June 29, 1965 C. F. STROM 3,191,292

METHOD OF PRODUCING ROLLED METAL ARTICLES

Filed July 16, 1963 7 Sheets-Sheet 1

Fig. 1.

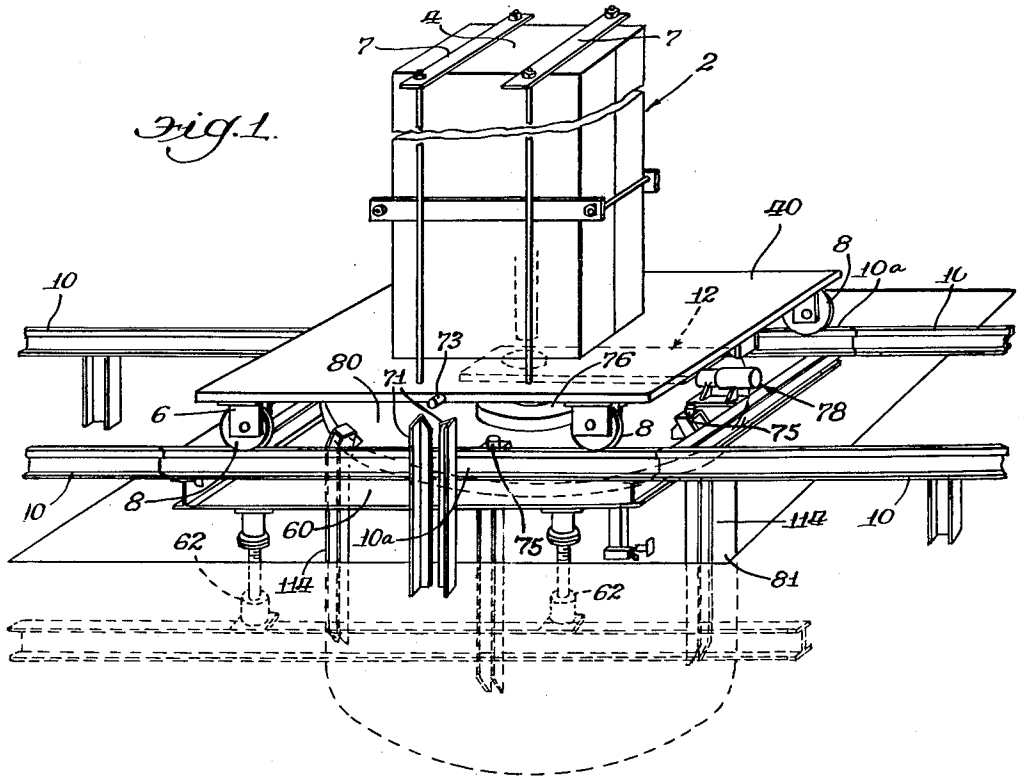
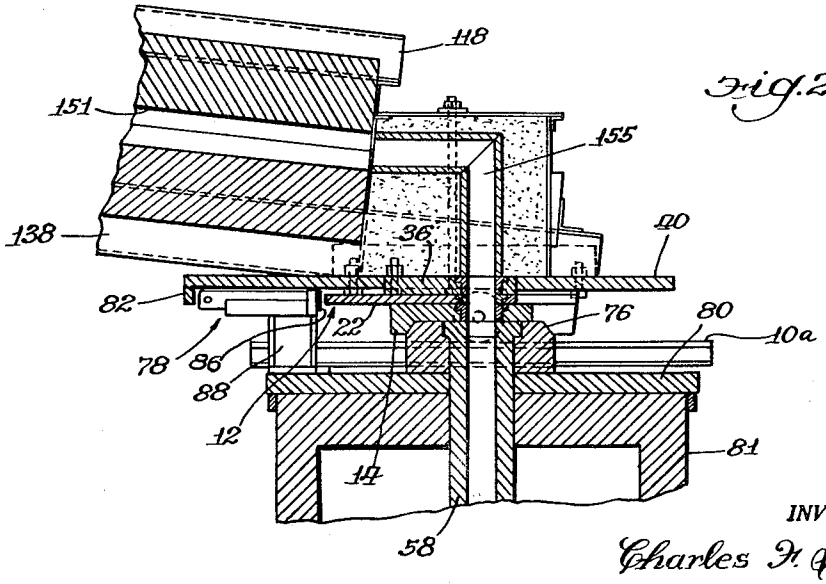


Fig. 23.



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METHOD OF PRODUCING ROLLED METAL ARTICLES

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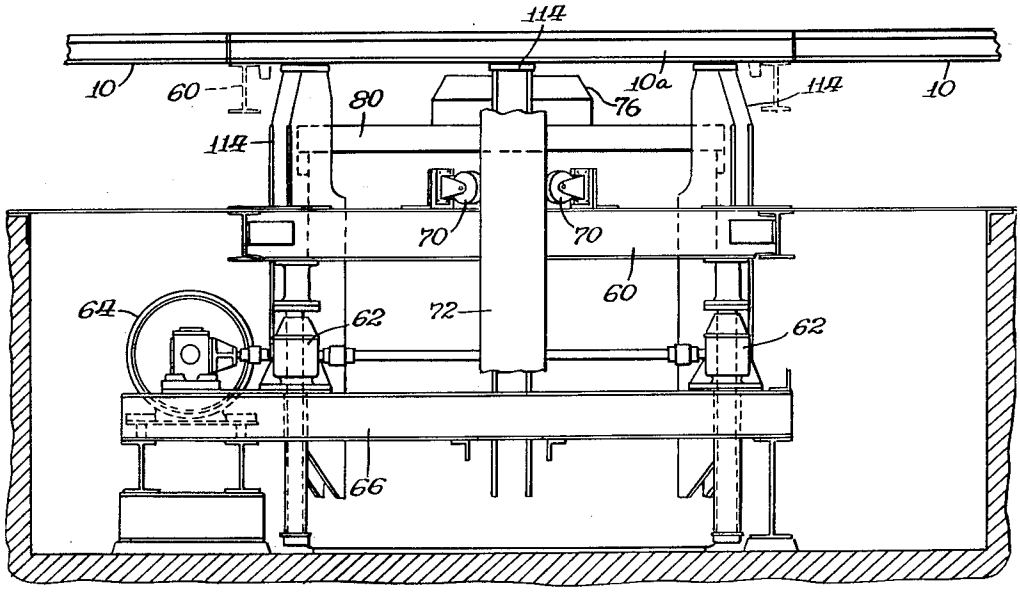


Fig. 3.

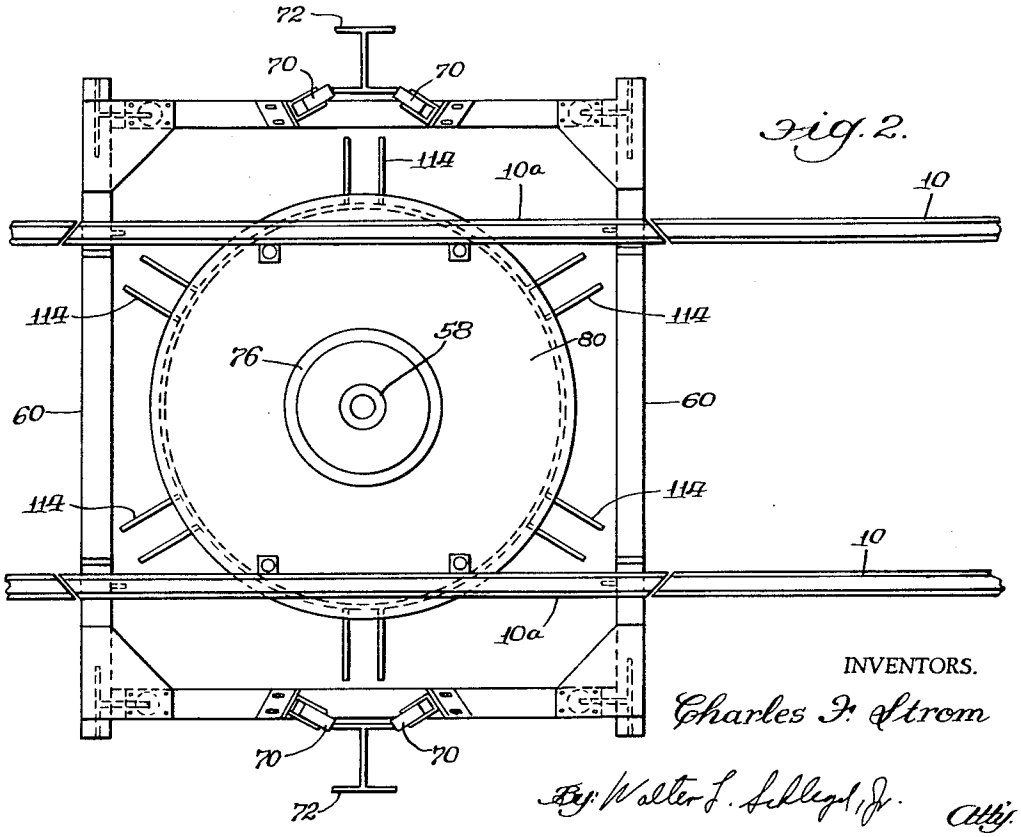


Fig. 2.

INVENTORS.

Charles F. Strom

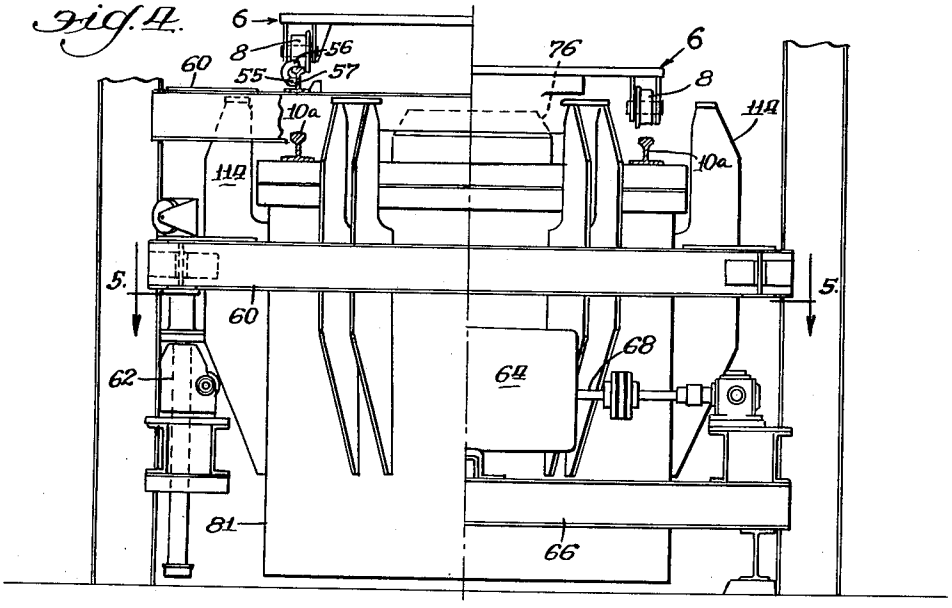
By: Walter L. Schlegel, Jr. Atty.

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METHOD OF PRODUCING ROLLED METAL ARTICLES

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Fig. 4.



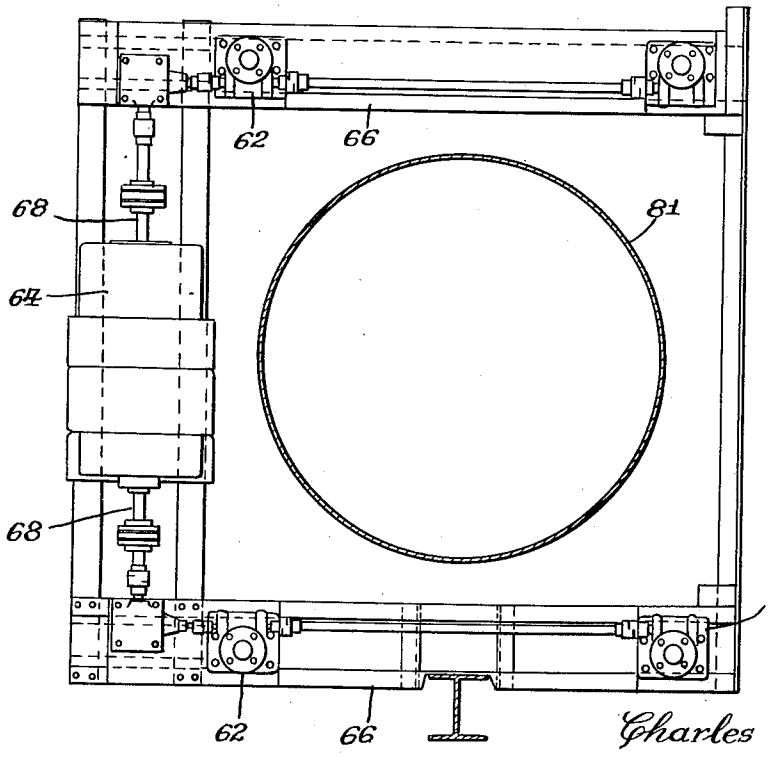


Fig. 5.

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METHOD OF PRODUCING ROLLED METAL ARTICLES

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Fig. 6.

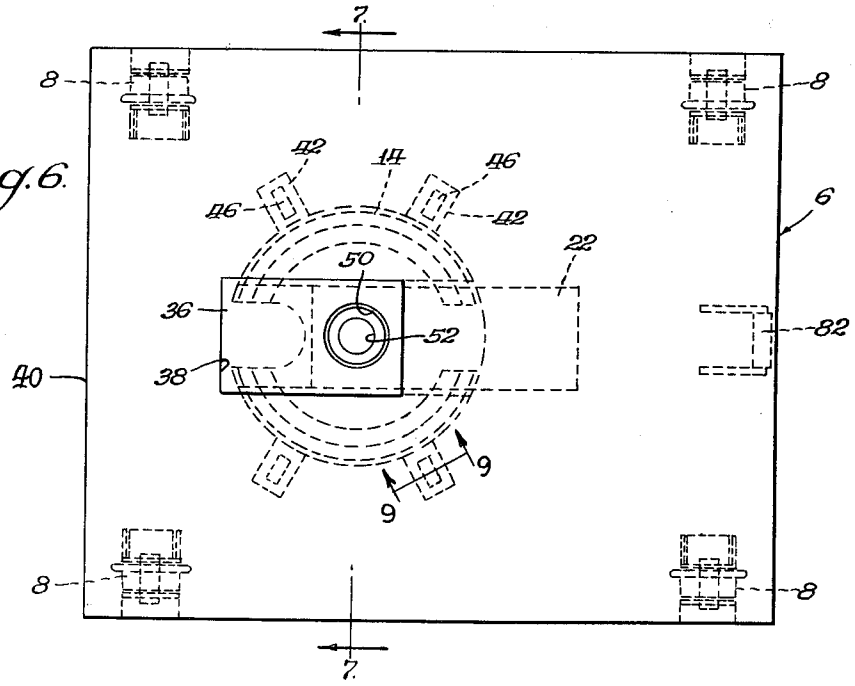


Fig. 7.

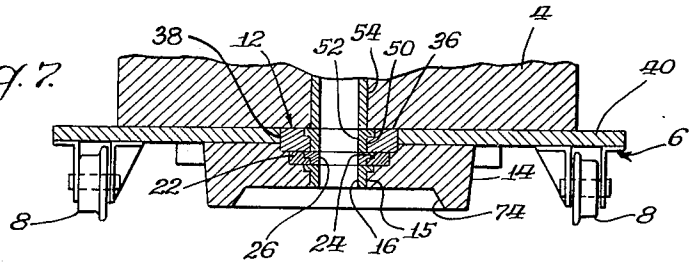


Fig. 8.

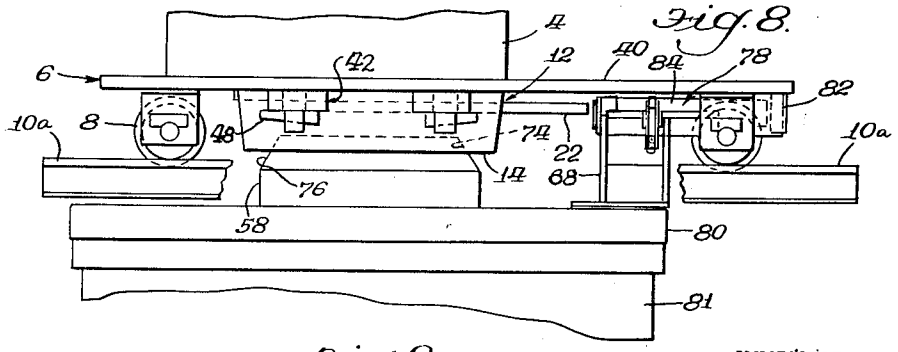
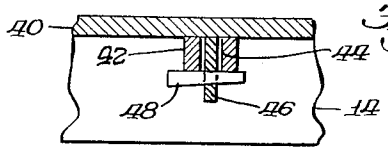


Fig. 9.



INVENTORS.

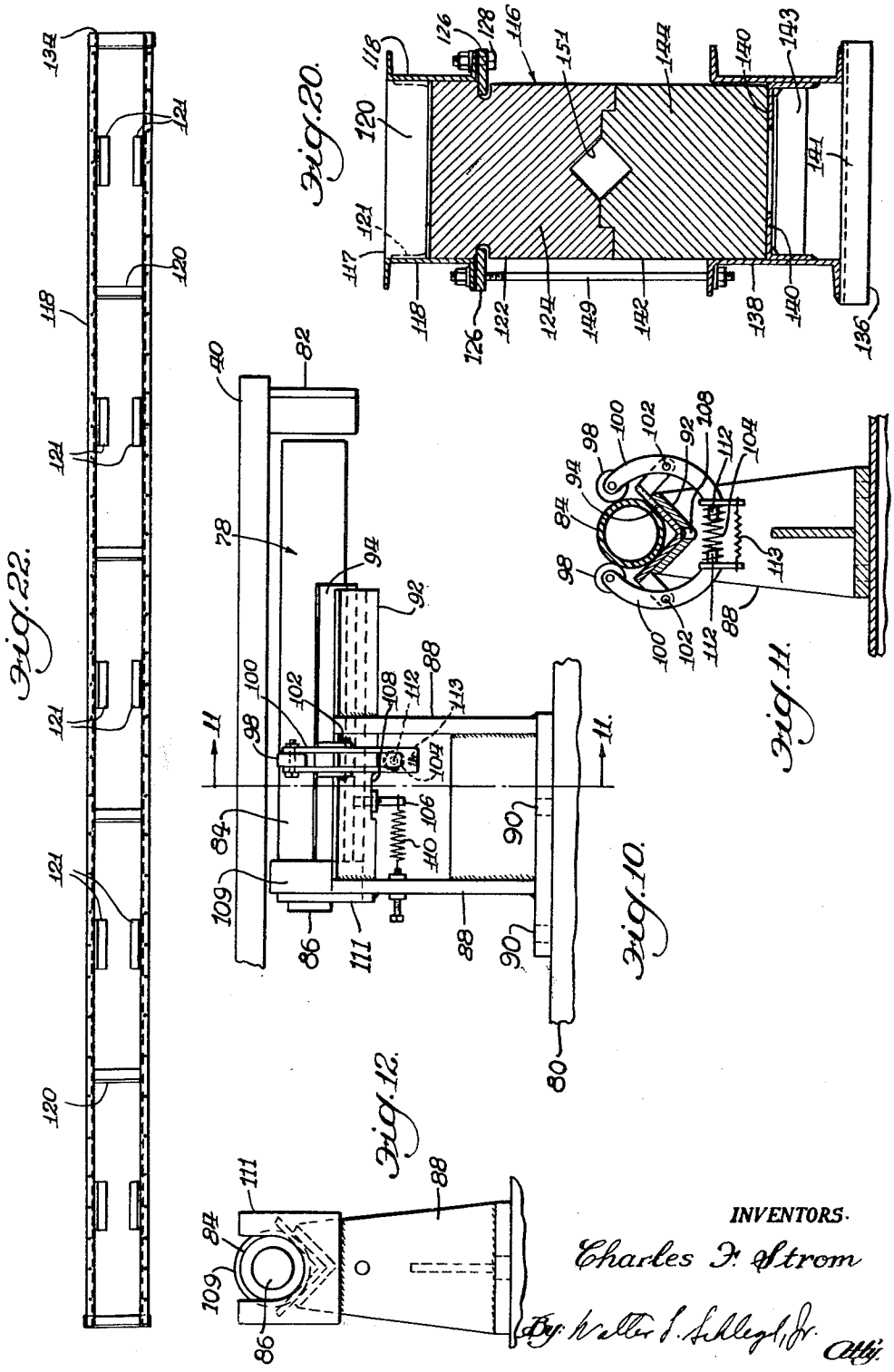
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June 29, 1965 C. F. STROM 3,191,292

METHOD OF PRODUCING ROLLED METAL ARTICLES

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METHOD OF PRODUCING ROLLED METAL ARTICLES

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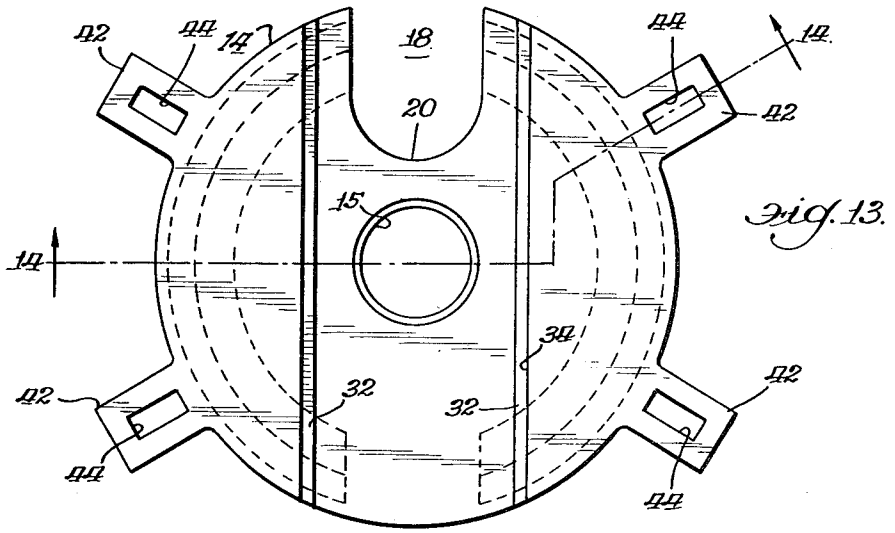


Fig. 13.

Fig. 14.

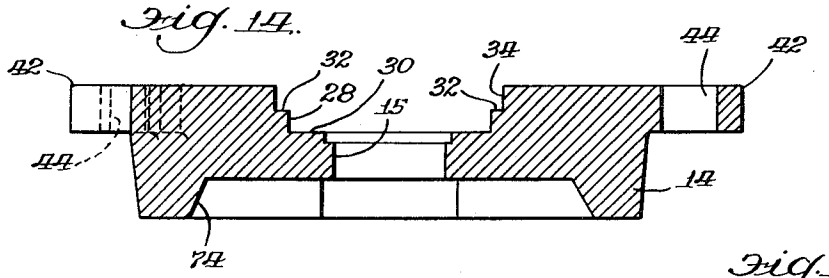
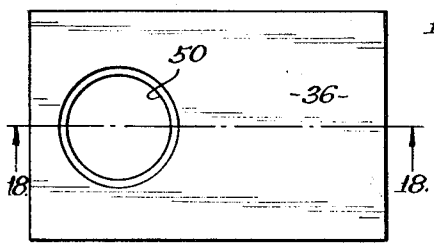
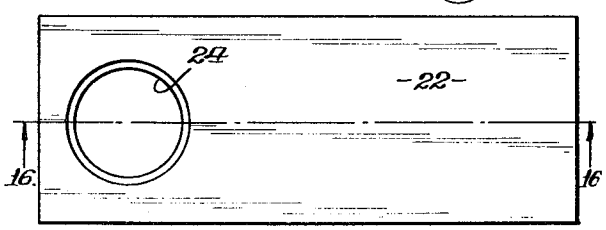


Fig. 15.

Fig. 17.





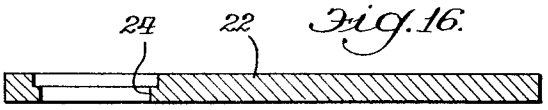


Fig. 16.

Fig. 18.



INVENTORS.

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METHOD OF PRODUCING ROLLED METAL ARTICLES

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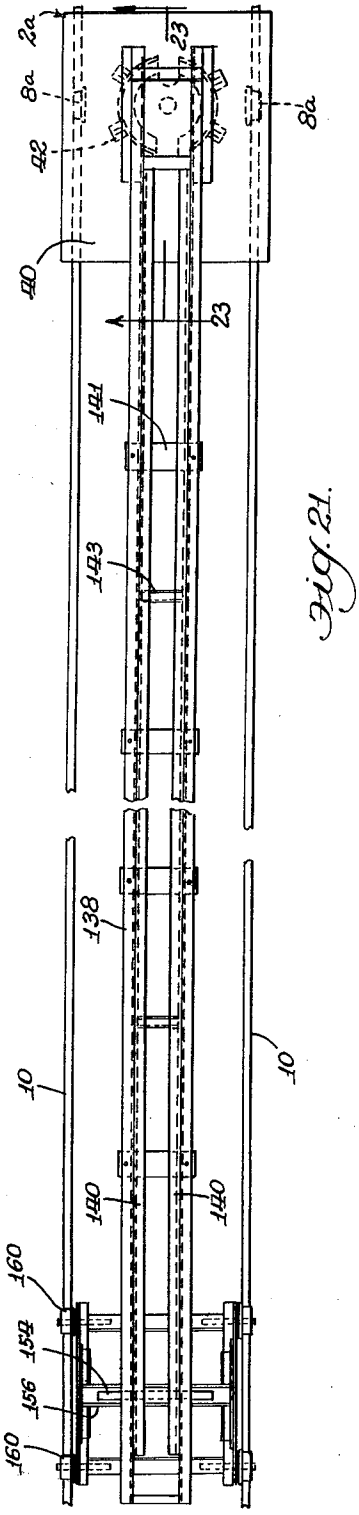


Fig. 21.

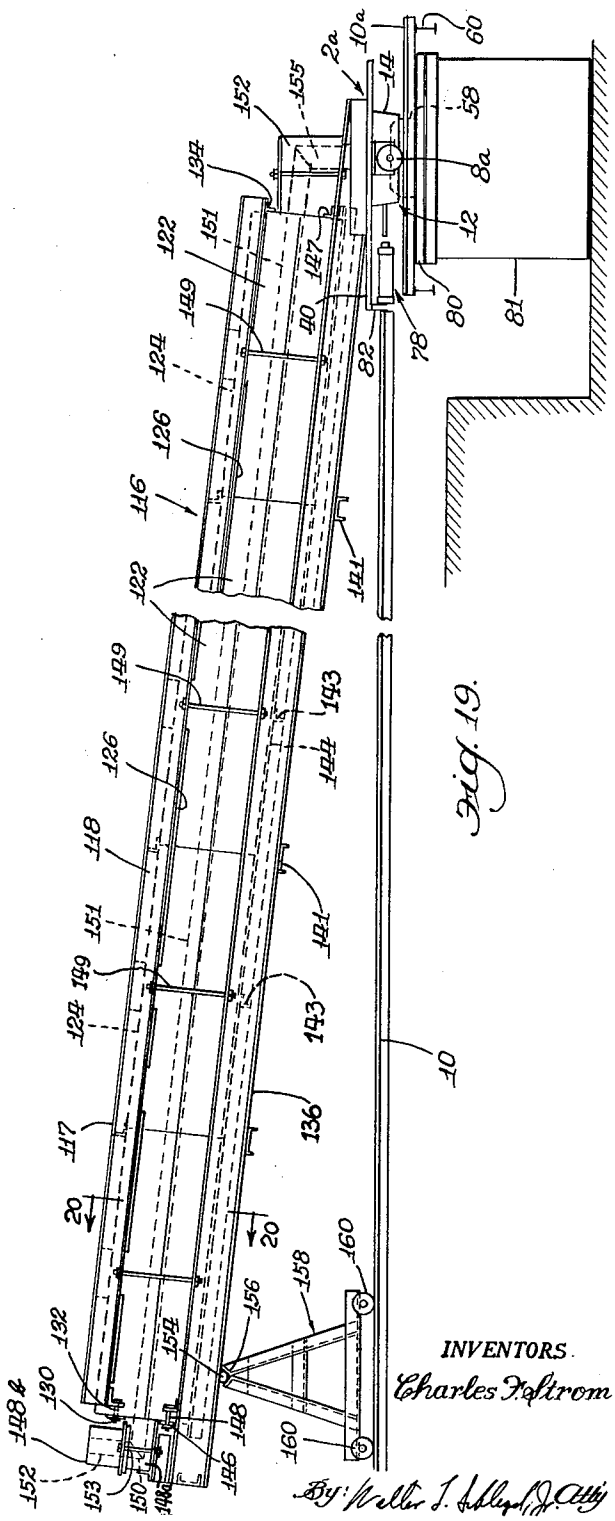


Fig. 19.

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By: Walter J. Ashley & Assoc. Atty

United States Patent Office 3,191,292 Patented June 29, 1965

3,191,292

METHOD OF PRODUCING ROLLED METAL ARTICLES

Charles F. Strom, Glen Ellyn, Ill., assignor to Amsted Industries Incorporated, Chicago, Ill., a corporation of New Jersey

Filed July 16, 1963, Ser. No. 295,547
11 Claims. (Cl. 29—528)

This invention relates to the production of metal articles, such as steel billets, blooms, or slabs, in pieces of desired cross-sectional dimensions and weights, directly from the molten metal and without the use of a primary mill.

This application is a continuation-in-part of my copending application Serial No. 25,498, now abandoned filed March 21, 1960 as a continuation-in-part of my application Serial No. 829,457, now abandoned, filed July 24, 1959, for Bottom Casting Articles in the name of Charles F. Strom.

According to prior art practices, steel ingots have been cast and stored in soaking pits. Such ingots have then been reheated, if necessary, and have been hot rolled in a primary mill to elongate the casting or ingot and reduce its cross-sectional area thereby forming a bloom having a length three or more times its maximum cross-sectional dimension and having a cross-sectional area not substantially in excess of 120 square inches. The blooms have then been rolled to form billets having a cross-sectional area not substantially in excess of thirty six square inches and having a length three or more times the maximum cross-sectional dimension. Sometimes ingots are rolled by a primary mill into oblong slabs having a cross-sectional area of the order of from 48 square inches to 360 square inches and having a length three or more times the maximum cross-sectional dimension. Such billets and slabs have then been rolled to form commercial products such as rods, tubes and sheets.

Previous prior art attempts to eliminate ingots and the necessity for soaking pits by casting blooms, billets (including tube rounds) and/or slabs on a commercial basis have been unsuccessful, and according to the invention it has been discovered that such blooms, billets (including tube rounds) and/or slabs can be cast by bottom pouring into an elongated graphite mold and can be directly rolled into commercial products.

For the purpose of this specification and claims, a "bloom" is hereby defined as a steel article having a substantially uniform cross-sectional area not substantially in excess of 120 square inches and a length three or more times its maximum cross-sectional dimension; a "billet" (including a tube round) is hereby defined as a steel article having a substantially uniform cross-sectional area not substantially in excess of thirty six square inches and a length three or more times its maximum cross-sectional dimension, and a slab is hereby defined as a steel article having a substantially uniform oblong cross-sectional area of from 48 square inches to 360 square inches and having a length three or more times its maximum cross-sectional dimension.

I have discovered that only the casting that can be successfully rolled directly into a commercial product, without the necessity for the previously described intervening steps, is one having an outer surface entirely free from external shrinkage voids or fissures.

I have further discovered that if such a casting is rolled at a temperature above the weld temperature of the metal in the casting, the internal shrinkage voids or fissures can be eliminated by the internal welding of the metal by the rolling operation. The reason for this is that the oxidation of the surfaces of the external fissures which

are exposed to the atmosphere results in surface imperfections which can not be removed by internal welding. However, where all of the shrinkage fissures are internal, there is no problem of oxidation and the rolling will cause an internal welding to take place with the result that near perfect products can be produced by a direct rolling operation.

Further, I have discovered that a casting having no internal shrinkage voids communicating with an outer surface can be produced by forming the casting in a chill mold which serves to seal off the outer surface of the casting. In addition to using a chill mold it is necessary to insure that the end surfaces of the casting are also free of shrinkage fissures. This can be done by using a chill stopper at opposite ends of the mold cavity or by using a chill cut-off at one end of the mold cavity and using a special type riser at the other end of the mold cavity.

It is therefore a primary object of the invention to provide a method for producing a rolled metal product whereby a casting can be rolled into a finished product without the necessity for intermediate ingot and primary rolling operations.

A more specific object of the invention is the provision of a method for producing rolled metal products wherein a casting free of external shrinkage fissures is produced for direct rolling while it is at a temperature above the weld temperature of the metal.

The foregoing and other objects and advantages of the invention will become apparent from a consideration of the following specification and the accompanying drawings, wherein:

FIGURE 1 is a perspective view of a preferred embodiment of the invention utilized in the pouring of a conventional mold;

FIGURE 2 is a top plan view of the novel apparatus;

FIGURE 3 is a side elevational view thereof;

FIGURE 4 is an end elevational view taken from the right of FIGURE 3;

FIGURE 5 is a fragmentary horizontal sectional view taken on line 5—5 of FIGURE 4;

FIGURE 6 is a top plan view of a novel mold assembly;

FIGURE 7 is a vertical sectional view on line 7—7 of FIGURE 6;

FIGURE 8 is a side elevational view of the novel mold assembly;

FIGURE 9 is a fragmentary view partly in vertical section taken on line 9—9 of FIGURE 6;

FIGURE 10 is a side elevational view of the support means for the cut-off power device;

FIGURE 11 is a vertical sectional view taken on line 11—11 of FIGURE 10;

FIGURE 12 is an end elevational view taken from the left of FIGURE 10;

FIGURE 13 is a top plan view of the cut-off slide support;

FIGURE 14 is a vertical sectional view taken on line 14—14 of FIGURE 13;

FIGURE 15 is a top plan view of the cut-off slide;

FIGURE 16 is a vertical sectional view taken on line 16—16 of FIGURE 15;

FIGURE 17 is a top plan view of the cut-off insert against which the mold gate seats;

FIGURE 18 is a vertical sectional view taken on line 18—18 of FIGURE 17;

FIGURE 19 is a side elevational view of a novel billet mold assembly to be utilized with the apparatus of FIGURES 1–18;

FIGURE 20 is a vertical sectional view taken on line 20—20 of FIGURE 19;

FIGURE 21 is a top plan view of the bottom or drag mold frame shown in FIGURES 19 and 20;

FIGURE 22 is a bottom plan view of the top or cope mold frame shown in FIGURES 19 and 20; and

FIGURE 23 is a vertical sectional view taken on line 23—23 of FIGURE 21.

In each of said figures, certain details have been omitted in the interest of clarity where adequately shown in other views.

Describing the invention in detail, a mold assembly generally designated 2 (FIGURE 1) comprises a mold 4 which is formed of a chill material which has a thermal conductivity coefficient value at 18° C. of the order of 0.1 cal./sec./cm.²/° C./cm., or greater. A highly desirable material having the desired capacity of thermal conductivity is graphite. The assembly 2 also comprises a car 6 to which the mold 4 may be clamped by conventional clamps 7 or by force of gravity. The mold 4 and car 6, during a pouring operation, as hereinafter described, move together as a unit or assembly 2 and may be interconnected in any desired manner.

The car 6 comprises wheels 8 which roll on tracks 10 and also comprises a cut-off or gate closing device generally designated 12. The cut-off 12 is best seen in FIGURES 6–8 and 13–18 and includes a slide support 14 having an opening or hole 15 with a bushing 16 (FIGURE 7) which may be of any desired material such as graphite, baked clay or shell. The slide support 14 has a cut-out or slot 18 (FIGURE 13) partly defined by an inner edge 20 for a purpose hereinafter described.

A slide or plate 22 preferably of cast iron, copper or any other desired chill material, having the above mentioned minimum thermal conductivity coefficient value, is slidably mounted on the support 14 and comprises an opening or aperture 24 having a bushing 26 similar in form and composition to bushing 16. The slide 22 is supported within a channel 28 (FIGURE 14) of the support 14 and is seated along a surface 30 thereof immediately below shoulders or ledges 32 which define another channel 34 within which is positioned a loose insert 36 (FIGURES 6–7 and 17–18) which is complementary to and removably mounted in an opening 38 of a top plate or panel 40 of the car 6.

The support 14 is releasably interlocked with the panel 40 by means of ears 42 on the support having apertures 44 within which are received lugs 46 on the underside of panel 40. The lugs 46 are slotted to receive wedge keys 48 which are driven to locking position shown in FIGURE 9 and which may be quickly removed by an impact against the small ends of the keys 48.

The insert 36 is provided with an opening or aperture 50 having a bushing 52 (FIGURE 7) similar to form and material to bushings 16 and 26, whereby when apertures 15, 24 and 60 are aligned, they define a continuous passage for the flow of molten metal into a gate 54 (FIGURE 7) of the mold 4.

The assembly 2 rolls along tracks 10 until one wheel strikes a retractible stop 56 (FIGURE 4) pivoted at 55 to an ear 57 on one rail segment 10*a* to locate the apertures 15, 24, and 50 in verticle alignment with the top of a pouring tube 58, the lower end of which comunicates with a source of material (not shown) to be cast, such as a ladle of molten metal. Under these conditions, the wheels 8 are supported by rail segments 10*a* which are separable from rails 10 and are vertically movable.

The segments 10*a* are supported by a frame 60 which is in turn supported at its corners, as by conventional worm gear screw jacks 62 operatively connected to a reversible electric motor 64. The jacks are mounted on foundation-supported beams 66 (FIGURES 3 and 4) and raise or lower the frame 60 in response to rotation of the armature shaft 68 of motor 64 in one direction or the other. The frame 60 is guided by rollers 70 (FIGURES 2 and 3) which are mounted on the frame and which engage vertical foundation-supported beams 72. The car is guided at each side thereof in aligned relationship with the top of tube 58 by foundation-mounted

guide rails 71 (FIGURE 1) which snugly confine therebetween a pin 73 on panel 40 of car 6.

When the assembly 2 is aligned with the top of tube 58, the motor 64 is energized to lower the frame 60 until a tapered recess 74 in the bottom of the support 14 engages a complementary tapered portion 76 of the upper end of tube 58. The frame continues to lower until the support 14 is clamped by force of gravity or by other means (not shown) against the tapered portion of tube 58 to afford a substantially airtight seal between the tube and the support 14, whereupon the metal in which the tube 58 is immersed is pressurized (as for example in the manner disclosed by U.S. Letters Patent No. 2,847,739 issued August 19, 1958 to E. Q. Sylvester) to flow the metal upwardly through apertures 15, 24 and 50 and gate 54 until the mold has been filled. Tilting of the car 6 during pouring is limited by lugs 75 (FIGURE 1) mounted on the top of brackets 114, hereinafter described.

After the mold has been filled the slide 22 is actuated, as hereinafter described, to cut-off flow of molten metal through the gate, whereupon pressure on the molten metal is released, the rail segments 10*a* are elevated to mating relationship with rails 10, and the assembly 2 is rolled along the rails past the stop 56 which has previously been pivoted to inoperative position. The stop 56 is then pivoted to operative position and another assembly 2 is rolled into position and poured as heretobefore described.

The manner in which the cut-off 12 is actuated can best be seen in FIGURES 8 and 10–12, wherein it will be seen that when the assembly 2 is supported on top of the tube 58, a power device 78 mounted on a cover 80 of a chamber or tank 81 containing the molten metal is disposed between the slide 22 and an abutment 82 depending from the underside of panel 40 so that actuation of the device 78, as by hydraulic or pneumatic pressure, to expand the device 78 to engage the abutment 82 and a ram or piston member 86 of the device 78 to engage the cut-off slide 22.

The device 78 has a limited stroke and at the end of said stroke, the slide 22 is at a position whereat its aperture 24 is beyond edge 20 of the support 14, whereupon molten metal in aperture 24 is dumped through slot 18 so that the bushing 26 need not be replaced for each pouring operation. Also release of pressure on the molten metal in the tank 81 dumps the metal in bushing 16 so that it need not be replaced for each pouring operation.

The device 78 is afforded a floating support so that, upon actuation thereof, the forces developed by the device 78 actuate the cut-off 12 to closed position are self-contained within the assembly 2. This novel support comprises a bracket 88 mounted on top of the cover 80 as by welding at 90. The bracket comprises a V-shaped channel 92 within which a complementary slide 94 is positioned. The cylinder member 84 is clamped into the slide 94 by clamp rollers 98 on levers 100 pivotally fulcrumed at 102 to the slide 94 and actuated by a compression clamping spring 104. The bottom of slide 94 comprises a pin 106 extending through an elongated slot 108 of the channel 92 and connected to an aligning tension spring 110 which upon release of device 78 urges a collar 109 of cylinder member 84 against a stop plate 111 attached to bracket 88, thereby yieldingly holding the cylinder member 84 in proper alignment with the space between slide 22 and abutment 82 as the assembly 2 is lowered to or raised from the position shown in FIGURE 8.

Upon energization of device 78, as heretofore described, the slide 94 permits enough axial movement of the device 78 so that the forces developed thereby are self-contained within assembly 2 and substantially no reactive forces are transmitted to bracket 88 or cover 80.

Upon removal of cylinder 84 from the clamps 98, which can be accomplished by manually lifting the cyl-

inder to compress spring **104**, the spring **104** is held in position upon bosses **112** of levers **100** by a slight force provided by a tension spring **113** connected to the lower ends of levers **100**.

It may be noted that the cover **80** may be clamped to the top of its container **81** by clamp means (not shown) mounted on foundation-supported brackets **114**, and the rail segments **10a** may be manually removed from, replaced upon, a frame **60** to accommodate insertion and removal of the cover **80** and a ladle (not shown) of molten metal into which the tube **58** extends. The construction of the container **81**, the ladle (not shown), the cover **80** and tube **58** is per se no part of the present invention and may be of any other desired construction and arrangement, with the tube mounted on the cover or elsewhere in communication with the molten metal in the container **81**.

It should be noted that bushings **16**, **26**, and **52** are flanged at their upper ends so that in their aligned position shown in FIGURE 7, the flange of bushing **16** engages slide **22**, the flange of bushing **26** engages insert **36** and the flange of bushing **52** engages the mold **4** around its gate **54**.

Referring now to FIGURES 19 to 23, which show a mold arrangement of the invention, a novel billet mold assembly **116** is disclosed for the casting of steel billets which can be rolled (without any surface conditioning and without any intermediate forming step such as forging or blooming) into commercial products such as wire or rods.

The mold assembly **116** comprise a top frame **117** defined by longitudinal side channels **118** welded to transverse angles **120** and **121**. A cope **122** formed of one or more blocks **124** of a chill material such as graphite having the previously described thermal conductivity characteristics is clamped against angles **120** and **121** by clamp bars **126** and bolt and nut assemblies **128**. The cope blocks **124** are also clamped by a clamp bar **130** and bolt and nut assemblies **132** (one of which is shown at the left of FIGURE 19) against an abutment angle **134** welded or otherwise secured to the frame channels **118**.

The mold assembly **116** also comprises a bottom frame **136** defined by longitudinal side channels **138** welded to longitudinal angles **140** and transverse angles **141** and **143**. A drag **142** formed of one or more chill material blocks **144** is seated against the angles **140** and is clamped by a clamp bar **146** and bolt and nut assemblies **148** (one of which is shown at the left of FIGURE 19) against an abutment angle **147** welded or otherwise secured to frame **136**.

The frames **117** and **136** are interconnected by readily releasable means, such as bolt and nut assemblies **149** to clamp the cope **122** and drag **142** together to define a casting cavity **151** in the shape of a conventional billet between twenty and thirty feet in length and approximately square in cross-section, measuring between two and six inches on a side.

In order to insure that the end of the casting opposite from the end adjacent the mold gate is free from shrinkage fissures, a special riser arrangement is povided.

The upper end of the mold assembly **116** is provided with a block **148***a* of a chill material which has the previously mentioned thermal conductivity coefficient value, such as graphite, having an opening **150** connected to cavity **151** and to a riser cavity **152** of another block **148***b* of the chill material clamped on top of block **148***a* as by bolt and nut assemblies **153** one of which is shown at the left of FIGURE 19.

The lower end of the cope **122** is provided with a block **152** of the chill material having a gate **155** connected to the lower end of the cavity **151** and to apertures **15**, **24**, and **50** (FIGURE 7) of the cut-off **12** on a car **2***a* substantially identical with the car **2** previously described except that the car **2***a* preferably has only one pair of wheels **8***a* because the drag **142** is pivotally supported at its opposite end by a pivot bar **154** welded to channels **138** and pivotally mounted in a V-shaped channel **156** of a car **158** having wheels **160** mounted on the rails **10**. The rail segments **10***a* and their elevating and lowering mechanism, as well as the pouring and cut-off mechanism are disclosed in FIGURES 1 to 18, and are not shown in detail in FIGURES 19 and 21.

Thus it will be understood that when the rail segments **10***a* are lowered to connect the gate **155** with the pouring tube **58**, as heretofore described, a pivoting action takes place between assembly **116** and rail segments **10***a* by means of wheels **8***a* and also pivoting action takes place between car **158** and assembly **116** by means of pivot bar **154**.

In actual practice, billets and slabs have been poured at a metal flow rate of about sixty-five pounds per second. These billets were approximately thirty feet in length and were square in cross-section, approximately 3¼ inches on a side. The cope **122** and drag **142** forming the mold in which such billets were cast were formed of graphite blocks machined on their mating surfaces as seen in FIGURE 20 to define the mold cavity **151**. It has been discovered that graphite produces a very fine dendritic structure at the surface of the casting, and according to the invention it is critical that the mold and riser, as well as the cut-off slide, be formed of a chill material which has the previously mentioned thermal conductivity coefficient value of at least 0.1 cal./sec./cm.^{2}/° C./cm. for pressure pouring of products such as blooms, billets, or slabs which are to be directly rolled.

The riser may, however, be connected to an upwardly facing opening of the mold at some point other than the extreme upper end of the mold, in which case said upper end is closed by a plate which is provided with tiny vent apertures permitting escape of air from the mold as it is filled with the molten steel. In such an arrangement, air also escapes through the riser as the mold is filled with the molten steel. The plate is also formed of such a chill material to cause rapid freezing of the molten steel as it contacts the plate.

In a mold having a cavity of about thirty feet in length or more, the longitudinal axis of the mold is preferably at an angle of the order of 24° or less with respect to horizontal.

To describe the complete process of producing a rolled metal product in accordance with the teachings of the invention, it will be understood that the casting is first formed by bottom pressure pouring, at a non-turbulent flow rate, as previously described, by the application of superatmospheric pressure on the metal in the container.

After the mold and riser cavities are filled and the flow of molten metal into the mold is cut-off by the slide mechanism previously described, the casting is then permitted to cool to the point where it has solidified sufficiently to permit its removal from the mold.

At this stage of the operation it will be understood that the entire outer surface of the casting, with the possible exception of the surface of the riser which has been exposed to the atmosphere, has been in contact with a chill surface of the mold, and/or cut-off slide, and is therefore entirely free of external shrinkage voids of fissures. Also, because of the riser arrangement, the end portion or upper end of the casting is, for a depth of several inches, free of shrinkage fissures.

At this point the riser end of the casting is cut-off to eliminate the sprue and to provide the desired length for the casting. The casting is cut through the portion which is free of shrinkage voids so that the outer end surface of the casting is, like the rest of the casting surface, free of shrinkage voids.

In the event that the temperature of the casting throughout its entirety has fallen below the weld temperature of the metal, and this is usually the case, the casting

is reheated until the temperature throughout the casting is above the weld temperature of the metal.

The casting is then ready to be rolled directly into a commercial product. During the rolling operation any internal shrinkage voids or fissures in the casting will be welded by rolling itself to insure a finished product free from internal flaws or imperfections and having a uniform granular structure.

I claim:

1. In a method of producing commercial rolled steel product directly from cast billets, blooms or slabs, the steps of: applying pressure against the upper surface of molten steel in a container to force the molten steel upwardly at a nonturbulent flow rate through a pouring tube into a bottom gate of an elongated chill mold having a thermal conductivity coefficient value at 18° C. of the order of 0.1 cal./sec./cm.^{2}/° C./cm., or greater, said mold having a riser at its upper end to seal internal shrinkage of the steel for a limited depth from the top of the mold; then, when the mold has been filled with said molten steel, closing said gate by a chill having a thermal conductivity coefficient value at 18° C. of the order of 0.1 or greater; then, after the steel in the mold has solidified into a casting, cutting off the riser at an area of the casting above said depth which is entirely solid and spaced from internal shrinkage cavities in said casting; then heating the casting to a temperature at least as great as its welding temperature; and then, without otherwise conditioning its outer surface, rolling the casting before it has cooled to a value below said welding temperature until all internal shrinkage has been eliminated by internal welding and the desired product is produced.

2. In a method of producing commercial rolled steel product directly from cast steel billets, blooms or slabs, the steps of: applying pressure against molten steel in a container to force the molten steel upwardly at a nonturbulent flow rate through a pouring tube into a bottom gate of an elongated chill mold formed of a material having a thermal conductivity coefficient value at 18° C. of the order of 0.1 cal./sec./cm.^{2}/° C./cm., or greater, and having at its upper end a riser to seal internal shrinkage of the steel for a limited depth from the top of the mold; after the mold has been filled with said molten steel, closing said gate by a chill member formed of a material having a thermal conductivity coefficient value at 18° C. of the order of 0.1 or greater; after the steel in the mold has solidified into a casting, cutting off the upper end of the casting at an area of the casting, above said depth, which is entirely solid and spaced from internal shrinkage cavities in said casting; heating the casting to a temperature at least as great as its welding temperature; and then rolling the casting, before it has cooled to a value below said welding temperature, until all internal shrinkage has been eliminated by internal welding and the desired product is produced.

3. In a method of producing commercial rolled metal product directly from cast billets, blooms or slabs, the steps of: applying pressure against molten metal in a container to force it upwardly at a nonturbulent flow rate through a pouring tube into a bottom gate of an elongated chill mold formed of a material having a thermal conductivity coefficient value at 18° C. of not less than 0.1 cal./sec./cm.^{2}/° C./cm. and having a riser at its upper end to seal internal shrinkage of the metal for a limited depth from the top of the mold; after the mold has been filled, closing said gate by a chill member formed of a material having a thermal conductivity coefficient value at 18° C. of not less than 0.1; after the steel in the mold has solidified into a casting, cutting off the upper end of the casting at an area of the casting, above said depth, which is entirely solid and free from internal shrinkage cavities; heating the casting to a temperature at least as great as its welding temperature; and then rolling the casting before it has cooled to a value below said welding temperature until all internal shrinkage has been eliminated by internal welding and the desired product is produced.

4. In a method of producing commercial rolled metal product directly from cast billets, blooms or slabs, the steps of: providing an air-tight avenue of communication between an air-tight container and an ingate at the lower end of an inclined elongated chill mold formed of a material having a thermal conductivity coefficient value at 18° C. of at least 0.1 cal./sec./cm.^{2}/° C./cm. and having at its upper end a riser for sealing internal shrinkage of the casting for a limited depth from the upper end of the mold; applying superatmospheric pressure to molten metal in the container to force it from the container into the mold; after the mold has been filled, closing the gate with a chill member formed of a composition having a thermal conductivity value at 18° C. of at least 0.1; after the metal in the mold has solidified into a casting, cutting of a portion of the upper end of the casting at an area above said depth which is entirely free from internal shrinkage cavities; heating the casting until the temperature throughout its entirety is above the weld temperature of the metal; and then, before the temperature of the casting has fallen below said weld temperature, rolling the casting until all internal shrinkage cavities have been eliminated by internal welding and the desired product is produced.

5. In a method of producing commercial rolled metal product directly from cast billets, blooms or slabs, the steps of: providing an air-tight avenue of communication between an air-tight container and an ingate at one end of an elongated chill mold formed of a material having a thermal conductivity coefficient value at 18° C. of at least 0.1 cal./sec./cm.^{2}/° C./cm. and having at its other end a riser for sealing internal shrinkage of the casting for a limited depth from the upper end of the mold; applying superatmospheric pressure to molten metal in the container to force it from the container into the mold; after the mold has been filled, closing the gate with a chill member formed of a composition having a thermal conductivity value at 18° C. of at least 0.1; after the metal in the mold has solidified into a casting, cutting of a portion of said other end of the casting at an area above said depth which is entirely free from internal shrinkage cavities; heating the casting until the temperature throughout its entirety is above the weld temperature of the metal; and then, before the temperature of the casting has fallen below said weld temperature, rolling the casting until all internal shrinkage cavities have been eliminated by internal welding and the desired product is produced.

6. In a method of producing commercial rolled steel product directly from cast billets, blooms or slabs, the steps of: applying pressure against the upper surface of molten steel in a container to force the molten steel upwardly at a nonturbulent flow rate through a pouring tube into a bottom gate of an elongated chill mold having a thermal conductivity coefficient value at 18° C. of the order of 0.1 cal./sec./cm.^{2}/° C./cm., or greater, said mold having an air vent in its upper end and means comprising a riser connected at its lower end to an upwardly facing opening of the mold to afford escape of atmosphere in the mold and to seal internal shrinkage of the steel for a limited depth from said opening of the mold; then, when the mold has been filled with said molten steel, closing said gate by a chill having a thermal conductivity coefficient value at 18° C. of the order of 0.1 or greater; then, after the steel in the mold and riser has solidified into a casting, cutting off the riser at an area of the casting above said depth which is entirely solid and spaced from internal shrinkage cavities in said casting; then heating the casting to a temperature at least as great as its welding temperature; and then, without otherwise conditioning its outer surface, rolling the casting before it has cooled to a value below said welding temperature until all internal shrinkage has been elim-

inated by internal welding and the desired product is produced.

7. In a method of producing commercial rolled steel product directly from cast billets, blooms or slabs, the steps of: applying pressure against molten steel in a container to force the molten steel upwardly at a nonturbulent flow rate through a pouring tube into a bottom gate of an elongated chill mold formed of a material having a thermal conductivity coefficient value at 18° C. of the order of 0.1 cal./sec./cm.^{2}/° C./cm., or greater, said mold having an air vent in its upper end and means comprising a riser connected at its lower end to an upwardly facing opening of the mold to afford escape of atmosphere in the mold and to seal internal shrinkage of the steel for a limited depth from said opening of the mold; after the mold has been filled with said molten steel, closing said gate by a chill member formed of a material having a thermal conductivity coefficient value at 18° C. of the order of 0.1 or greater; after the steel in the mold and riser has solidified into a casting, cutting off the steel of the riser at an area of the casting, above said depth, which is entirely solid and spaced from internal shrinkage cavities in said casting; heating the casting to a temperature at least as great as its welding temperature; and then rolling the casting, before it has cooled to a value below said welding temperature, until all internal shrinkage has been eliminated by internal welding and the desired product is produced.

8. In a method of producing commercial rolled metal product directly from cast billets, blooms or slabs, the steps of: applying pressure against molten metal in a container to force it upwardly at a nonturbulent flow rate through a pouring tube into a bottom gate of an elongated chill mold formed of a material having a thermal conductivity coefficient value at 18° C. of not less than 0.1 cal./sec./cm.^{2}/° C./cm., said mold having means to afford escape of all atmosphere in the mold comprising an air vent aperture in the upper end of the mold and also comprising a riser connected at its lower end to an upwardly facing opening of the mold to afford escape of said atmosphere from the mold and to seal internal shrinkage of the metal for a limited depth from said opening of the mold; after the mold has been filled, closing said gate by a chill member formed of a material having a thermal conductivity coefficient value at 18° C. of not less than 0.1; after the metal in the mold and riser has solidified into a casting, cutting off the metal of said riser at an area of the casting, above said depth, which is entirely solid and free from internal shrinkage cavities; heating the casting to a temperature at least as great as its welding temperature; and then rolling the casting before it has cooled to a value below said welding temperature until all internal shrinkage has been eliminated by internal welding and the desired product is produced.

9. In a method of producing commercial rolled steel product directly from cast billets, blooms or slabs, the steps of: applying superatmospheric pressure against molten steel in a container to force it upwardly at a nonturbulent flow rate through a pouring tube into a bottom gate of an elongated chill mold formed of graphite blocks having a thermal conductivity coefficient value at 18° C. of not less than 0.1 cal./sec./cm.^{2}/° C./cm., means to afford escape of all atmosphere in the mold comprising an air vent aperture in the upper end of the mold and also comprising a riser connected at its lower end to an upwardly facing opening of the mold for affording escape of said atmosphere and for sealing internal shrinkage of the steel for a limited depth from said opening of the mold; after the mold has been filled, closing said gate by a chill member formed of a material having a thermal conductivity coefficient value at 18° C. of not less than 0.1 cal./sec./cm.^{2}/° C./cm.; after the steel in the mold and riser has solidified into a casting, cutting off the steel of the riser at an area of the casting above said depth which is entirely solid and free from internal shrinkage cavities; heating the casting to a temperature at least as great as its welding temperature; and then rolling the casting before it has cooled to a value below said welding temperature until all internal shrinkage has been eliminated by internal welding and the desired product is produced.

10. In a method of producing commercial rolled metal product directly from cast billets, blooms, or slabs, the steps of: providing an air-tight avenue of communication between an air-tight container and an ingate at one end of an elongated chill mold formed of graphite and having at its other end a riser for sealing internal shrinkage of the casting for a limited depth from the upper end of the mold; applying superatmospheric pressure to molten metal in the container to force it from the container into the mold; after the mold has been filled, closing the gate with a chill member; after the metal in the mold has solidified into a casting, cutting of a portion of said other end of the casting at an area above said depth which is entirely free from internal shrinkage cavities; heating the casting until the temperature throughout its entirety is above the weld temperature of the metal; and then, before the temperature of the casting has fallen below said weld temperature, rolling the casting until all internal shrinkage cavities have been eliminated by internal welding and the desired product is produced.

11. In a method of producing commercial rolled metal product directly from cast billets, blooms or slabs, the steps of: providing an air-tight avenue of communication between an air-tight container and an ingate at the lower end of an inclined elongated chill mold formed of a material having a thermal conductivity coefficient value at 18° C. of at least 0.1 cal./sec./cm.^{2}/° C./cm., said mold having means for affording escape of all atmosphere in the mold comprising an air vent aperture in the upper end of the mold and also comprising a riser connected at its lower end to an upwardly facing opening of the mold for affording escape of said atmosphere from the mold and for sealing internal shrinkage of the casting for a limited depth from said upwardly facing opening of the mold; applying superatmospheric pressure to molten metal in the container to force it from the container into the mold; after the mold has been filled, closing the gate with a chill member formed of a composition having a thermal conductivity value at 18° C. of at least 0.1; after the metal in the mold and riser has solidified into a casting, cutting off the metal of said riser at an area above said depth which is entirely free from internal shrinkage cavities; heating the casting until the temperature throughout its entirety is above the weld temperature of the metal; and then, before the temperature of the casting has fallen below said weld temperature, rolling the casting until all internal shrinkage cavities have been eliminated by internal welding and the desired product is produced.

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