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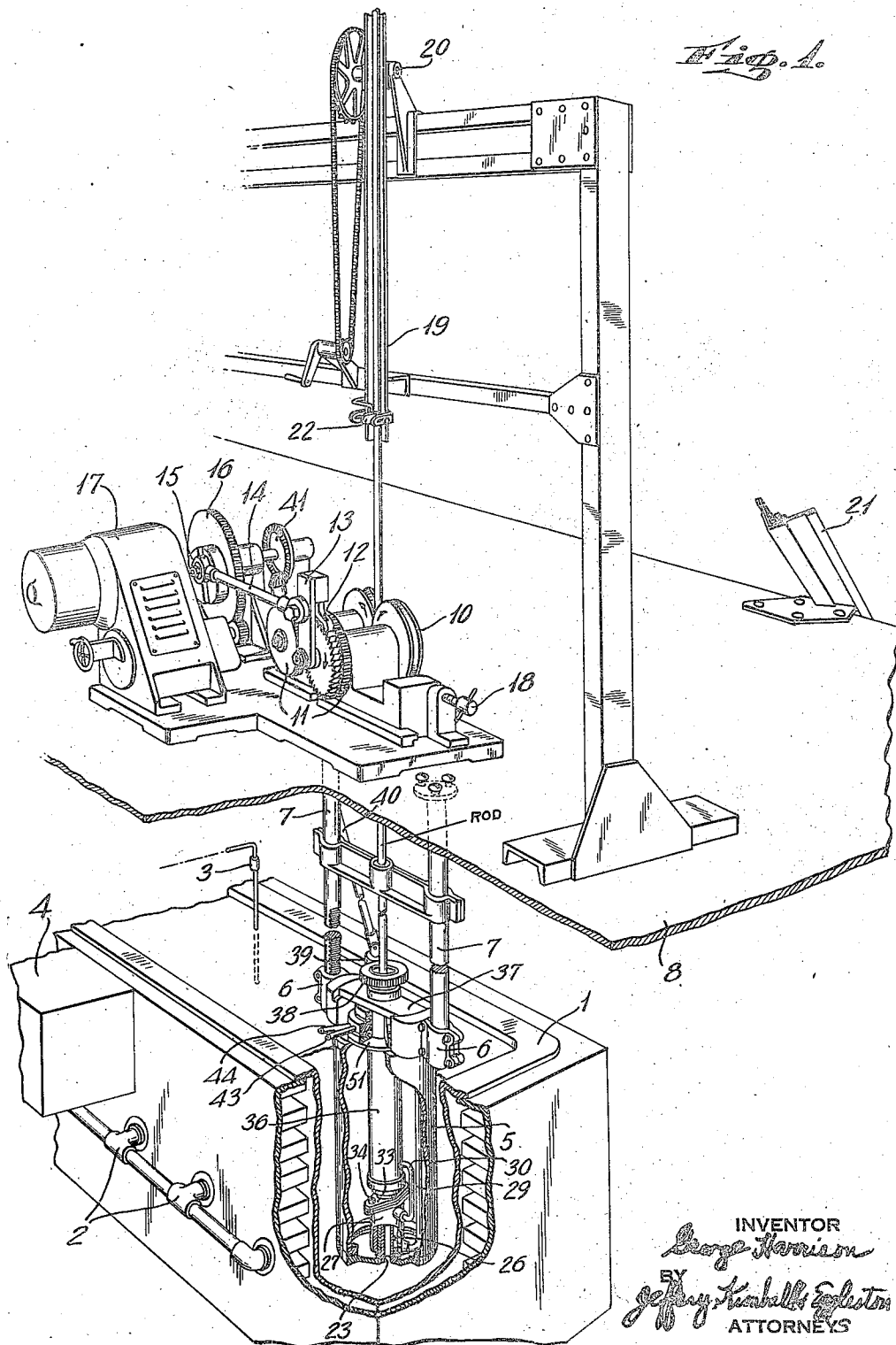
G. HARRISON

2,405,355

ROD-CASTING MACHINE AND METHOD

Filed June 18, 1941

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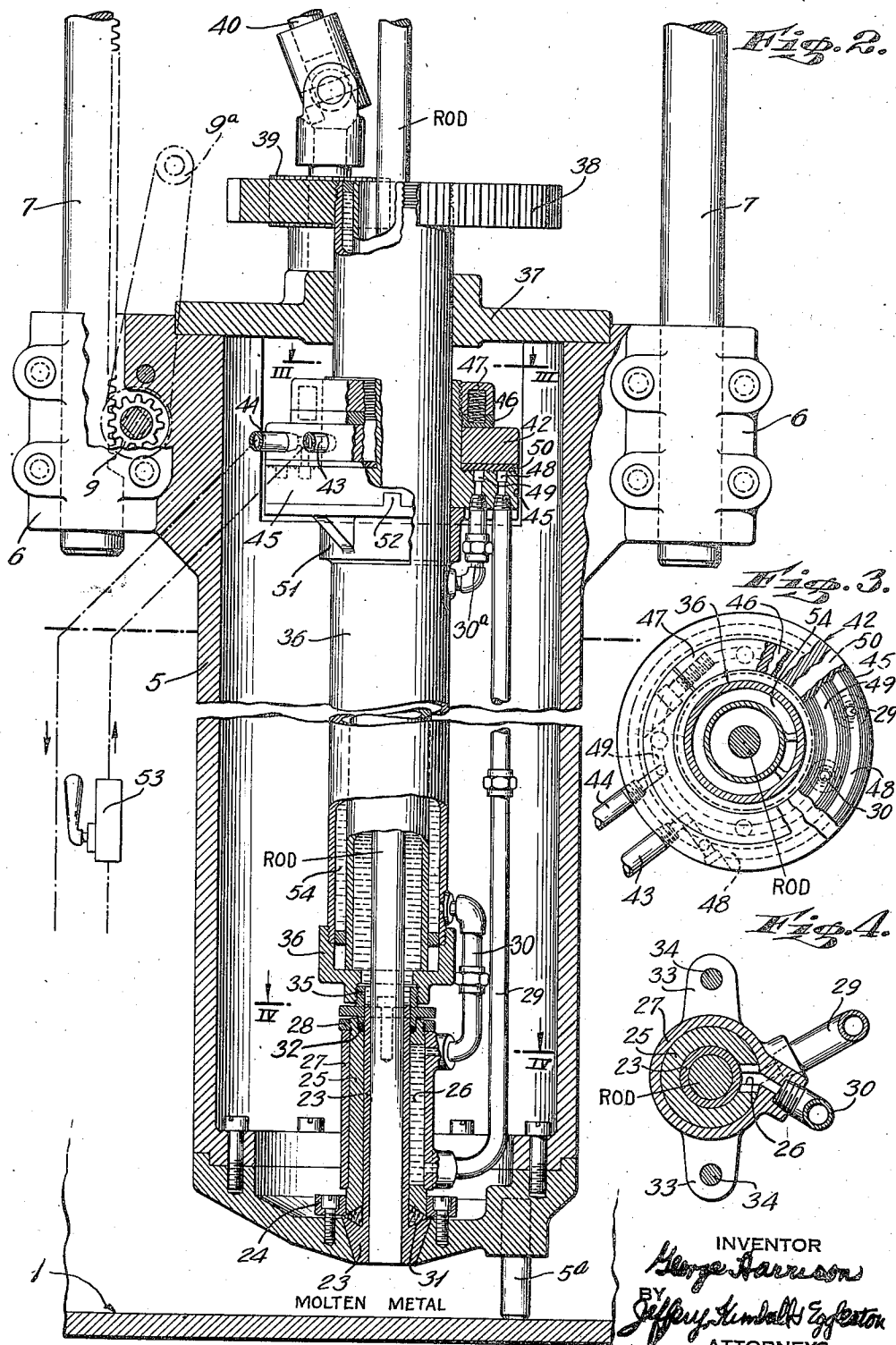
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Fig. 6.

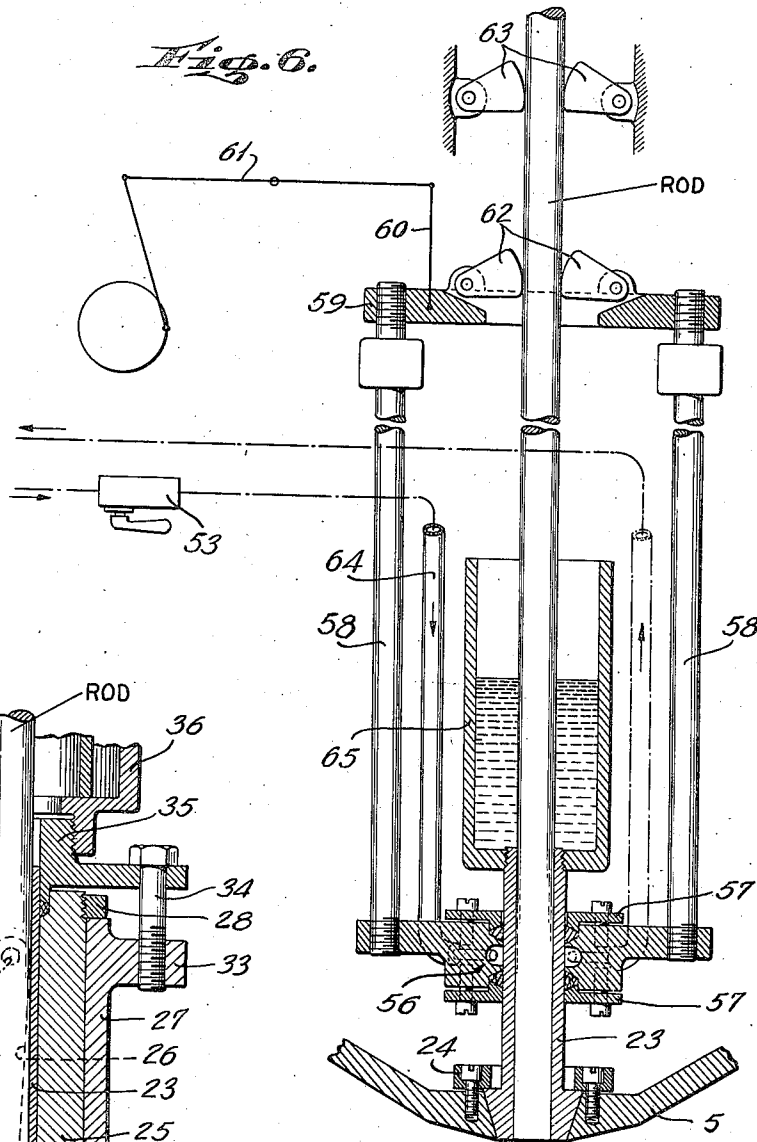
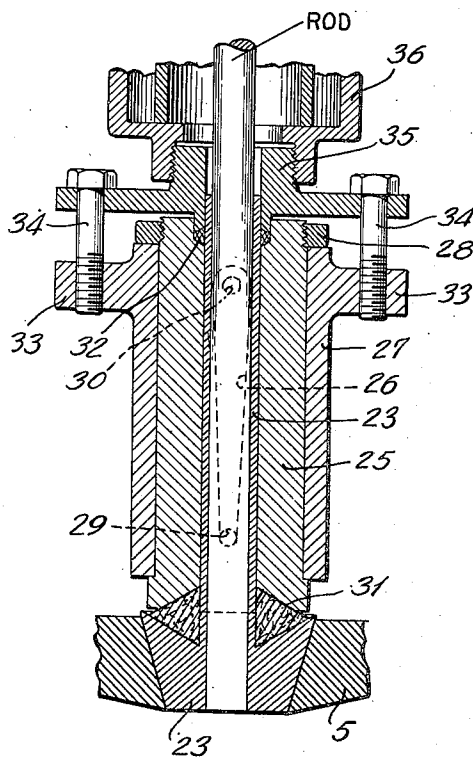


Fig. 5.



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ROD-CASTING MACHINE AND METHOD

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42 Claims. (Cl. 22—57.2)

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This invention is a machine and method for continuously casting metal rod, including within this term tubular and other sectional shapes, the general object being the manufacture of rod of continuously homogeneous texture and uniform strength at cost lower than currently possible by other methods. It is herein described as employed for casting zinc-base alloys but the principles involved are applicable to all metals or substances of which the conditions at the casting temperature are not harmful to the casting mechanism, as will presently appear.

In the accompanying drawings,

Fig. 1 is a broken-out somewhat condensed perspective view of one head of a multiple rod-casting machine incorporating the invention in a form at present preferred;

Fig. 2 is an enlarged axial section with parts in elevation of the casting die and related mechanism;

Fig. 3 is a section of Fig. 2 on lines III—III partly broken out;

Fig. 4 is a section on line IV—IV;

Fig. 5 is an axial section of the die tube and related parts sidewise of Fig. 2; and

Fig. 6 is a modified form.

The metal stock to be formed into rod is held as a molten bath in a receptacle or kettle 1 heated by flues and burners indicated at 2 and equipped with a heat-regulating system adapted to hold the bath at a constant temperature. The regulation system can be organized according to known principles and is represented in Fig. 1 simply by the thermostat 3, dipping into the bath. This will be understood to be appropriately connected in governing relation to the fuel system, and to be of such type as to hold the temperature steady with little variation, preferably not more than 5 degrees plus or minus, a constant temperature being important. The bath is desirably maintained at not more than a few degrees, say 10°, above the melting point of the metal, the amount above the melting point being referred to as the superheat.

Fresh metal is added to the bath as it is used up, and at a rate equal to its consumption, so that the bath level is also held substantially constant, as suggested by the dash line in Fig. 2. Metal feeders suitable for holding constant levels are known and such a feeder will be understood to be represented by the part marked 4 in Fig. 1, and to be automatic in its action.

The parts specifically concerned with the conversion of the molten metal into rod are enclosed in a pot or well 5 so supported that it dips more

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or less into the metal in the kettle to receive the molten material from a point removed from the side walls as well as from the bottom of the kettle, where the temperature is least subject to fluctuation. For this purpose the pot is supported by its guide ears 6 on two vertical frame bars 7 which are rigidly secured to and depend from an upper deck 8 fixed in position over the kettle at a suitable distance above it. One of these bars can be formed with rack teeth, as indicated, for engagement with a pinion 9 (Fig. 2) housed in one of the ears, so that by the use of a crank 9^a applied to the pinion the pot and all its parts can be raised or lowered. The bars are of sufficient height to permit the pot to be raised entirely clear of the kettle when that is desired. For normal use, the pot is lowered until its foot 5^a touches or rests on the kettle bottom but it can be held at any depth of immersion according to conditions, and by any equivalent mechanical structure.

The deck 8 supports the mechanism for removing or delivering the rod as produced by the casting agency in the pot. This mechanism comprises a pair of grooved gripping rolls 10 embracing the rod and geared to each other by mating spur gears 11, one of which is supplemented with ratchet teeth and driven by a pawl 12. The pawl is carried on a swinging arm 13 rocked back and forth by a link 14 connecting with the crank pin 15 of a power wheel 16, the latter being driven by a variable speed motor 17. This method of drive gives an intermittent rotation to the gripping rolls in the direction to lift the rod, and the extent of the lift is controlled by the throw of the crank pin 15 which is adjustable in its slot in the power wheel 16 for that purpose. By virtue of the manner in which the casting is done, as presently explained, the gripping rolls are required to exert only a moderate pressure on the rod, not enough to deform it, and such pressure can be established and adjusted by the set-up screw 18.

The rolls feed the rod upwardly into a trough or holder 19 which is hinged to swing on a horizontal axis 20 on the superstructure of the deck 8. When a sufficient length has been thus delivered, it is cut off just below the holder 19, by a saw not shown, and the holder is then cranked over on its hinge 20 until its top end (not included in the drawings) comes into approximate registry with the receiver 21 and the rod slides by gravity into the latter. A retaining clutch 22 is fixed on the holder 19 to support the rod against reverse movement after it has been cut off.

The casting operation takes place, as stated,

within the enclosure of the pot. Specifically the act occurs in a die 23 which, as shown in Figs. 2 and 5, is a tube with a conical head by which it is clamped in a conical hole in the pot bottom by means of a clamp ring 24. It is made of very hard material, of a kind not attacked or dissolved by the metal of the bath at the casting temperature and is smooth and polished on its inner surface, which surface can also be hardened by nitriding or the like. A satisfactory material, for use with zinc-aluminum alloys, is one of the so-called hard steel alloys of the air-hardening class which is capable of resisting thermal shock and retains its hardness at red heat or high temperatures. The dimensions of the tube are determined to a considerable extent by the size of the rod and the rate of production, higher rates requiring longer tubes. For one-half inch round rod, and smaller, it is practicable for the tube to be about 6 inches long with a wall thickness of about .060 inch. It can be lined with graphite or ceramic when that is necessary to resist attack by the particular molten metal.

Being located in the submerged bottom part of the pot, molten metal flows into the tube and longitudinally or upwardly therein by virtue of its hydrostatic head, which, under the circumstances, is constant, and at a rate equal to the rate at which the rod is withdrawn from the upper end of the tube by the gripping rolls and which must of course conform to or balance with the rate at which heat is removed from the die, so that metal passes through the die as fast as and no faster than it solidifies or freezes therein. For casting zinc-base alloy (such as Zn 96%, Al 4%, with some Mg), a lift of about 2.3 inch, at the rate of about 67 lifts or strokes per minute, has yielded excellent results for long runs ($\frac{3}{8}$ inch round rod), but both lift and interval are subject to variation according to conditions, so long as the progress through the die conforms to the rate at which the heat is removed.

Escape of heat from the die occurs partly in the lateral sense, that is, through the die tube wall to the surrounding medium within the pot, which includes a water jacket on the tube as presently described, and partly in the longitudinal sense through the conducting path provided by the rod itself which extends to a cooled or cooler region above. The quantity of heat to be thus removed is the latent heat of the metal plus its superheat, being therefore different for different metals and different sizes of rod. By virtue of the location of the cooling agencies within the pot their operation is out of the influence of atmospheric conditions, the space inside the pot being otherwise automatically maintained at constant temperature by reason of its immersion in the constant temperature bath. Thus regulation of the cooling effect is exceptionally positive and the balance referred to having been once established is easily maintained for long periods.

The water jacket is constructed in the present case as a two-part unit comprising the parts 25 and 27, although it could be made in one part. The cylindrical sleeve 25 is fitted to rotate on the die tube and is provided with a vertical, narrow water slot 26 (Figs. 2, 4 and 5) cut through its wall for nearly its full length, about $3\frac{1}{4}$ inches for a 6-inch tube. This sleeve is enveloped by an outer sleeve 27 tightly fitted over it, covering the slot and clamped in place between a shoulder at the lower end of the die and a nut 28 at its upper end, thus forming an assembly, the parts of

which rotate as a unit. Water is passed through the jacket slot in direct contact with the wall of the die tube. It is supplied from a slip-coupling presently described, by a pipe 29 to the bottom of the slot and passes out at the top by pipe 30 leading to an upper jacket and thence by pipe 30^a back to the coupling. These water fittings revolve with the water jacket. The water is supplied under pressure sufficient to avoid or at least minimize vaporization in the slot from its contact with the hot tube wall, 10 to 20 pounds per square inch being generally sufficient for zinc alloy work.

Water leakage from the jacket is prevented by a lower packing 31 between the foot of the jacket and the die head, and by another packing 32 at the upper end of the jacket. The jacket sleeve fits the die tube with a clearance when cold of not less than about .006", which is sufficient to avoid seizing as well as any undue escape of the water. In this connection it is noted that deposit of salts out of the water tends to make the junction self-sealing, even under the pressure condition. The cooling is thus accomplished by forced circulation under non-vaporizing conditions.

This water-jacket, which may be called a partial water jacket, since the water does not embrace the whole of the tube, is made progressively effective around the tube by being rotated thereon. The rotation is imparted to it by means of its ears 33 at its upper end connected by means of two bolts 34 with a flanged fitting 35 tightly screwed or welded into the lower end of a rotary driving tube 36, the upper end of which is journaled in the cross-head or cover 37 of the pot and provided with a gear 38. The central part of the flanged fitting 35 serves as the compressor element of the packing 32, tightened by drawing up the bolts 34. The other packing 31 is sufficiently compressed by the weight of the water jacket and driving tube and other rotating parts for which parts this packing serves also as a step bearing in the present case.

The gear 38 on the drive tube 36 is driven by a pinion 39 (Figs. 1 and 2) journaled on the cover 37, and itself driven by a universally jointed shaft 40 from a bevel wheel 41 (Fig. 1) fast on the power shaft that carries the crank gear 16 above referred to. This pinion shaft can be disconnected at one of its joints when the pot is raised from the kettle or it can be constituted of a flexible shaft or a telescopic shaft, in which case disconnection will not be necessary. One revolution of the power shaft in the present case produces one revolution of the gear 38, and through the connections just described, one revolution of the water jacket on the die tube. It also swings the pawl 12 through one complete excursion so that during some part of the jacket revolution the rod is lifting by the gripping rolls.

The slip-coupling above referred to, by means of which the rotary water jacket is connected with the external stationary part of the water system, can be variously designed according to known principles. In the present case, it comprises a ring 42 (Figs. 2 and 3) held stationary around the rotating drive tube and furnished with water connections 43 and 44 to the outside system. These may be rigid enough to hold the ring against rotation or they may be flexible and other means may be provided to prevent the rotation. This ring is confined between a mating ring 45 revolving with the drive sleeve and the washer 46 of a ring nut 47 screwed to the top of

the tubular boss of ring 45 and therefore revolving with it. The washer is spring-pressed by springs housed within the nut, to keep the rings pressed together. The rotating ring 45 is formed with two concentric channels 48 and 49 in constant connection respectively with the ports of the inlet and outlet connections 43 and 44 in the fixed ring, and the pipes 29 and 30 are respectively connected to those channels. A rubber gasket 50 sandwiched between the mating rings prevents leakage, and a gasket of this material in the presence of water also reduces friction. Additionally to the channels the rotating ring is scored or grooved, as indicated, to retain water on its rubbing face, against the rubber. The water ring 45 is supported by a flanged collar 51 shrunk on the driving tube to which it is keyed by a rib and slot as indicated at 52.

The top part of the pot is open as indicated, to accommodate the water pipes 43 and 44, and the water supply is by way of a valve 53 in the inlet line which can be adjusted and is adapted to provide close regulation of the water rate through the jacket slot 26. Within the term "water" as herein used, is included any other appropriate liquid coolant, though normal tap water is satisfactory.

The tube 36, besides constituting the drive for the partial water jacket on the die tube, also constitutes a heat exchanger for removing heat from die tube, longitudinally through the freshly formed rod, and for cooling the rod itself. It contains a body of oil or other appropriate liquid in contact with a considerable length of the rod and surrounded by a jacket space 54 included in the water system as already indicated. The cooled oil cools the rod and also protects it from oxidation while it is hot. Also it lubricates the die as presently explained.

In the operation of the apparatus above described the effect of the forced circulation through the narrow slot 26 of the water-jacket is to produce a local chilling of the tube over the limited area with which the water has contact. The travel of this chilling zone around the tube produces two effects. First, it exercises a preliminary but transient chilling effect on the liquid metal as it enters the lower part of the tube, serving to freeze a layer of such metal lying next to the inner tube surface in advance of the metal nearer the tube axis, thus forming an initial shell or skin around such still liquid metal. Second and at the same time, and due to the unbalanced temperatures affecting opposite sides of the die tube wall, such wall is slightly distorted from its natural circular or other sectional shape. This distortion progresses as a wave around the wall of the tube, as the jacket rotates. It may be assumed to make a round tube section slightly elliptical but in any event it gives the tube a less internal diameter in one direction than in others and this shortened diameter progresses around the tube consonantly with the rotation of the chilling zone which causes it. The die tube wall is thin enough to permit this distortion without injury.

Freezing involves crystallization and is a progressive action, particularly in alloys, whereof the solid solutions of the alloy components crystallize first and the eutectics later. Thus with the provisions for heat removal properly determined, the zone of transition, from liquid to solid, can be considered in any case as having some longitudinal extent, the metal therein being generally plastic. It is softer in its lower part

than in its upper part and at some point it is fictile, by which is meant that while plastic it is stiff enough to be self-sustaining in the shape given to it.

The effect of the rotating distortion wave therefore is to mold or model the metal, where it is fictile, to a somewhat smaller diameter conforming to the least diameter of the distorted tube, thus giving the shaped metal a cross-area slightly less than that of the tube bore. Such cross-area is retained in the rod, it being noted here that the hydrostatic pressure, incidental to pot immersion, is so selected as not to disturb this condition once given, and the envelope of first-frozen skin does not obstruct or affect it but appears to assist in retaining it against such pressure. The net effect is to produce the rod in a slightly smaller section than the die, and this avoids the excessive pressure and friction that otherwise would occur between the solid rod and the interior surface of the exit part of the die tube, above the transition zone.

Friction occurring at this point, that is, between the transition zone and the die exit, has been the trouble spot in prior rod-casting machines, causing rod breakage and irregular action, but by creating a distortion wave in the wall of the die in the manner described, or in other ways that may be found feasible, this friction can be largely eliminated, even in the case of an adverse relation of thermal coefficients of the rod and die metal. An immediate advantage is that lubrication becomes possible and effective because the fine crevice between rod and die permits and, by the capillary effect, invites penetration of the oil downwardly into the die under the pressure head of the oil receptacle 36. Such effects obviously occur regardless of the cross-sectional shape of the rod, and thus in all cases the gripping rolls have easier work and the rod surface is substantially free of machine marks caused by them or by scoring by the die. Additionally to this advantage, the filling of the crevice with the oil perfects the heat transfer path from rod to tube, because any liquid film is a much better conductor than a layer of air or gas.

For lubrication, any lubricant can be used but the invention prefers one that has a high boiling point and is completely volatile, such as paraffin, since such a lubricant leaves no carbonized residue on either the tube wall or the rod, to be later cleaned off.

The width of the water slot in the rotating water jacket is desirably narrow with relation to the die, say not over one-half its inner diameter, in order to make a pronounced unbalance of temperature on its opposite sides thus to create the distortion wave. For $\frac{1}{2}$ " round rod a $\frac{3}{8}$ " slot is sufficient and for the same reason, the water is forced through it at a low temperature and high rate, consistently with the rate of metal advance. Usual tap temperature will suffice. The length of the slot is sufficient if it covers the length of the transition zone, allowing for some variation of the position of the latter, but any extension of the slot above the actual zone produces no excessive die friction since the rod is already of less than bore cross-area, and the oil is present in any event to reduce such friction as develops. The chilling zone may pass once or several times over a given point in the column of metal rising through the die, so long as the total cooling effect is adequate to maintain the balance.

It is pointed out that the preliminary skin-

forming effect of a moving partial water jacket differs from that of ordinary rod-casting die tubes, completely water-surrounded, by the fact that it occurs from a transient and non-continuing chilling action and the freezing caused thereby does not therefore progress immediately inward, and the heat of the interior metal inside the skin is thus allowed to escape, to a large extent, upwardly to the cool oil bath through the good conducting path formed by the metal that has already frozen, so that freezing of the bulk of the metal progresses downwardly or axially of the column, avoiding the core formation incident to excessive lateral cooling and yielding a desirable uniformity of crystal structure. This downward progress of the freezing is effectively promoted by making the water slot 26 wider at its top end, where its chilling effect removes heat from the solid rod rather than from liquid metal. The partial jacket thus exerts a graduated cooling effect on the die which is greater at the solid end of the transition zone than at the liquid end.

A different application of the casting principles above described is illustrated largely in diagram by Fig. 6. The die tube here shown may be taken as the same as that above described but the chilling agency in this case is a partial water-jacket 56 which is small axially instead of peripherally. The water therein, confined against leakage by top and bottom packing glands 57, entirely surrounds and is in direct contact with the tube, but is applied only to a narrow band circling the tube. This results in a horizontal or transverse chilling zone, which in this case is reciprocated on the tube and thereby creates a distortion wave in the form of a circular constriction of the tube moving up and down upon it. On each reciprocation this constriction traverses the whole transition zone, shaping or modeling the mass therein where it is fictile to the cross-area of the constriction, which is less than that of the tube undistorted, so that the effect is generally the same as above described, producing a rod of slightly less cross-area than that of the die which makes it and therefore free of excessive die friction.

Such a water-jacket can be reciprocated in any suitable way, for example, by a yoke structure represented by the rods 58 and cross-head 59 connected by a link 60 to a crank-operated lever 61, understood to be adjustable as before, for stroke variation. The clutch pawls 62, carried on or associated with the reciprocating yoke, grip the rod on their upstroke so that both rod and water-jacket move upwardly together. On the down stroke, the rod is retained by the fixed clutch pawls 63 so that the molten metal freshly arrived in the die tube is momentarily stationary therein as the water-jacket moves downwardly around it. The stroke is greater than the width of the water slot so that in such descent the cooling produces the same preliminary skin by its momentary or transient action, as before. Otherwise the construction of this form is like that already described, water being supplied under pressure to the partial jacket through jointed, telescopic or flexible pipe connections indicated at 64 and the rate of supply being under the control of an appropriate regulator valve 53 as before.

In this form also, the fresh-cast and still hot rod is protected from oxidation, cooled and also lubricated in the die by oil in the cup 65 attached to the top of the die tube, which can also be

water-cooled as in the other form. In this form as in the other the machine is set in action by the use of a starting rod as customary in this art.

In both cases it will be apparent that for rods of different cross areas, or metals of different melting points, appropriate mutual adjustment of the several variable factors is required in order to maintain a constant rate of production with the necessary constant balance between input and outgo of heat. In a given machine, larger rods will in general require a slower progress through the tube, or a tube of greater length, except of course to the extent that cooling action may be augmented to accommodate the greater heat input. The nature of such adjustments will be apparent to those understanding the principles involved which have been above described and which can obviously be applied singly or otherwise and in machines widely varying in function and design, and it will be understood that in its broader aspects this patent is intended to be without limitation to any particular machine construction or to the manner of removing the rod from the die whether intermittently or continuously, or the means for causing such movement or to the casting of any particular kind of metal and further that certain of the features herein disclosed may be used beneficially independently of the others all within the scope of the claims which follow.

I claim:

1. In the method of continuously casting rod by passing initially molten metal through a die tube, the step of creating a distortion wave in the wall of the die tube effective at the transition zone to reduce die friction beyond such zone.

2. The method of continuously casting rod comprising passing initially molten metal through a thin-walled die tube while subjecting the tube to an intermittent chilling effect at a frequency adapted to facilitate the exit of the cast rod therefrom.

3. The method of continuously casting rod by passing initially molten metal into a die tube and withdrawing rod therefrom, which includes the step of introducing lubricant into the exit of the die tube counter to the rod movement there-through.

4. The method of continuously casting rod which includes passing initially molten metal upwardly through a die tube and into a bath of liquid communicating with the tube exit.

5. The method of continuously casting rod which comprises passing initially molten metal through a die tube, modelling the fictile metal in the transition zone so as to produce a crevice between the die and rod beyond such zone and applying lubricant to the emerging rod so that it enters said crevice.

6. The method of continuously casting rod which consists in intermittently advancing initially molten metal through a die tube while creating a distortion wave in the wall of the die tube effective at the transition zone to reduce die friction at the die exit.

7. The method of continuously casting rod which consists in advancing initially molten metal through a die tube while creating a chilling zone in the wall of the tube at the transition zone, and moving said chilling zone with relation to said tube.

8. The method of continuously casting rod comprising advancing initially molten metal step by step through a die tube and moving a chilling

zone over the tube at the transition zone in the intervals between steps.

9. The method of continuously casting rod comprising advancing initially molten metal through a die tube while continuously rotating a chilling zone around the tube wall.

10. In the process of continuously casting rod by introducing initially molten material into one end of a die tube while removing rod from the other end, the improvement which consists in applying a chilling agency to said tube so as to cool one side of it more than another side, thereby distorting the cross-section of such tube, and rotating such agency about the tube during the progress of the material through said tube.

11. In the process of continuously casting rod by introducing initially molten material into one end of a die tube while removing rod from the other end, the improvement which consists in applying a chilling agency to said tube so as to cool one portion of its length more than another portion of its length thereby shrinking the cross-section of the tube relatively to such other portion and reciprocating such chilling agency with respect to the tube during the progress of the material therethrough.

12. In a continuous rod-casting machine the combination with the die tube and means for passing initially molten metal therethrough, of a receptacle connected to the exit of said die tube and holding a body of high-boiling, completely volatile and non-carbonizing lubricant in surrounding contact with the emerging rod and adapting such lubricant to enter a crevice between the wall of the die tube and the rod therein.

13. The method of continuously casting rod comprising supplying molten metal to one end of a die tube, to be withdrawn as rod from the other end, while subjecting the tube to a recurring chilling effect applied while the metal is advancing through the tube and prior to the freezing of its interior metal.

14. The method of continuously casting rod which comprises passing initially molten metal through a die tube and subjecting the tube to a periodically recurring chilling effect applied at the transition zone while the metal is fictile.

15. The method of continuously casting rod which includes passing initially molten metal through a die tube and directly into a bath of liquid communicating with the tube exit, while subjecting the tube to a recurrent chilling effect at the transition zone while the rod is passing through it.

16. The method of continuously casting rod which comprises passing initially molten metal through a die tube while subjecting the tube to a periodically recurring chilling effect, applied at the transition zone, said chilling effect being more pronounced at the solid end of said zone than the liquid end and occurring at intervals adapted to facilitate the movement of the rod.

17. The method of continuously casting rod which consists in passing initially molten metal through a die tube under a constant pressure at the entrance of such tube and while subjecting such tube to a periodically recurring chilling effect adapted to facilitate removal of the rod and coincidently pulling the rod from the exit of said tube.

18. A method of continuously casting rod by supplying molten metal to one end of a die tube and withdrawing rod from the other, which consists in introducing the molten metal into the tube under a non-varying hydrostatic head, and

subjecting such metal to a surface chilling as it enters the transition zone in said tube while periodically flexing the tube wall at said transition zone to reduce the diameter of the tube and hence of the fictile metal therein and thereby facilitate the withdrawal.

19. Continuous rod-casting apparatus including a pot immersed in the bath of molten material to be cast to provide an interior space free of such material and having its casting die mounted with its transition zone within the pot below the bath level.

20. Continuous rod-casting apparatus having its casting die mounted in upright position with its lower end in and opening through the bottom wall of a pot that is immersed in a bath of the molten material to be cast, cooling means within the pot and means for lifting the rod from the die.

21. Continuous rod-casting apparatus comprising a casting die mounted upright and with its lower end constantly open and located in a fixed position communicating with a molten bath at a fixed distance below the level of such bath and adapted to receive molten material solely by the hydrostatic pressure of the bath, means for maintaining the bath at a substantially constant temperature and at a substantially constant level, and means for lifting the rod through and from the upper end of the die.

22. Continuous rod-casting apparatus comprising a thin walled tube constituting a casting die receiving molten material at one end and delivering cast rod at the other, combined with means for creating a recurring distortion wave in the wall of the die effective to reduce the diameter of the die at the location of the transition zone therein.

23. Continuous rod-casting apparatus comprising a die tube receiving molten material at one end under a pressure sufficient only to keep it filled with such material, means for removing cast rod from its other end, and means for creating a distortion wave traversing the die tube wall and coinciding with the location of the transition zone therein.

24. Continuous rod-casting apparatus comprising a die tube, means for establishing a chilling zone in the wall thereof of an extent less than the tube surface, and means for causing such zone to traverse the part of the tube enclosing the transition zone.

25. Continuous rod-casting apparatus comprising a die tube, a partial water jacket for the transition zone thereof and means for moving such jacket over the part of the tube surrounding the transition zone.

26. In the combination of claim 25, the jacket-moving means being adapted for rotating the jacket around the die tube.

27. In the combination of claim 25, the jacket-moving means being adapted for reciprocating the jacket axially of the die tube.

28. Continuous rod-casting apparatus comprising a die tube having its entrance at its lower end and communicating with a bath of molten metal under a pressure sufficient only to keep it filled with such material, means acting on the tube to reduce the cross-area of the fictile material therein relatively to the area of the tube bore and means for upwardly removing the cast rod.

29. The combination of the preceding claim wherein the removing means imparts a step by step movement to the cast rod.

30. Continuous rod-casting apparatus comprising a die tube, external means acting on the tube for causing reduction of the cross-area of the

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solidified material moving through it, relatively to the cross-area of the tube, and means for introducing a lubricant into the crevice between the rod and the exit part of the die tube.

31. The combination of the preceding claim in which the die tube delivers upwardly and the lubricant-introducing means is a receptacle connected with the exit of the die tube, delivering thereto by the pressure of gravity.

32. Continuous rod-casting apparatus comprising a die tube, having its entrance end communicating with a molten bath of the material to be cast and its exit end communicating with a receptacle holding a liquid in contact with the hot emerging rod and a heat exchanger applied to said receptacle.

33. Continuous rod-casting apparatus comprising a stationary die tube, a water jacket movable thereon to cool it, and means for moving said jacket comprising a heat-exchanger for cooling the rod emerging from the die tube.

34. Continuous rod-casting apparatus comprising a pot immersed in a molten bath, a die tube in the wall of said pot below the liquid level receiving molten material from the bath for delivery as rod within the pot, and a water jacket for the tube within the protection of the pot.

35. Continuous rod-casting apparatus comprising a die tube, means for intermittently advancing initially molten material through it, and means acting on the tube in the intervals between advances to reduce the cross-area of the fictile material therein relatively to that of the die exit.

36. Continuous rod-casting apparatus comprising a die tube, a slot-shaped water-jacket rotatable thereon, means for advancing initially molten material through the tube and means for rotating the jacket at least one revolution while said material is traversing the water-cooled length of said tube.

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37. Continuous rod-casting apparatus comprising a die tube, means for causing initially molten material to move intermittently through it, a partial water-jacket on said tube, and means for reciprocating the jacket on the tube in step with the intermittent movements.

38. Continuous rod-casting apparatus comprising a die tube, a partial water-jacket thereon and means for moving said jacket on the tube and said material in the tube in the same direction in unison intermittently.

39. Continuous rod-casting apparatus comprising a die tube receiving molten material and delivering rod upwardly, a pair of gripping members acting to lift the rod, a water-jacket movably mounted on the die, a single driving member conjointly operating said members and jacket, and means for changing the lifting movement imparted to said gripping members relatively to the movement imparted to the jacket.

40. Continuous rod-casting apparatus including a pot vertically movable into and out of the bath of molten metal and having its casting die mounted in the wall of the pot to receive metal from below the bath level, the interior of the pot constituting a space otherwise devoid of molten metal.

41. Continuous rod-casting apparatus comprising a pot vertically and adjustably movable to a selected degree of immersion in a metal bath and containing within it a die tube to receive metal from the bath and means above the bath for lifting rod from the tube in the pot.

42. A die-tube for continuous rod casting having a tube wall capable of thermal distortion and a rotary water jacket acting on the full length but not the full circumference of the transition zone in said tube, said jacket having a greater cooling action adjacent the solid end of the zone therein than at the liquid end thereof.

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