Aug. 10, 1943. **P. M. PAYNE** **2,326,164**

METAL-CASTING METHOD AND APPARATUS

Filed Oct. 7, 1940 2 Sheets-Sheet 1

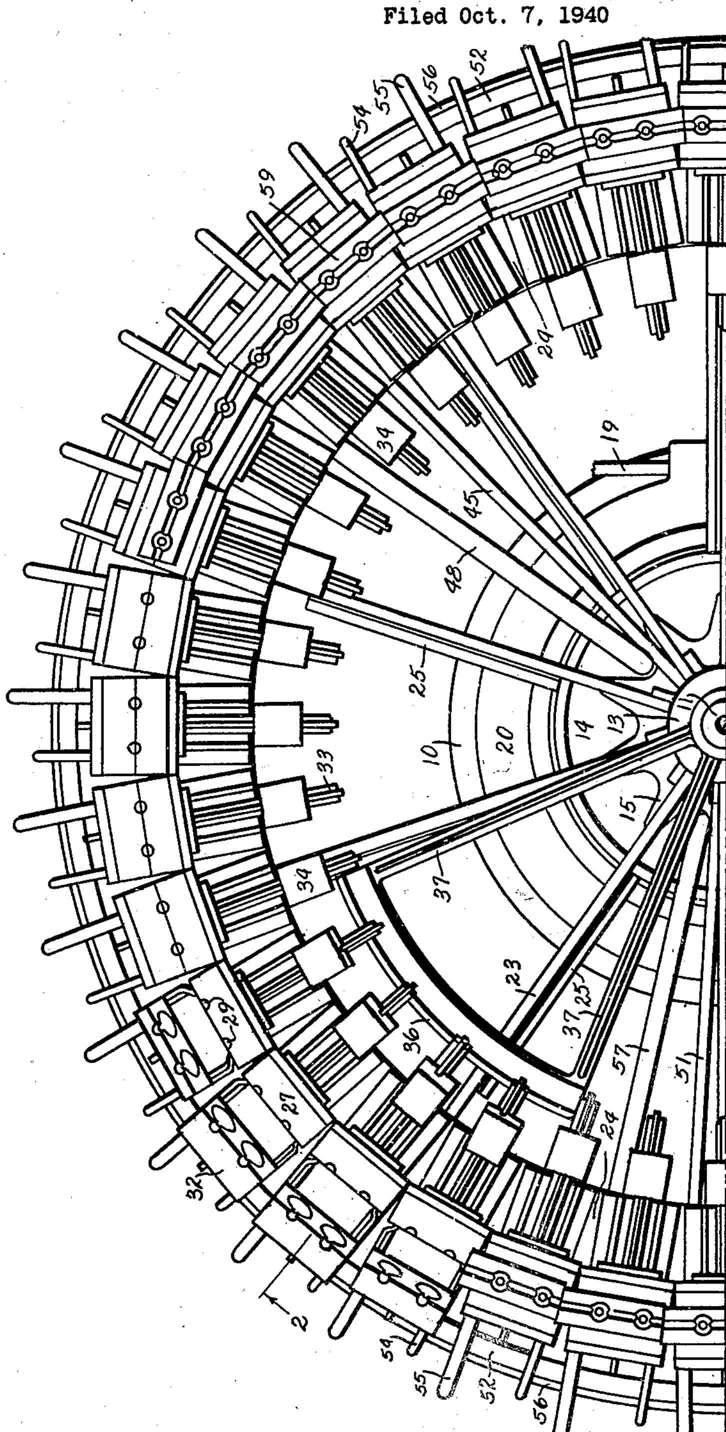

FIG. 1

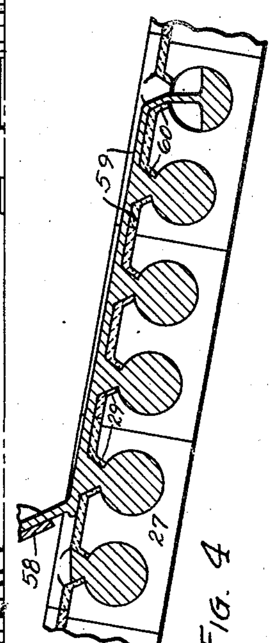

FIG. 4

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METAL-CASTING METHOD AND APPARATUS

Filed Oct. 7, 1940 2 Sheets-Sheet 2

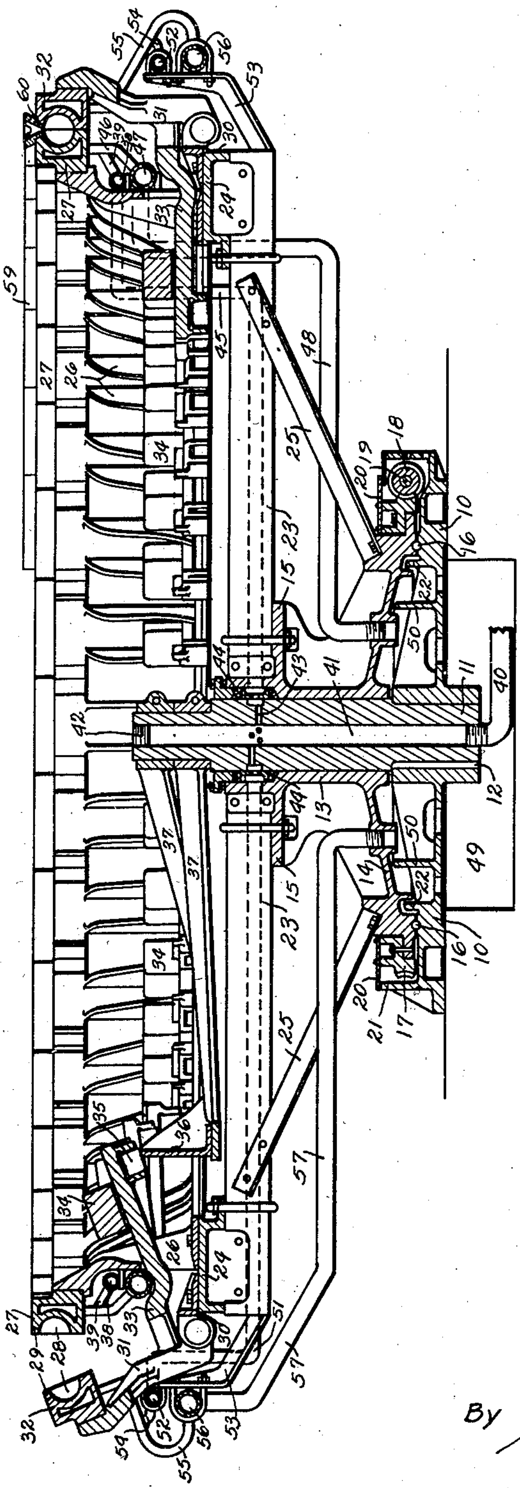

FIG. 2

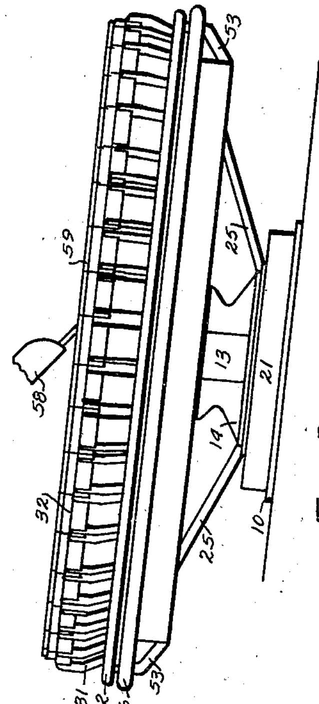

FIG. 3

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2,326,164

METAL-CASTING METHOD AND APPARATUS

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Application October 7, 1940, Serial No. 360,089

7 Claims. (Cl. 22—75)

This invention relates to the art of moulding objects and articles from molten metal in chill-type moulds, and has as an object to provide an improved method and means whereby metallic articles and objects may be moulded with enhanced speed, efficiency, and accuracy.

A further object of the invention is to provide an improved method and means continuously operable to form metallic castings of high quality and uniformity.

A further object of the invention is to provide an improved method and means continuously and advantageously operable for the rapid and economical production of compact, homogeneous, uniform grinding balls substantially free from pipes, cavities, and comparable faults characteristic of moulding operations.

A further object of the invention is to provide an improved method and means operable to maintain a shrinkage head of molten metal in feeding relation with castings formed in chill-type moulds until cooling and solidification of such castings is substantially complete.

A further object of the invention is to provide an improved, continuously-operable apparatus for the casting of grinding balls and comparable metallic articles.

A further object of the invention is to provide improved means for the feeding of molten metal to the mould cavities in a continuously-operable casting machine.

A further object of the invention is to provide improved means operable to automatically discharge completed castings from chill-type moulds in a casting machine.

A further object of the invention is to provide improved means automatically operable to normally maintain separable chill-type mould sections in cooperating relation in a casting machine.

A further object of the invention is to provide an improved ball-casting machine compact in form, susceptible of convenient and inexpensive installation and operation, which is characterized by high production at low cost, which requires a minimum of maintenance and attention for efficient operation, and which is productive of finished castings of high quality.

My invention consists in the construction, arrangement, and combination of elements hereinafter set forth, and in the methods and operative phases hereinafter described, all as pointed out in my claims and illustrated by the accompanying drawings in which—

Figure 1 is a half-plan view of an improved ball-casting machine embodying the principles of my invention and susceptible of operation to give effect to my improved method. Figure 2 is a vertical section taken axially of the improved machine substantially on the indicated line 2—2 of Figure 1. Figure 3 is a side elevation of the improved machine as operatively installed and at substantially right angles to the showing of Figure 2. Figure 4 is a fragmentary, detail section, on an enlarged scale, through adjacent mould units in position to receive molten metal.

As shown in the drawings, the numeral 10 designates a preferably circular, skeletonized, and suitably braced base member, preferably formed of metal by casting or moulding as an integral unit, and adapted to be disposed in bearing relation against a supporting surface for the operative support of the other elements constituting the apparatus. The member 10 is formed with a central, axial bore wherein the lower end of a shaft 11 is snugly fitted and secured against rotation, as by means of a key 12, to project axially of and upwardly beyond said base member. A suitably-braced hub member 13 is formed as an integral unit, by casting or moulding, and is provided with an axial bore adapted to telescopically receive and fit closely about that portion of the shaft 11 immediately above the base member 10, and said hub 13 is formed with a radially-extending, somewhat conical flange 14 adjacent its lower end and disposed to overlie and substantially cover the upper surface of the member 10, and with a radial flange 15 of lesser extent in spaced relation upwardly from the flange 14 adjacent, but somewhat below, the upper end of the hub sleeve. The hub 13 is adapted to be supported by the base member 10 for rotation about the shaft 11, and to this end outer circular portions of the base member upper surface and the hub flange lower surface are brought into close proximity and arranged for engagement against anti-friction devices 16 disposed there to facilitate rotation by said hub member relative to said base member. A worm gear 17 is formed on or securely fixed to and about the periphery of the hub flange 14 for meshing engagement with a horizontal-disposed worm 18 rotatably carried in suitable bearings formed for that purpose adjacent one margin of the base member 10, and a driving shaft 19 is suitably engaged with the worm 18 to connect the latter with a source of power, not shown, whereby said worm may be rotatively driven to rotate the hub member 13 at relatively much reduced speed about the shaft 11. An annular plate 20 is secured to and in covering relation with the gear 17 and is disposed for cooperation of its outer margin with the upper margin of an annular flange 21 which rises from and circumferentially of the base member 10 in housing relation with the gear 17, said plate 20 and flange 21 serving to enclose the gear 17 and protect the latter from undesirable contact with dirt, dust, and foreign matter while providing a trough wherein suitable lubricant may be held and thereby supplied to the gear and anti-friction devices 16. An annular rib 22 preferably rises from the upper surface of the base member 10 just within the orbit of the anti-friction devices 16, and the upper margin of said rib 22 is freely received in a suitable recess or annular groove formed for such purposes in the lower surface of the flange 14, said rib and groove serving to prevent escape of lubricant inwardly of the base member and likewise protecting against the entrance of foreign matter to and between the bearing surfaces of the hub assembly and base member.

The hub flange 15 and upwardly-adjacent portion of the hub 13 are suitably worked to receive and fixedly support the inner ends of a plurality of identical spokes 23 which are thereto secured in uniformly-spaced, radially-extending relation to receive against the upper surface of their outer ends and fixedly support a ring member 24 thereby disposed in concentric relation with the shaft 11 for rotation about said shaft with the hub 13. Suitable braces 25 preferably engaged between an outer upper portion of the hub flange 14 and outer portions of the spokes 23 to stiffen and brace the rotatable assembly.

Fixed to and in upstanding relation with the inner portion of the ring member 24, identical bracket units 26 are disposed in uniformly-spaced relation entirely about the rotatable assembly, and each of said units individually supports a separate chill-type mould half or section 27 on and in outwardly-extending relation with its upper end, said sections 27 having a uniform length such as to close closely against the circumferentially-adjacent sections to complete a circular mould assembly. The mould sections 27 are hollow to facilitate circulation of a cooling medium, and the outer vertical face of each such section is formed to present one-half of the mould impression necessary to form the article to be cast. Since the apparatus illustrated is adapted for the casting of grinding balls, the mould impression interrupting the vertical face of each section 27 will be in the form of a hemisphere, and it is convenient to make the mould sections 27 of such length as to each accommodate two or more identical mould impressions, the number necessarily depending upon the size of the finished grinding ball in relation to the length of the section 27. In addition to the mould impressions, indicated at 28, the sections 27 are formed with one-half of a conical throat or feeding neck 29 communicating through the upper surface of the section 27 with each of the mould impression halves 28.

Secured to the outer portion of the ring member 24, and projecting radially outwardly therebeyond, a hinge member 30 is disposed in radial alignment with each of the bracket units 26 to provide a horizontally-disposed hinge axis in tangential relation with the ring member 24 adjacent each of the bracket units 26. A yoked bracket arm 31 is hingedly secured at its lower end to each of the hinge members 30 and extends upwardly from such hinge connection to swing in a vertical arc toward and away from the corresponding bracket unit 26, and each of the arms 31 fixedly supports a mould half or section 32, identical with the sections 27, disposed to close against a complementary section 27 and complete a mould assembly when the supporting bracket arm 31 is moved inwardly toward the corresponding unit 26. Each of the mould sections 32 is hollow for circulation of cooling fluid therethrough and is provided in intersecting relation with its vertical face with the mould impressions and pouring gate openings necessary for registering cooperation with the corresponding elements in the mould section 27 for completion of the mould form necessary to form and complete the object or article to be cast. Thus, in the apparatus shown, when the mould section 32 is moved into engaging relation of its inner vertical face with and against the outer vertical face of its complementary mould section 27, each such mould assembly includes two spherical cavities and a conical pouring gate communicating through the upper surface of the mould assembly with each of said cavities, so that filling of said cavities with molten metal results in the moulding of two grinding balls in each mould assembly. To normally maintain each mould section 32 in normal mould-forming engagement against its complementary mould section 27, and to provide means for actuating each bracket arm 31 about its hinge mounting for selective separation of the mould sections 32 and 27, an actuating arm 33 is fixed at its outer end to each of the arms 31 and extends radially and inwardly through a suitable opening formed for such purpose in the vertical web of the corresponding bracket unit 26 and across the upper surface of the ring member 24 to adjustably support a counterweight 34 slidably disposed on and in clampable relation with its inner extension. The inner end of each arm 33 is normally free and unsupported, so that the counterweight 34 associated with said arm acts to urge the inner end of the arm downwardly and thereby swing the bracket arm 31 about its hinge axis until the mould section 32 carried by the bracket arm 31 is brought into mould-completing engagement with its complementary section 27, such engagement serving to limit downward travel of the weight 34 and its supporting arm while said weight maintains the mould sections in interengagement. The actuating arms 33 are employed to separate the mould section of their respective mould assemblies for discharge or removal of completed castings therefrom at a suitable stage in the operative cycle of the apparatus, and for such purpose each of the arms 33 is equipped with a roller 35 disposed for rotation below the inner end of the arm in position to engage and ride along the upper margin of an arcuate cam track 36 suitably disposed relative to and in fixed relation with the rotatable assembly. The cam track 36 is arcuate in plan to conform with the orbit of rotation containing the rollers 35, and the cam margin of said track is so disposed and contoured as to engage and gradually elevate the roller-equipped inner end of each successive arm 33 and subsequently lower and release the arms so engaged, the amplitude of the cam action being such as will swing the associated bracket arm 31 about its hinge mounting for separation of the mould section 32 relative to the fixed section 27 a distance sufficient to permit the completed castings to drop away from the mould impressions and between the mould sections. The cam track 36 may be conveniently supported and positioned on the outer ends of radial arms 37 which adjustably engage at their inner ends with an upward extension of the free end of the fixed shaft 11, such a mounting making convenient adjustments in the length of the cam track through substitution of cam track units of varying lengths, as well as providing convenient means for selectively adjusting the operative position of the cam track relative to the orbit of the machine rotation.

The individual mould sections 27 and 32 of the mould assemblies are separately cooled for chilling effect through suitable connection in and with a system wherethrough water, or some equivalent cooling medium, may be continuously circulated. Any suitable arrangement of elements constituting a flow-circulating system for the purpose specified may be employed in co-operation with the other elements of the apparatus, a convenient and practical arrangement constituting such a system being illustrated in the drawings. As shown, a supply pipe 38 is formed as a circle of suitable radius which is mounted on and in fixed relation with the bracket units 26 beneath the mould sections 27 and is operatively connected with each of said mould sections by means of branch pipes 39 so that fluid pressure-fed to the pipe 38 will be delivered within the hollow portions of all of the mould sections 27. Cooling fluid may conveniently be fed to the pipe 38 through a supply line 40 which communicates with either end of an axial bore 41 formed through the fixed shaft 11, the opposite end of said bore being closed by means of a plug 42, and the fluid received within the bore 41 flows through openings or channels 43 disposed radially of the shaft 11 to open above the hub flange 15 into a distributing chamber provided between the outer wall of the shaft 11 and an upward cylindrical extension of the hub 13 and sealed against escape of fluid therefrom by means of suitable packing rings or glands 44. A pipe 45, or a plurality of such pipes, communicates between the distributing chamber above described and the pipe 38, so that when fluid under pressure is supplied through the line 40, such fluid is delivered to the pipe 38 and thence through the branch pipes 39 to the cooling compartments of the mould sections 27. To complete the circulation of fluid through the mould sections 27, each of said sections is provided with an outlet or return flow pipe 46 which communicates with and discharges into a circular conduit 47, of relatively large diameter, which is supported by and disposed about the bracket units 26 adjacent the pipe 38, and a discharge line 48 communicates between the conduit 47 and suitable openings formed for such purpose in the hub flange 14 to carry flow from the conduit 47 to and through said flange 14 for discharge and escape through openings in the base 10 to a sump 49 from whence the fluid may be discharged to waste or pumped for reuse through the circulating system, an annular flange 50 rising from the base 10 to terminate adjacent the under surface of the hub flange 14 serving as a baffle to confine the discharged fluid away from contact with the gears and bearings of the apparatus mounting. The movable mould sections 32 may be similarly cooled by means of fluid from the distributing chamber which is fed through a line or lines 51 to a ring-pipe 52 fixedly supported by means of brackets 53 beneath and outwardly of said mould sections 32, a flexible tube 54 connecting each of the cooling compartments of the sections 32 with the pipe 52. Return flow of fluid from the sections 32 is had through flexible tubes 55 to a return conduit 56, of ring type, which is fixedly supported on the brackets 53 adjacent the pipe 52 and from whence the fluid is discharged through a pipe 57 communicating through the hub flange 14 within the sump 49. With the arrangement illustrated and above described, a continuous flow of cooling fluid is maintained through the hollow interior of the mould sections 27 and 32 while the entire apparatus is in rotation about the shaft 11, and the desired level of cooling fluid may readily be maintained within said mould sections by proper positioning of the discharge ends of the fluid inlet pipes upwardly within the mould sections, or by regulating the volume of fluid inflow relative to outflow through any suitable means, such as valves, and the like.

The apparatus thus far described constitutes a complete ball-casting machine wherein a plurality of separable mould assemblies is mounted and rotatively driven about a fixed axis in such a manner as to maintain the mould assemblies in closed relation throughout a major portion of their orbit and to automatically separate and again close said assemblies at any position and to any desired degree relative to the rotational orbit. With the apparatus rotating at suitable speed, molten metal is fed to the mould impressions of the closed mould assemblies at the proper point in the orbit of rotation, so that the mould impressions are filled and the resulting casting cooled by circulation of fluid through the mould sections and about the mould impressions, whereafter the mould sections are automatically opened to permit the cooled castings to fall away from the apparatus prior to reclosing of the mould assemblies. While any operatively suitable arrangement of means for filling the mould impressions with metal may be employed in giving effect to the operative cycle of the apparatus shown and described, a very important feature of the invention is found in the particular method of pouring the mould impressions hereinafter described, particularly since the quality and homogeneity of the finished castings, as well as the productive speed of the apparatus, may be materially influenced by the pouring methods employed.

To give full effect to the principles of the invention, the improved ball-casting machine, constructed and arranged as illustrated and above described, is operatively installed with the axis of the shaft 11 inclined somewhat away from the perpendicular so as to dispose the plane of rotation common to the mould assembly upper surfaces at a small angle with the horizontal, and such disposition of the apparatus can conveniently be accomplished by elevating one side of the base 10 without in any way disturbing the symmetrical relationship of the elements constituting the apparatus. When the apparatus is positioned for rotation about an axis inclined away from the vertical, the point of delivery of the molten metal is located in registering relation above the center line of the mould assemblies and approximately 90 degrees in the direction of mould assembly rotation ahead of or in leading relation with the low point of the rotational plane; a spout 58 being shown as a means for supplying molten metal to the mould assemblies, which spout is located half way between the high and low points of the orbit of rotation and on that side of the apparatus where the mould assemblies are ascending as they rotate from the low to the high point of the orbit. To receive the molten metal from the spout 58 and direct flow thereof through the openings 29 and within the mould impressions of the mould assemblies, a pouring trough or track 59 is superposed on the mould assemblies in position to receive discharge flow from said spout. The trough 59 is formed of suitable refractory material, such as sand, vermiculite, and like readily-mouldable material having low heat conduction properties, in the form of sectional units adapted to overlap the joint between adjacent mould assemblies and abut to form a continuing channel wherein the molten metal may flow. The sections of the trough 59 are formed with openings adapted to register and permit communication through the trough with the openings 29 of the mould impressions, and said trough openings are preferably defined by hollow, frusto-conical necks 60, formed from the same material as the trough sections and integrally with the latter, arranged to engage within and line the mould openings 29. The trough sections 59 are supported by the separable sections of the mould assemblies and close over the line of separation between said mould sections, hence are destroyed when the mould sections are separated for release of castings and must be replaced as the mould assemblies are rotated for recharge. A supply of the trough sections 59 is prepared in advance and the successive trough sections are placed in position on the mould assemblies after the latter have been closed ready for pouring, so that a number of trough sections 59 are in position to form a trough of considerable length on the mould assemblies approaching the spout 58.

It is the function of the inclination given to the plane of mould assembly rotation, in cooperation with the pouring trough 59 and filler neck liners 60, to maintain a supply of molten metal adjacent the point of last cooling of each casting to fill shrinkage voids, pipes, and the like, for the production of a casting free from faults, of high quality, and uniformity of texture.

This result is accomplished by permitting the molten metal to flow down the incline of the trough 59 for some distance, filling the mould cavities traversed, before the apparatus is placed in rotation, and thereafter so adjusting the rate of metal flow to the speed of apparatus rotation as to successively fill the mould impressions approaching the spout 58 well in advance of their passing under said spout, so that the completely filled mould impressions are moved for a distance under the stream of molten metal flow along the trough 59, the low heat-conducting properties of the trough 59 and liners 60, together with the heat of the molten metal in the trough 59, serving to maintain a supply of metal in fluid condition in the filler necks or hot tops communicating with the mould impressions and hence in position to flow into and fill any voids, cavities, and pipes which may develop in cooling of the casting, and at the same time provide a path of escape for air and other gases which might be entrapped within the mould or solidifying metal with undesirable effect on the finished product.

In the practice of the improved method through the improved apparatus shown and described, the point of metal feed is located between the high and low points of the rotational orbit on that side of the machine where the mould assemblies are ascending, the cam track 36 is arranged to open the mould assemblies some 120 to 180 degrees of rotation after the moulds have passed under the charging spout and to maintain the mould assemblies open long enough for complete discharge of finished castings, and sections of the trough 59 are placed in position on the mould assemblies for some 90 degrees of rotation in trailing relation with the spout position, whereafter molten metal is fed through the spout 58 to the trough 59 and is permitted to flow down the incline of said trough, filling the mould impressions traversed, a distance, perhaps corresponding to three or more mould sections, best suited to the character and temperature of the metal employed and the type, size and quality of the casting desired, whereafter the apparatus is set in rotation in a direction such as will bring the poured mould impressions upwardly toward and beneath the spout 58 at a speed so adjusted to the rate of metal flow as to maintain the point of mould impression pouring in spaced relation downwardly of the incline away from said spout. As will be obvious, successive sections of the trough 59 are placed in position on the rotating mould assemblies to maintain the continuous character of said trough, cooling fluid is continuously circulated through the mould sections to cool and chill the metal filling the mould impressions, molten metal flow is maintained in the desired quantity from the spout 58, and the cam track 36 automatically functions to separate successive mould assemblies after cooling of the castings therein is completed and thereby permit discharge of the castings from the apparatus; the opening of mould assemblies destroying the trough sections carried thereby so that when the mould assemblies are automatically permitted to reclose they are then ready for a repetition of the operative cycle. By this means is provided a simple, rapid, and economical method of continuously and repetitiously moulding articles of metal with a high degree of uniformity, homogeneity and quality. The cooperating mould sections may of course carry mould impressions of various shapes and sizes, and the metal supplied to fill the mould impressions may be of any specific character and alloy suited to the production of the castings desired, the adaptation of the method and apparatus to the production of grinding balls being but typical of the many specific applications to which the method and apparatus is adapted.

Since many changes, variations, and modifications in the specific form, construction, and arrangement of the elements shown and described, may be had without departing from the spirit of my invention, I wish to be understood as being limited solely by the scope of the appended claims, rather than by any details of the illustrative shown and foregoing description.

I claim as my invention:

1. The method of casting metal which consists of moving a gang of gated moulds along an upwardly-inclined path, providing a continuous pouring trough on the upper surface of said mould gang in heat-insulating communication through the mould gates, feeding molten metal to said trough for gravity flow therealong and consequent successive filling of progressively-lower moulds, and subsequently correlating the rate of metal flow with the speed of mould travel to maintain the point of mould filling well below the point of metal feed and at the lower end of a stream of molten metal in said trough whereunder the filled moulds travel for escape of gases and filling of shrinkage cavities during the cooling of their contents.

2. The method of casting metal which consists of arranging a gang of gated moulds for travel

along an upwardly-inclined path, providing a continuous pouring trough on the upper surface of said mould gang in heat-insulating communication through the mould gates, feeding molten metal to said trough for gravity flow therealong and consequent successive filling of progressively-lower mould cavities, and subsequent moving of the mould gang upwardly past the point of metal feed at a rate of speed such as will maintain the point of mould filling at a gate several moulds below the point of metal feed and at the lower end of a stream of molten metal in said trough whereunder the filled moulds travel a considerable distance for escape of gases and filling of shrinkage cavities during cooling of their contents.

3. The method of casting metal which consists of mounting a gang of gated moulds in end adjacency for travel along an upwardly-inclined path beneath a metal-pouring spout, providing a refractory pouring trough along the upper surface of said mould gang in heat-insulating communication through the mould gates, feeding metal from said spout into said trough for gravity flow therealong and consequent successive filling of progressively-lower mould cavities, and subsequently moving said mould gang upwardly along its path of travel and beneath said spout at a rate such as will maintain a stream of molten metal in said trough for the filling of mould cavities well before their passage under the pouring spout and whereunder the filled moulds travel a considerable distance for escape of gases and filling of shrinkage cavities during cooling of their contents.

4. The method of casting metal which consists of mounting a gang of gated moulds having a pouring trough on its upper surface in heat-insulating communication through the mould gates for travel along an upwardly-inclined path beneath a pouring spout, feeding molten metal from said spout into said trough, subsequently moving said mould gang upwardly along its inclined path beneath said spout, and correlating the rate of molten metal flow with the speed of mould travel to maintain a stream of metal in said trough for complete filling of the successive mould cavities well prior prior to their passage under said spout and whereunder the filled moulds travel a considerable distance for escape of gases and filling of shrinkage cavities during cooling of their contents.

5. The method of casting metal which consists of mounting a gang of gated moulds for rotation in a plane inclined to the horizontal, maintaining a continuous, refractory pouring trough on the upper surface of and in heat-insulating, gated relation with the mould gang which moves along an upwardly-inclined path, feeding molten metal to said trough during its upwardly-inclined travel, and correlating the rate of metal flow with the speed of mould travel to maintain a stream of molten metal in said trough for successive filling of mould cavities below and well in advance of their passage under the incoming metal flow and whereunder the filled moulds travel a considerable distance for escape of gases and filling of shrinkage cavities during initial cooling of their contents.

6. In metal-casting apparatus having a turntable rotatable in a plane inclined to the horizontal, means for rotating said turntable, separable mould assemblies in end adjacency circumferentially of said turntable, and means for automatically opening said mould assemblies as an incident of turntable rotation and for maintaining said mould assemblies closed during the ascending portion of their rotational orbit, means for supplying molten metal to fill the cavities of said mould assemblies, said means comprising frusto-conical gates opening at their larger ends through the upper surfaces of the mould assemblies, a pouring trough carried by said mould assemblies during the ascending portion of their orbital travel, said trough consisting of a plurality of like end-abutting sections of heat-insulating, refractory material disposed on the upper surfaces of the mould assemblies in covering relation with the parting line between the separable units of each assembly, each of said trough sections having a longitudinal channel intersecting its upper surface, frusto-conical bosses depending from its lower surface to engage within and cover the walls of the corresponding mould gates, and a passage communicating through each of said bosses and with the flow channel of its section, and a molten metal delivery spout fixedly positioned to discharge molten metal to said trough during ascending orbital travel of said mould assemblies, whereby molten metal is caused to flow downwardly of said trough and against the direction of turntable rotation.

7. Metal-casting apparatus comprising a fixed shaft upstanding at a slight angle to the perpendicular, a turntable rotatable about and in perpendicular relation with said shaft, means for rotating said turntable, outwardly-facing mould sections bracket-supported in end adjacency circumferentially of and above said turntable, complementary, inwardly-facing mould sections hingedly supported for actuation through a vertical arc into and out of registration with said fixed mould sections, means operable as an incident of turntable rotation to maintain the mould sections of each pair in closed registration during ascending travel of the turntable and to separate the mould sections of each pair for discharge of their contents during descending travel of said turntable, pouring gates formed in and opening through the upper surface of said mould sections, longitudinally-channeled, refractory pouring trough sections, each formed with an apertured boss adapted to engage and seat within the pouring gates of the mould assemblies, disposed in end-abutting relation on the closed mould assemblies during ascending travel of the latter, and means for feeding molten metal to the trough formed by said sections.

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