to weld together.

8. The method as defined in claim 7 and in which heat is extracted from the skin by the said second support at a relatively-slow rate as compared to the heat extraction by the said axially-movable support, to thereby provide two temperature-gradient zones in the said skin.

9. The method as defined in claim 8 and in which the skin, after becoming sufficiently thick and strong to be self-supporting, is caused to move substantially unsupported across a gap between the said axially-movable support and the said second support.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,822,256	Watt	Sept. 8, 1931
2,075,394	Hazelett	Mar. 30, 1937
2,108,753	Low	Feb. 15, 1938
2,130,202	Tama	Sept. 13, 1938
2,187,720	Williams	Jan. 23, 1940
2,225,373	Goss	Dec. 17, 1940
2,285,740	Merle	June 9, 1942
2,290,083	Webster	July 14, 1942
2,301,027	Ennor	Nov. 3, 1942
2,376,518	Spence	May 22, 1945