March 15, 1927. 1,620,830

W. D. MOORE ET AL

METHOD OF AND APPARATUS FOR CENTRIFUGALLY CASTING METAL BODIES

Filed Dec. 20, 1923 5 Sheets-Sheet 1

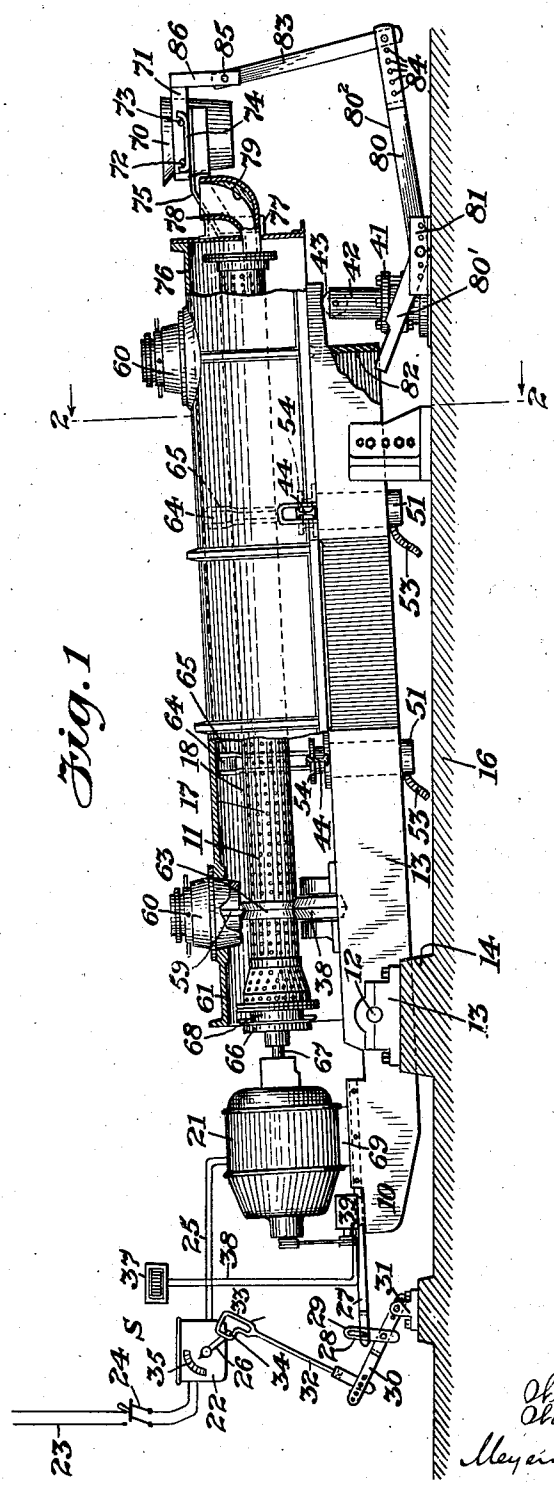


Fig. 1

INVENTOR
William D. Moore
Walter Morgan
BY
Meyer & Cavanagh
ATTORNEYS

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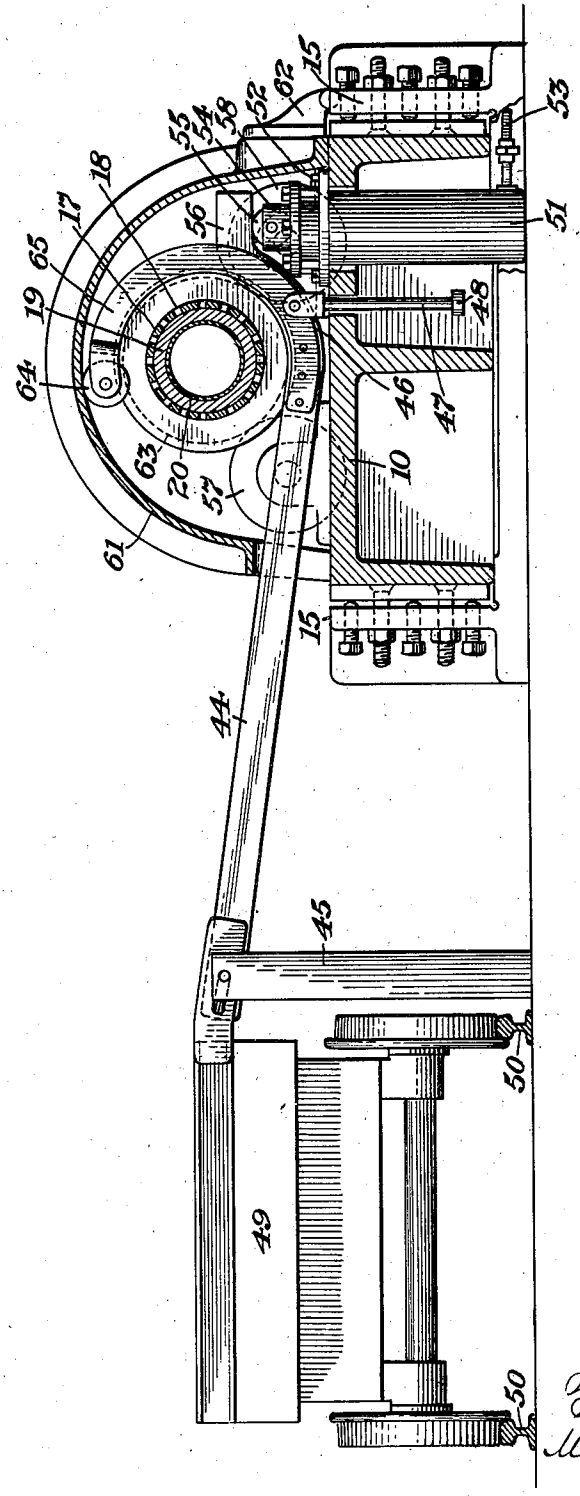


Fig. 2.

INVENTOR
William D. Moore
Walter Morgan
BY
Meyers & Cavanagh
ATTORNEYS

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Fig. 3

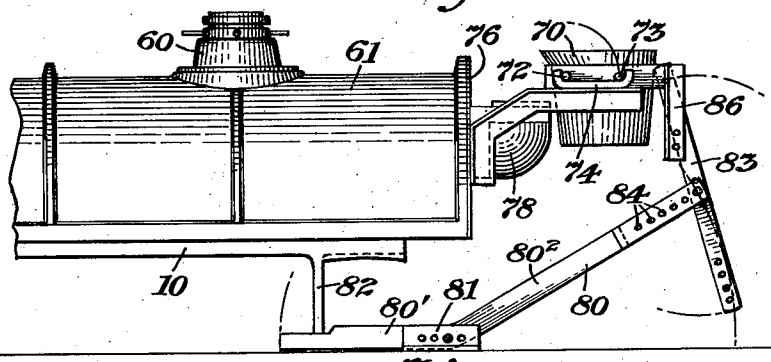


Fig. 4

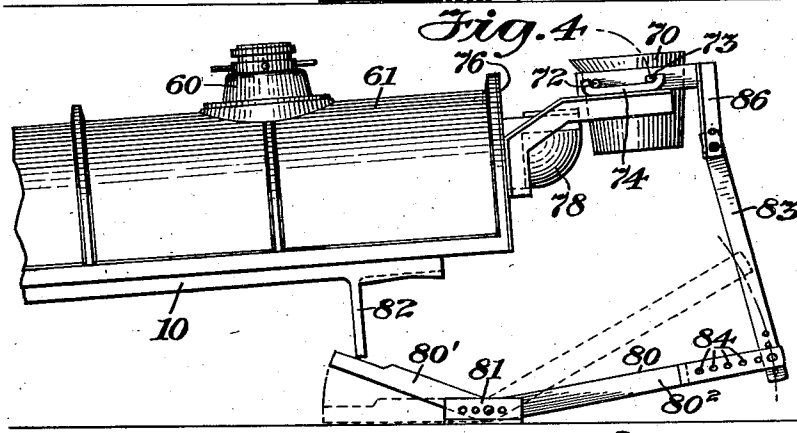
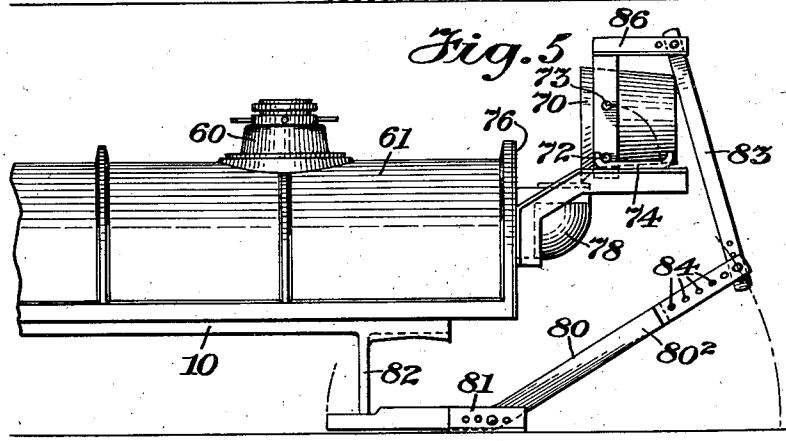


Fig. 5



INVENTOR
William D. Moore
Walter Morgan
BY
Meyers & Cavanagh
ATTORNEYS

March 15, 1927. W. D. MOORE ET AL 1,620,830

METHOD OF AND APPARATUS FOR CENTRIFUGALLY CASTING METAL BODIES

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Fig. 6

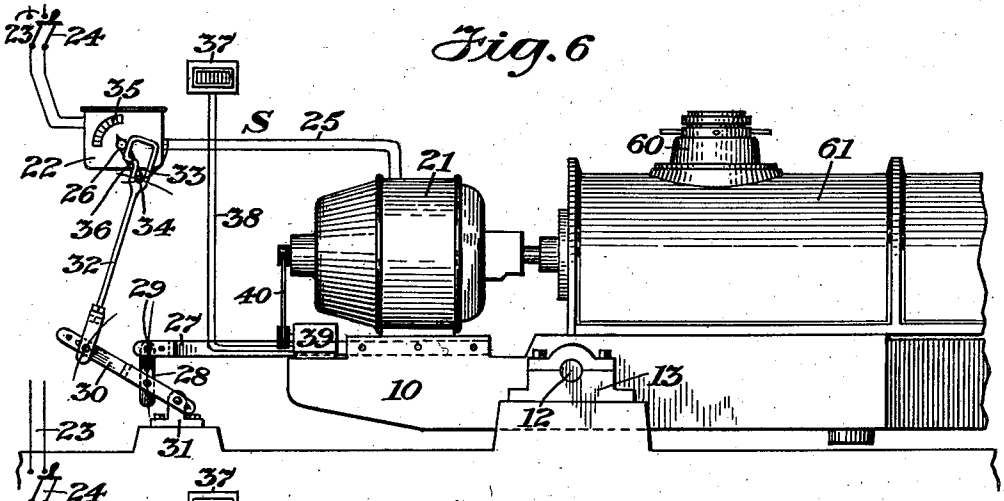


Fig. 7

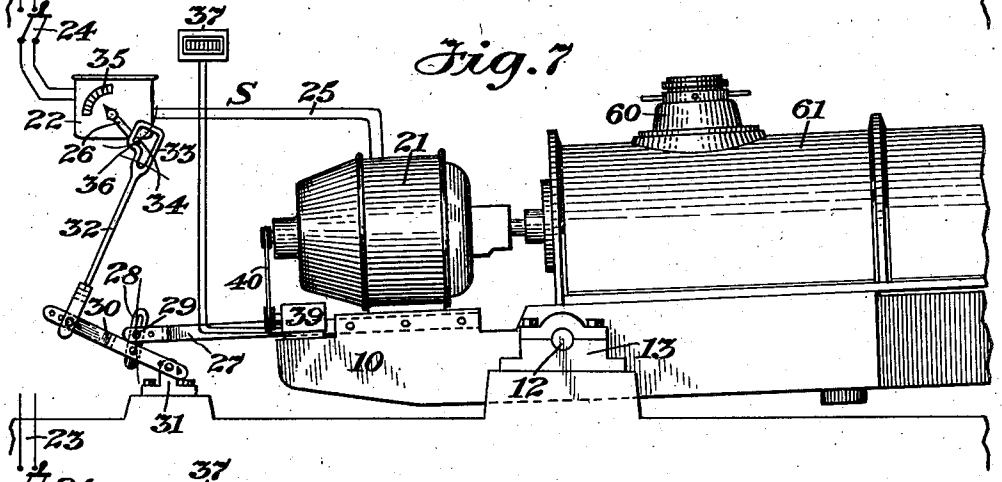
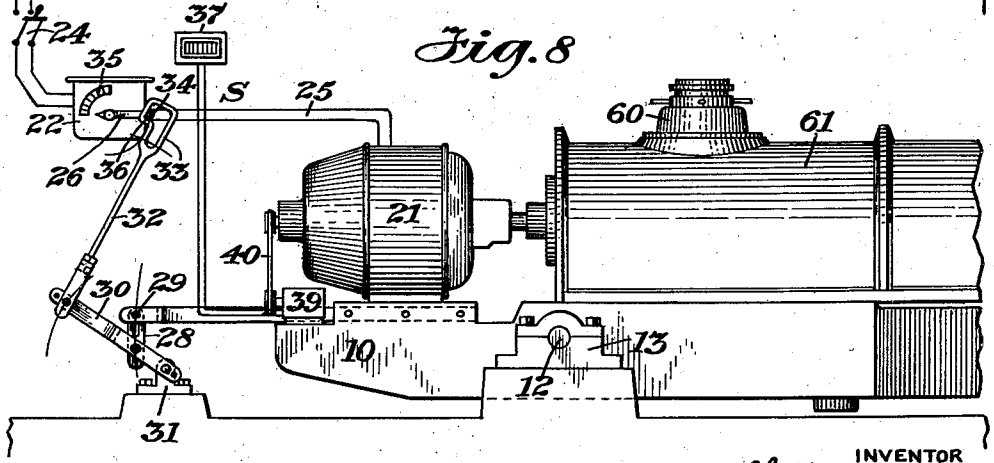


Fig. 8



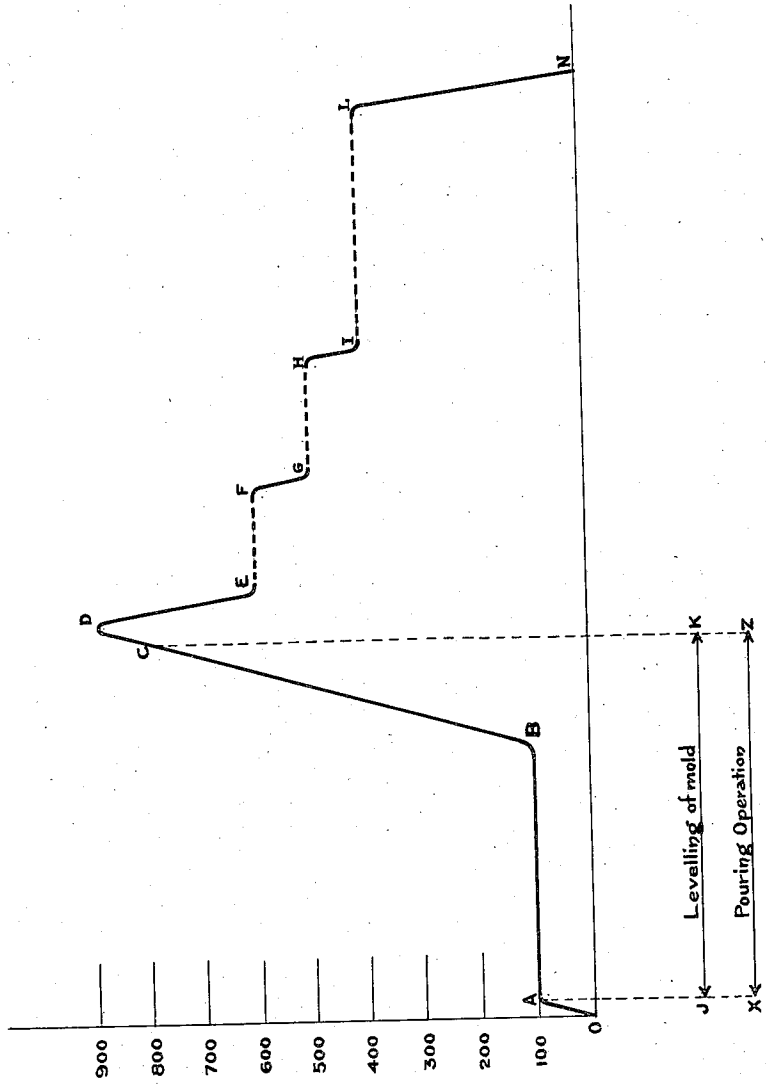
INVENTOR
William D. Moore
Walter Morgan
BY
Meyer & Cavanagh
ATTORNEYS

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Fig. 9



INVENTOR
William D. Moore
Walter Morgan
BY
Meyers & Cavanagh
ATTORNEYS

Patented Mar. 15, 1927. 1,620,830

UNITED STATES PATENT OFFICE.

WILLIAM D. MOORE AND WALTER MORGAN, OF BIRMINGHAM, ALABAMA, ASSIGNORS, BY MESNE ASSIGNMENTS, TO SAND SPUN PATENTS CORPORATION, OF NEW YORK, N. Y., A CORPORATION OF DELAWARE.

METHOD OF AND APPARATUS FOR CENTRIFUGALLY CASTING METAL BODIES.

Application filed December 20, 1923. Serial No. 681,702.

This invention relates to the art of making metal castings, and more particularly to a method of and apparatus for centrifugally casting hollow metal bodies such for example as ferrous pipe; and has special reference to the provision of improvements in the method and apparatus disclosed in the application of William D. Moore, Ser. No. 622,082 filed March 1, 1923, now Patent No. 1,471,052 of Oct. 16, 1923, and the method and apparatus disclosed in the copending application of William D. Moore and Walter Morgan, Ser. No. 656,180 of August 7, 1923.

The principal object of the present invention resides in the production of an improved centrifugal casting machine and of an improved method of operating the same in which a casting operation may be effected in a simplified manner with an increased efficiency and economy.

More specific objects of our present invention comprehend the provision of an improved method of controlling the speed of rotation of a rotary or centrifugal mold, of charging the mold with molten metal and imparting to the same a movement supplementary to the rotary movement for effecting or producing an even distribution of the metal in the mold while changing and predetermining the speeds of rotation thereof; the further provision of an improved method in which the supplementary movement of the mold which consists of the levelling of the mold from an inclined to a horizontal position is carried out while first rotating the mold at a relatively low speed during a part of the levelling period and by then increasing the speed of the mold to a relatively high speed during another and subsequent part of the levelling period; the still further provision of an improved method in which the mold is charged with molten metal during the time of the levelling operation; and the production of apparatus by which these steps may be carried out with comparative ease and facility.

To the accomplishment of the foregoing and such other objects as may hereinafter appear, our invention consists in the methods, the steps and the elements and their relation one to the other as hereinafter particularly described and sought to be defined in the claims, reference being had to the accompanying drawings which show a preferred embodiment of our invention, and in which:

Fig. 1 is an elevational view of the casting machine showing the same at one stage of the casting operation,

Fig. 2 is an enlarged view of the same taken in cross-section on the line 2—2, Fig. 1,

Figs. 3 to 5 are fragmentary views of the pouring end of the casting machine showing the same in successive stages of a casting operation,

Figs. 6 to 8 are fragmentary views of the speed control end of the casting machine showing the same in successive stages of a casting operation, and

Fig. 9 is a graphical view showing the inter-relation between the operation of the mold, the controlling of the speed thereof, and the pouring of the metal in the casting operation.

As disclosed in the aforementioned application Serial No. 622,082, the method of centrifugally casting hollow metal bodies to which the present invention appertains includes the steps of charging a rotary mold with molten metal and of coordinately operating the mold by imparting thereto a motion supplemental to the rotary motion thereof while the molten metal is still in a fluid state so as to effect a uniform distribution of metal in the mold to produce a uniform and homogeneous casting. More specifically, in the practice of this method a rotary mold is charged with molten metal and is moved from a position inclined to the horizontal to a substantially horizontal position while the metal is still in a molten state or condition.

In accordance with this invention, the apparatus which is employed for carrying out the steps of the method preferably comprises a mold supported for movement between inclined and horizontal positions with means for moving the mold to the horizontal position during a pouring operation; and referring generally to Figs. 1 and 2 of the drawings, the said apparatus preferably comprises a frame or bed 10 which may be a unitary casting removably supporting a rotary mold generally designated as 11, the said frame being movable between inclined and horizontal positions about an axis preferably adjacent one end of the bed, the bed being to this end provided with the trunnions 12 journalled in spaced bearings 13 on both

sides of the machine, the said bearings being securely bolted to spaced concrete piers 14 on both sides of the machine, the movement of the bed being guided by means of the spaced guide standards 15 mounted on and secured to the foundation 16.

The mold 11 preferably comprises a refractory rotary mold which includes a flask 17 having a plurality of perforations 18 distributed over the body of the same and forming vent holes for the gases and steam generated during a casting operation, the said flask being provided with a refractory lining such as the moist sand lining 19 preferably surfaced with a facing 20 (see Fig. 2 of the drawings). The mold 11 is rotated by means of a driving means 21 which preferably comprises an electric motor mounted on the bed 10 at the pivotal end thereof, the said motor being preferably arranged coaxially with the mold 11 for movement to and from the mold to permit the coupling and uncoupling of the motor, as will be described more in detail hereinafter.

As heretofore mentioned, one of the principal objects of our present invention relates to the provision of an improved method of operating the mold and of imparting a supplementary movement thereto while the metal is in the fluid state, the improved method consisting in the control of the speed of rotation of the rotary mold and more specifically in the changing and predetermining of the speeds of rotation thereof, and in the coordinating of such speed control with the steps of charging the mold and of imparting to the same the supplementary movement. The improved steps in the method are shown graphically in Fig. 9 of the drawings, in which the control of the speed of the mold is shown related to the pouring operation and to the step of levelling the mold or moving the mold from the inclined to the horizontal position, the graph representing the speeds of rotation of the mold with time as the abscissa and speed as the ordinate. For purposes of explicit description, we have denoted the actual speeds of operation and the relative time factors, this data applying more particularly to the production of six-inch pipe, and it will be understood that the relative times and speeds are given by way of illustration only and not by way of limitation, and may be varied with considerable latitude for different size pipes.

Referring still to Fig. 9 of the drawings, in carrying out the steps of the method the mold is first moved to a position inclined to the horizontal and is then started revolving at a low speed as represented by the line O—A, and for six inch pipe this may be set to about 100 revolutions per minute. The pouring of the metal then commences as represented by the point X on the line X—Z, or the pouring may commence as the mold is started revolving, and the mold is continued at the low speed of rotation as shown by the line A—B during the pouring operation. After the greater part of the metal has been delivered into the mold, and more specifically after 75% of the time of the pouring operation, the speed of rotation of the mold is increased as represented by the line B—C until the mold reaches a relatively high speed, which for six-inch pipe may be approximately 900 R. P. M., the said maximum speed being attained within a second or two after the termination of the pouring operation, the maximum speed being indicated by the point D on the line B—C—D. In accordance with our present improved process, movement of the mold from the inclined to the horizontal or level position takes place during the pouring operation and substantially coextensive therewith, this being depicted in the graph by the line J—K being equal to and coextensive with the line X—Z. In the practice of the method the levelling of the mold and the pouring operation may for the example given consume about ten seconds, during which time the mold is rotated at the relatively low speed for about six or seven seconds and the speed of the mold is increased from the low to the relatively high speed during the period of about three or four seconds.

Immediately after the high speed of rotation has been reached, the speed of rotation of the mold is rapidly reduced to an intermediate speed, such for example as 600 R. P. M., as represented by the line D—E, at which speed the mold is allowed to revolve for approximately one minute as indicated by the line E—F. The speed of the mold may then be reduced to about 500 R. P. M., as indicated by the line F—G, and this speed is maintained for approximately one minute as shown by the line G—H, after which the speed is reduced to a medium speed, which may be about 400 R. P. M., as indicated by the line H—I, and revolved at this speed until the metal assumes a congealed state or has solidified sufficiently to permit removal of the mold from the machine, the time of running the mold at the medium speed being generally designated by the line I—L, after which the speed is reduced and the machine stopped, as indicated by the line L—N.

It will thus be seen that in the practice of the method the mold is started rotating at a relatively low speed while in the inclined position, and the mold is then moved from the inclined to the substantially horizontal or level position, and during such levelling the mold is operated by first continuing the rotation of the same at a relatively low speed during a part such as 75% of the levelling period, and by then increasing

the speed of rotation of the same to a relatively high speed during the remainder of the levelling period, after which the speed is reduced in steps to a medium speed and maintained thereat until the metal congeals. It will be further evident that in the practice of this method the pouring operation is carried out during the levelling of the mold, and that about three-quarters of the pouring of the metal is effected while the mold is rotating at the relatively low speed, the remainder of the pouring operation being carried on while the speed of the mold is being increased. It has been found that this control of the speeds and these interrelations of the speed of the mold with the levelling of the same and the pouring of the metal produces not only efficient casting results, but permits of the utilization of simple automatic apparatus for carrying out the process.

The apparatus we prefer to provide for practicing the speed control steps of the method comprises mechanism which is in part automatically and in part manually operated to permit a control of the same with working precision by means of unskilled labor. More specifically, we provide apparatus constructed for controlling the speeds automatically in the initial stages of the casting operation such as during the pouring and levelling steps, and for permitting manual control of the speeds in the latter stages such as during the congealing of the metal and the cooling of the casting.

The apparatus we prefer to employ for automatically and manually controlling the speeds is shown particularly in Figs. 1 and 6 to 8 of the drawings, this apparatus preferably comprising a motor controller 22 located at a remote control station generally designated as S, the said motor controller being connected to the main line 23 controlled by means of the manually operable switch 24, the said controller being electrically connected to the motor 21 by means of the connecting line generally designated as 25. Cooperating with the controller and more particularly with the lever 26 thereof, we provide means which is preferably operated by movement of the bed 10 for actuating the controller lever at a predetermined point of the levelling of the mold to increase the speed of rotation of the motor 21, the said means being so constructed that during the first part of the levelling step, the speed of rotation of the mold is maintained at the relatively low speed as heretofore mentioned and the speed of rotation of the mold is increased during the later stage of the levelling thereof. The said means preferably comprises an operating arm 27 attached to the bed at the motor end thereof, the said arm 27 being connected to a link 28 by means of a pin and slot mechanism 29, the said link 28 being in turn connected to a lever 30 fulcrumed on a supporting bracket 31, the outer end of the lever being adjustably connected to an operating link 32 the upper end of which is provided with a loop member 33 which receives the handle 34 of the controlling lever 26, the association of these parts being such that the bed 10 may be moved from a horizontal to an inclined position without moving the handle 34, and such that when the bed is moved in the reverse direction, that is from the inclined to the horizontal position, the handle 34 is operated at a predetermined point of the levelling of the mold to increase the speed of the mold, the association being furthermore such that after the levelling of the bed and the mold thereon, the speed of the mold may be thereafter manually controlled as heretofore described.

This association is shown in Figs. 6 to 8 of the drawings, Fig. 6 showing the bed 10 in the horizontal position, Fig. 7 showing the same in the inclined position prior to a casting operation, and Fig. 8 showing the same in the horizontal position after the levelling step. When the casting machine is in the horizontal position as shown in Fig. 6, the control lever 26 is positioned so that when the main line switch 24, which is normally open as shown, is closed, a predetermined low speed of operation is effected such as 100 R. P. M. in the illustration above given. In Fig. 6 the lever 26 is fixed relatively to the dial 35 so as to obtain this predetermined low speed. As the bed 10 is moved from the horizontal position shown in Fig. 6 to the inclined position shown in Fig. 7 by means which will be described in detail hereinafter, the operating arm first moves downwardly about the pivotal axis 12, and due to the pin and slot connection 29 the first stage of the downward movement of the operating arm 27 has no effect on the lever 30, the last stage of movement of the operating arm, however, being effective for moving the lever 30 and the operating link 32 downwardly, causing the loop 33 in this link to slide along the control lever handle 34 without imparting any motion to the same, the adjustment of the operating link being such that just as the machine attains its predetermined inclined position, the shoulder 36 drops in under the control lever handle 34, as clearly shown in Fig. 7 of the drawings. As before indicated, the adjustment of the lever 26 is such that in this position of the operating link 32 the control lever is located in a predetermined position to cause the motor 21 to revolve the mold at a low speed at approximately 100 R. P. M. in the example given. This predetermined low speed may be varied, however, by means of the adjustable connection between the link

32 and the lever 30 provided as clearly shown in the drawings.

With the parts in the position shown in Fig. 7 of the drawings, the pouring of the metal and the levelling of the machine is begun, the machine being levelled from the position shown in Fig. 7 to that shown in Fig. 8. During this levelling or lowering step the operating arm 27 moves a predetermined distance without affecting the operation of the controller 22, this being due to the pin and slot loose connection 29 between the operating arm 27 and the link 28. When, however, the levelling of the mold reaches the point B in the graph heretofore described, the link 28, the lever 30 and the operating link 32 are operated to move the controller handle from the position shown in Fig. 7 to that shown in Fig. 8, increasing the speed of rotation of the mold to the relatively high speed.

Immediately after the machine reaches the horizontal position, the operator manually shifts the link 32 about its pivot to disengage the shoulder 36 of the loop 33 from the underneath side of the control lever handle 34 and then rotates the handle to slow down the speed of the motor in steps as heretofore described in connection with the graph of Fig. 9 of the drawings until finally the control lever is returned to the position shown in Fig. 6, after which the main line motor switch 24 is opened and the machine stopped. The flask is then removed from the machine and another one inserted, and the operation is ready to be repeated. If desired, a speed indicator 37 connected by means of the lines 38 to the generator 39 may be provided for indicating the exact speeds attained, the said generator 39 being suitably connected by means 40 to be operated by the motor 21. In this construction it will therefore be seen that the critical points of changing speeds and the exact speeds desired are automatically obtained, and are synchronized with the lowering operation of the machine in a simple and efficient manner.

For moving the bed 10 and the parts carried thereby between the tilted and the horizontal positions, we provide a fluid operated means which is described and claimed in our copending application for method of and apparatus for centrifugally casting metal bodies, Serial No. 656,180, filed Aug. 7, 1923, the said fluid operated means generally comprising one or more hydraulic cylinders 41, one of which is shown in Fig. 1 of the drawings, firmly planted on the foundation 16 at the pouring end of the machine, each hydraulic cylinder being provided with an operating plunger 42 having a roller 43 at its upper end engaging the bed 10, as clearly shown in Fig. 1 of the drawings. The hydraulic cylinder or cylinders are operated by a control valve means (not shown) which is preferably located so as to be manipulated by the operator at the control station S.

As already mentioned, after a casting operation has been effected, the mold with its casting is removed from the machine and is replaced by a new mold ready for the making of another casting. For the transfer of the molds in and out of the casting machine we preferably employ the apparatus which is described and claimed in our above mentioned copending application, the said apparatus generaly comprising a mold elevating means in the form of a plurality of elevating track rails 44 (see Figs. 1 and 2) each pivotally mounted at one end on a standard 45 and provided at the other end with a mold embracing portion 46, said track rails being movable from an inclined descended position shown in Fig. 2 to an elevated horizontal or level position, a stop bolt 47 pivotally attached to the rail mechanism and provided with a head 48 for engaging the underneath wall of the bed 10 being provided for limiting the upward movement of the track rails to the straight level or horizontal position, this position being desired so that the molds may with equal facility be rolled from the machine to the track rails and from the rails to the machine. The molds may be removed from the rails 44 to a car 49 movable on the track rails 50 or by any other means such as by a a crane or overhead trolley.

The means for operating the elevating track mechanism preferably comprises fluid operated means which may be controlled by the operator at the station S, the said fluid operated means being conveniently carried by so as to be movable with the bed 10. This is shown generally in Figs. 1 and 2 of the drawings as comprising the spaced hydraulic cylinders 51, 51, one for each elevating rail, each cylinder being securely attached ot the bed 10 as by means of the securing bolts 52. To the said cylinders are connected the hydraulic branch lines 53, which in turn are connected to a control line (not shown) running to the operating station S and controlled by means of a hydraulic valve operable by the operator at said station, these parts forming no part of our present invention, the same being disclosed and claimed in the above mentioned copending application. These hydraulic cylinders 51 are operable for causing the ascent and descent of plungers 54, each of the plungers being provided with a terminal roller 55 cooperating with a projecting portion 56 which may be formed integrally with a track rail 44 for effecting the elevating and lowering of the same.

For efficiently supporting the mold for rotation of the casting machine while per-

mitting a quick interchange of molds and for protectively housing the mold during a casting operation, we preferably provide the roller supporting means set forth in the above mentioned copending application, said supporting means including sets of supporting rollers spaced longitudinally of the machine, each set comprising preferably two lower rollers 57 and 58 carried by the bed and a top roller 59 journalled for adjustment in a housing 60 which is firmly attached to the top of a hood 61, the latter being hingedly mounted on the bed as by means of the hinges 62 (see Fig. 2). Each of the flasks 17 is provided with spaced bands such as 63 for rotatably mounting the mold in the said rollers.

When a filled mold is to be removed from the casting machine and a newly prepared mold to be replaced therefor, the hood 61 is moved to an elevated position and in the preferred construction this is accomplished simultaneously with the operation of the elevating rails 44, preferably by means of rollers 64 journalled at the ends of curved extension arms 65 which are attached to the elevating rails 44, the construction being such that when the plungers 54 are operated to cause the elevation of the lifting rails 44, the rollers 64 ride in engagement with the inner wall of the hood and raise the same from the position shown in Figs. 1 and 2 of the drawings to an elevated position to permit the rolling out of the mold. When a new mold is rolled into the casting machine the reverse operation of the plungers causes the simultaneous lowering of the lifting rails 44 and the hood 61 to the position as shown in Figs. 1 and 2, as will be apparent.

To permit the interchangeability of the molds, the driving motor 21 is arranged to be coupled to and uncoupled from the flask 17 as heretofore mentioned, and to this end a coupling means is provided which preferably comprises a male coupling member 66 keyed or otherwise attached to the motor shaft 67 and receivable by a female coupling member 68 which conveniently forms the end plate of the mold 11, the coupling and uncoupling of the motor being effected by the axial movement of the motor, the latter being to this end mounted on a slidable motor base 69.

To carry out the pouring step simultaneously and also coextensively with the levelling of the mold as heretofore mentioned, we provide a pouring ladle which is mounted on for movement with the mold carrying bed, and which is constructed to be operated by movement of the bed during the levelling of the same. The apparatus we prefer to employ is shown in Figs. 1 and 3 to 5 of the drawings, said apparatus comprising a tiltable ladle 70 carried in a frame 71 provided with the two sets of trunnions 72 and 73 seated in a rocker frame 74 forming part of a ladle mounting 75, the said mounting being suitably attached to the end plate 76 of the hood 61. The end plate 76 also carries a mounting 77 for the runner box or pouring spout 78, which runner box preferably consists of an all cast iron construction provided with a replaceable wearing shoe 79 for taking up the cutting action that may take place during a pouring operation.

For operating the ladle during the levelling of the machine, we provide a mechanism which may comprise an angle lever 80 desirably fulcrumed on the bracket 81 arranged approximately on the floor level, the said lever including an arm 80′ adapted to be engaged by a leg 82 forming part of the bed 10 and an arm 80^2 to which is adjustably connected a link 83, the said link being adjustably receivable in any one of the apertures 84 provided in the arm 80^2, the upper end of this link being pivotally connected by means of the pin 85 to a depending arm 86 fixed to the ladle frame 71.

Referring now to Figs. 3 to 5 of the drawings, we show the sequential steps of the pouring operation. In the position shown in Fig. 3, the link 83 is disconnected from the depending arm 86 so that the ladle 70 is caused to assume the erect or vertical position shown. Prior to elevating the casting machine a charge of molten metal is poured into the receiving ladle 70 by means of a trolley ladle (not shown) which moves from the cupola to the receiving ladle and after the ladle receives its charge the casting machine is elevated to the inclined position shown in Fig. 4. The link 83 is then attached to the arm 86 of the ladle frame, and the lever 80 assumes the full line position shown in said figure ready for the levelling and pouring steps. The casting machine is then moved as heretofore described, from the position shown in Fig. 4 to that shown in Fig. 5, the lever 80 moving from the full line to the dotted line position of Fig. 4 and assuming the full line position of Fig. 5, the operation being such that the ladle 70 is tilted from the erect position to the metal expelling position, as will be apparent, the pouring of the metal into the runner box 78 and into the mold 11 being thus made coextensive with the levelling of the machine. After this operation the link 83 is disconnected from the arm 86 and the ladle returned to the erect position permitting the same to be cleaned and recharged.

With the provision of this construction we are enabled to locate the ladle in such a position with reference to the runner box or pouring spout as to produce a minimum drop in the stream from the lip of the ladle to the bottom of the spout, thus reducing the cutting action of the metal on the re-

placeable shoe in the runner, and as to effect, moreover, a reduction of the pitch or range of the metal stream in the pouring of the same. With our present construction, moreover, the ladle instead of pivoting on a trunnion located at the center of gravity thereof, tilts on a trunnion materially to one side and towards the top of the ladle, this creating a very stable condition and insuring a steady movement of the metal during the pouring operation, this eliminating furthermore any danger or liability of the ladle becoming top-heavy and upsettable.

By mounting the ladle on the bed of the machine the elevation of the ladle is considerably reduced, and since the ladle is charged in the horizontal position of the machine as shown in Fig. 3, the trolley ladle may be maintained at a desirable working height. The mounting of the ladle on the machine furthermore provides opportunity to properly dress the ladles between casts, care and maintenance of the machine being thereby considerably facilitated.

The manner of practicing our improved process and operating our improved machine will in the main be fully apparent from the above detailed description thereof. In performing a complete casting operation the runner box 78 and ladle 70 are first prepared and a lined and properly faced mold is rolled into the casting machine, after which the operator at the station S operates the cylinders 51 to effect a lowering of the mold 11 and the hood 61 to the position shown in Figs. 1 and 2. The motor 21 is then coupled to the mold and the runner box 78 which is longitudinally movable in the mounting 77 is then moved into position with the pouring spout thereof projecting into the pouring opening of the mold. The ladle 70 is then given its charge of molten metal, after which the link 83 is connected to the ladle frame arm 86. The operator at the station S then effects the elevation of the bed and mold to the inclined position shown in Figs. 1, 4 and 7. The same operator then closes the switch 24 which starts the motor running and the mold rotating at the low speed, and then effects the levelling of the casting machine by operating the hydraulic cylinder 41. The lowering of the machine is effected gradually and relatively slowly, the movement of the machine to the horizontal producing the pouring of the metal into the mold, as shown in Figs. 3 to 5 of the drawings. After about three-quarters of the metal pouring and mold tilting takes place, the motor controller 22 is operated to increase the speed of the machine to a relatively high speed, the high speed being obtained substantially when the mold reaches the horizontal and the pouring operation has been completed.

After the mold reaches the horizontal position, the speed of the motor 21 is controlled to reduce the speed of the mold in steps, and the same is finally brought to a halt, after which the mold is removed for replacement by a new mold for a repetition of this cycle of operation.

While we have described our method and shown our apparatus in the preferred manner and form, it will be obvious that many changes and modifications may be made in the steps of the method and in the structure of the apparatus disclosed without departing from the spirit of the invention.

For example, the range of speeds will vary for the size of pipe employed. Thus in the making of an eight-inch pipe the mold will first be rotated at a predetermined speed of 250 or 300 R. P. M. instead of 100 R. P. M. above described, which speed is maintained during the major part of the casting operation, and immediately thereafter the speed is increased to about 800 R. P. M., such speed being maintained for about five to ten seconds, after which the speed is gradually reduced back to 500 or 600 R. P. M., where it is allowed to continue until the casting is cooled sufficiently to stop the machine and discharge the mold. For a four-inch pipe the speeds may be again varied, and we have found that for this size pipe the initial speed of the machine should be relatively low, the rotation being reduced to a point of simply "goosing" the motor sufficiently to roll the flask over several times during the casting operation, and this may not amount to more than 10 R. P. M., after which the speed is increased to a high speed. Other numerous changes may be made without departing from the spirit of the invention defined in the following claims.

We claim:

1. In the art of centrifugally casting hollow metal bodies, the method which consists in charging a mold with molten metal, in moving the same from a position inclined to the horizontal to a substantially horizontal or level position, and in operating the mold during the levelling thereof by first rotating the same at a relatively low speed during a part of the levelling period and by then increasing the speed of rotation of the same during another part of the levelling period.

2. In the method of centrifugally casting hollow metal bodies in a rotary mold movable from a tilted to a substantially horizontal or level position, the steps of levelling the mold while a metal charge therein is still in a fluid condition and of operating the mold during the levelling thereof by first rotating the same at a relatively low speed during a part of the levelling period and by then increasing the speed of rotation of the same during another part of the levelling period.

3. In the method of centrifugally casting

hollow metal bodies in a rotary mold movable from a tilted to a substantially horizontal or level position, the steps of simultaneously levelling the mold and charging the same with molten metal and of operating the mold during the levelling thereof by first rotating the same at a relatively low speed for a part of the levelling period and by then increasing the speed of rotation thereof for another part of the levelling period.

4. In the art of centrifugally casting hollow metal bodies, the method which consists in rotating a mold at a relatively low speed while the mold is in a position inclined to the horizontal, in introducing molten metal into the mold at the elevated end thereof, in moving the mold from its inclined to a substantially horizontal or level position while the metal is still in a fluid condition, in continuing the rotation of the mold at the relatively low speed for a part of the levelling period of the mold, and in then increasing the speed of rotation of the mold.

5. The method of centrifugally casting hollow metal bodies of claim 4 in which the increasing of the speed of rotation of the mold is produced during another part of the levelling period of the same.

6. In the art of centrifugally casting hollow metal bodies, the method which consists in rotating a mold at a relatively low speed while the mold is in a position inclined to the horizontal, in moving the mold from its inclined to a substantially horizontal or level position, in charging the mold with molten metal during the levelling thereof, and in operating the mold during the levelling thereof by first continuing the rotation of the same at the relatively low speed for a part of the levelling period and by then increasing the speed of rotation of the same during another part of the levelling period.

7. In the art of centrifugally casting hollow metal bodies, the method which consists in charging a mold with molten metal, in moving the same from a position inclined to the horizontal to a substantially horizontal or level position, and in operating the mold during the levelling thereof by first rotating the same at a relatively low speed for about three-quarters of the levelling period and by then increasing the speed of rotation of the same during the remainder of the levelling period.

8. In the art of centrifugally casting hollow metal bodies, the method which consists in rotating a mold at a relatively low speed while the mold is in a position inclined to the horizontal, in moving the mold from its inclined to a substantially horizontal or level position, in charging the mold with molten metal during the levelling thereof, and in operating the mold during the levelling thereof by first continuing the rotation of the same at the relatively low speed for about three-quarters of the levelling period and by then increasing the speed of rotation of the same during the remainder of the levelling period.

9. In the art of centrifugally casting hollow metal bodies, the method which consists in charging a mold with molten metal, in moving the same from a position inclined to the horizontal to a substantially horizontal or level position, in operating the mold during the levelling thereof by first rotating the same at a relatively low speed during a part of the levelling period and by then increasing the speed of rotation of the same to a relatively high speed during another part of the levelling period, and in thereafter gradually decreasing the speed of rotation of the mold.

10. In the art of centrifugally casting hollow metal bodies, the method which consists in charging a mold with molten metal, in moving the same from a position inclined to the horizontal to a substantially horizontal or level position, in operating the mold during the levelling thereof by first rotating the same at a relatively low speed during a part of the levelling period and by then increasing the speed of rotation of the same to a relatively high speed during another part of the levelling period, and in then rotating the mold at a medium speed until the metal assumes a congealed state.

11. In the art of centrifugally casting hollow metal bodies, the method which consists in charging a mold with molten metal, in moving the same from a position inclined to the horizontal to a substantially horizontal or level position, in operating the mold during the levelling thereof by first rotating the same at a relatively low speed during a part of the levelling period and by then increasing the speed of rotation of the same to a relatively high speed during another part of the levelling period, and in then reducing the speed of rotation of the mold in steps to a medium speed and continuing the said medium speed until the metal assumes a congealed state.

12. In the art of centrifugally casting hollow metal bodies, the method which consists in rotating a mold at a relatively low speed while the mold is in a position inclined to the horizontal, in moving the mold from its inclined to a substantially horizontal or level position, in charging the mold with molten metal during the levelling thereof, in operating the mold during the levelling thereof by first continuing the rotation of the same at the relatively low speed for a part of the levelling period and by then increasing the speed of rotation of the same to a relatively high speed during another part of the levelling period and in there-

after decreasing the speed of rotation of the mold to the medium speed and maintaining the same at the medium speed until the metal congeals.

13. In the art of centrifugally casting hollow metal bodies, the method which consists in inclining a rotary mold, in moving the mold from its inclined to a substantially horizontal or level position, and in delivering molten metal into the mold to charge the same during the levelling thereof, the period of charging of the mold being coextensive with the period of levelling of the same.

14. In the method of centrifugally casting hollow metal bodies in a rotary mold movable from a tilted to a substantially horizontal position, the step of delivering a full charge of metal into the mold during the time of movement thereof from the tilted to the substantially horizontal position.

15. In the art of centrifugally casting hollow metal bodies, the method which consists in rotating a mold at a relatively low speed, in imparting to the mold a further movement other than a rotary movement, in operating the mold during such further movement by first continuing the rotation of the same at the relatively low speed for a period of time and by then increasing the speed of rotation of the same, and in charging the mold with molten metal during such further movement thereof.

16. In the art of centrifugally casting hollow metal bodies, the method which consists in rotating a mold, in imparting to the mold a further movement other than a rotary movement for a given period of time while a metal charge therein is still in a fluid state, and in operating the mold during such further movement by first rotating the same at a relatively low speed during the greater part of the said period of such movement and by then increasing the speed of rotation of the same during the remaining part of the said period.

17. In the art of centrifugally casting hollow metal bodies, the method which consists in rotating a mold, in imparting to the mold for a given period an axial tilting movement, and in delivering molten metal into the mold to charge the same during the said period.

18. In the art of centrifugally casting hollow metal bodies, the method which consists in rotating a mold, in imparting to the mold for a given period an axial tilting movement, and in delivering molten metal into the mold to charge the same during the said period, the period of delivery of the metal being substantially co-extensive with said given period.

19. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold mounted for levelling movement between inclined and substantially horizontal positions, mechanism for moving the mold from the inclined to the substantially horizontal position, and means for rotating the mold at a given speed during part of the period of such levelling movement and for increasing the speed of rotation of the mold during another part of the levelling period.

20. An apparatus for centrifugally casting hollow metal bodies comprising a rotary refractory mold mounted for levelling movement between inclined and substantially horizontal positions, mechanism for moving the mold from the inclined to the substantially horizontal position, and means for rotating the mold at a given speed during part of the period of such levelling movement and for increasing the speed of rotation of the mold during another part of the levelling period.

21. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold and instrumentalities for uniformly distributing a charge of molten metal throughout the body of the mold comprising means for rotating the mold and mechanism for imparting to the mold a movement supplemental to the rotary movement, the said means being operative for rotating the mold at a given speed during part of the period of such supplemental movement and for increasing the speed of the mold during another part of such period.

22. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold mounted for leveling movement between inclined and substantially horizontal positions, means for rotating the mold, mechanism for moving the mold from the inclined to the substantially horizontal position, and means operated at a predetermined point of the levelling movement of the mold for increasing the speed of rotation thereof.

23. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold mounted for levelling movement between inclined and substantially horizontal positions, mechanism for moving the mold from the inclined to the substantially horizontal position, and means for rotating the mold at a given speed during part of the period of such levelling movement and for increasing the speed of rotation of the mold during another part of the levelling period, said means being operated by the levelling movement of the mold to effect the increasing of the speed thereof.

24. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold mounted for levelling movement between inclined and substantially horizontal positions, means for rotating the mold, mechanism for moving the mold from the inclined to the substantially horizontal position, and means operative for increas-

ing the speed of rotation of the mold during the latter part of the levelling period thereof.

25. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold mounted for levelling movement between inclined and substantially horizontal positions, means for rotating the mold at a relatively low speed, mechanism for moving the mold from the inclined to the substantially horizontal position and means effective for permitting the rotation of the mold at the relatively low speed during a part of the levelling period thereof and for increasing the speed of rotation of the mold during another part of the said levelling period.

26. An apparatus for centrifugally casting hollow metal bodies comprising a mold, means for rotating the same at a relatively low speed, mechanism for imparting to the same an axial tilting movement supplemental to the rotary movement for a given period, and means effective for permitting the rotation of the mold at the relatively low speed during a part of the period of the said supplemental movement and for increasing the speed of rotation of the mold during another part of the said period.

27. An apparatus for centrifugally casting hollow bodies comprising a rotary mold, a support therefor movable between inclined and substantially horizontal or level positions, mechanism for rotating the mold, means for controlling the speed of rotation of said mechanism, and linkage mechanism connecting said support and said means and operative for automatically effecting an increase in the speed of rotation of the mold during the latter part of the levelling movement of the mold.

28. An apparatus for centrifugally casting hollow bodies comprising a rotary mold, a support therefor movable between inclined and substantially horizontal or level positions, mechanism for rotating the mold at a relatively low speed, means for controlling the speed of rotation of said mechanism, and linkage mechanism connecting said support and said means and operative for permitting rotation of the mold at said low speed for the first part of the levelling movement of the same and for automatically effecting an increase in the speed of rotation of the mold during the latter part of the levelling movement of the mold.

29. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold mounted for levelling movement between inclined and substantially horizontal positions, mechanism for moving the mold from the inclined to the substantially horizontal position, means for rotating the mold at a given speed during part of the period of such levelling movement and for increasing the speeed of rotation of the mold during another part of the levelling period, and means for charging the mold with molten metal during the said levelling period.

30. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold mounted for levelling movement between inclined and substantially horizontal positions, means for rotating the mold, mechanism for moving the mold from the inclined to the substantially horizontal position, means operated at a predetermined point of the levelling movement of the mold for increasing the speed of rotation thereof, and means operated by the levelling movement of the mold for charging the same with molten metal during such levelling movement.

31. An apparatus for centrifugally casting hollow metal bodies comprising a rotary mold mounted for levelling movement between inclined and substantially horizontal positions, means for rotating the mold, mechanism for moving the mold from the inclined to the substantially horizontal position, means operative for increasing the speed of rotation of the mold during the latter part of the levelling period thereof, and means for charging the mold with molten metal during the said levelling period.

32. An apparatus for centrifugally casting hollow metal bodies comprising a mold, means for rotating the same, mechanism for imparting to the same a movement supplemental to the rotary movement for a given period, means controlled by said supplemental movement to cause the rotating means to rotate the mold at the relatively low speed during a part of the period of the said supplemental movement and means for causing the rotating means to increase the speed of rotation of the mold during another part of the said period, and means for charging the mold during said given period.

33. A centrifugal casting apparatus comprising a rotary mold mounted for movement between inclined and substantially horizontal positions, means for rotating the mold and mechanism for moving the mold from the inclined to the substantially horizontal or level position and simultaneously charging the mold, the period of charging being coextensive with the period of levelling movement of the mold.

34. A centrifugal casting apparatus comprising a rotary mold and instrumentalities for uniformly distributing a charge of metal throughout the body of the mold, including means for rotating the mold, and mechanism for imparting to the mold a supplemental movement in a direction to modify the direction of flow of the molten metal due to the rotation of the mold, during a given period, and means to simultaneously charge the

mold with molten metal over a period of time substantially co-extensive with the duration of such supplemental movement.

35. A centrifugal casting apparatus comprising a rotary mold mounted for movement between inclined and substantially horizontal positions, a pouring ladle connected for movement with the said mold, and mechanism for moving the mold from the inclined to the substantially horizontal position and simultaneously operating said ladle.

36. A centrifugal casting apparatus comprising a rotary mold mounted for movement between inclined and substantially horizontal positions, a tiltable pouring ladle connected for movement with the said mold, and mechanism for moving the mold from the inclined to the substantially horizontal position and simultaneously tilting said ladle.

37. A centrifugal casting apparatus comprising a rotary mold, means for rotating the same, means for imparting to the same a movement supplemental to the rotary movement, and a pouring ladle connected to the mold so as to partake of the supplemental movement thereof, and means operated by the supplemental movement of the mold for operating the ladle to produce a pouring operation.

38. A centrifugal casting apparatus comprising a rotary mold, a support therefor movable between inclined and substantially horizontal positions, a runner box carried by said support and associated with said mold, a ladle also carried by said support and associated with said runner box, means for moving said support from the inclined to the horizontal position, and means operated by such last mentioned movement for operating the ladle to effect a pouring operation.

39. A centrifugal casting apparatus comprising a rotary mold, a support therefor movable between inclined and substantially horizontal positions, a runner box carried by said support and associated with said mold, a tiltable ladle also carried by said support and associated with said runner box, means for moving said support from the inclined to the horizontal position, and means operated by such last mentioned movement for tilting the ladle from an erect to a discharging position whereby a pouring operation is effected during the period of movement of the mold from the horizontal to the inclined position.

40. The step in the method of casting centrifugally in tilting molds, which consists in introducing the molten metal in a continuous stream of a volume such that the introduction of a selected charge will be completed substantially simultaneously with the attainment of the mold to horizontal position.

41. The step in the method of centrifugally casting hollow bodies in tilting molds, which consists in regulating the flow of molten metal to the mold in accordance with the movement of the mold from tilted to level position.

42. The step in the method of casting centrifugally in tilting molds, which consists in coordinating the operations of leveling and pouring to be coincident in time and coextensive in duration.

43. The method of casting hollow bodies centrifugally in rotary molds, which consists in inclining the mold, leveling the mold quickly, and introducing a charge of molten metal coincidently in time, and coextensively in duration with the leveling operation.

44. The method of casting hollow bodies centrifugally in rotary molds, which consists in inclining the mold, leveling the mold quickly, and regulating the inflow of a charge of molten metal in accordance with the inclination of the mold.

45. The method of casting hollow bodies centrifugally in rotary molds, which consists in inclining the mold, leveling the mold quickly, and introducing a charge of molten metal into the mold, coincidently in time and coextensively in duration with the leveling operation, and while the mold is rotating at a relatively low speed, and afterwards rotating the mold at a relatively high speed.

46. The method of casting hollow bodies centrifugally in rotary molds, which consists in inclining the mold, leveling the mold quickly, introducing a charge of molten metal coincidently in time and coextensively in duration with the leveling operation, and regulating the inflow of the metal in accordance with the inclination of the mold.

47. In a centrifugal casting machine, a tilting mold, and mechanism for introducing molten metal into the mold operated by the movement of the mold to horizontal position.

48. In a centrifugal casting machine, a tilting mold, mechanism for introducing molten metal into the mold operated by the movement of the mold to horizontal position, and a pouring spout into which the metal delivers for conducting the molten metal to the mold.

49. In a centrifugal casting machine, a tilting mold, a tilting ladle for the molten metal at the elevated end of the mold, and mechanism operated by the leveling of the mold to tilt the ladle, including a pouring spout into which the ladle delivers for conducting the molten metal to the mold, and a common support for the ladle and the spout.

50. In a centrifugal casting machine, a tilting mold, means to tilt the mold, mechanism to introduce molten metal into the mold operated by the restoration of the mold to horizontal position, and means to rotate the mold at a selected speed during the introduction of the molten metal.

51. In a centrifugal casting machine, a

tilting mold, means to tilt the mold, mechanism to introduce molten metal into the mold operated by the restoration of the mold to horizontal position, and means to rotate the mold at a selected speed during the leveling thereof, and at a higher speed after such leveling.

52. In a centrifugal casting machine, a tilting mold, means to lift one end of the mold thereby to tilt the same, and mechanism for introducing a charge of molten metal into the mold operated to introduce by the return of the mold to level position.

Signed at Birmingham in the county of Jefferson and State of Alabama this 17th day of December A. D. 1923.

WILLIAM D. MOORE.
WALTER MORGAN.