

Sept. 11, 1934.

L. G. NILSON

1,972,945

APPARATUS FOR AND PROCESS OF CASTING METALS

Filed Oct. 30, 1930

3 Sheets-Sheet 1

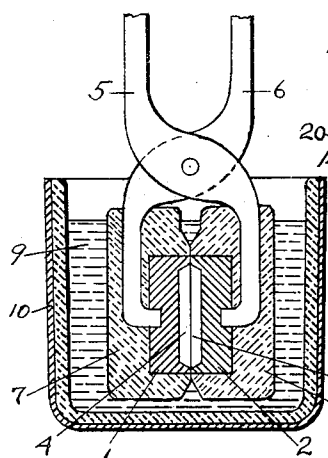


Fig. 1.

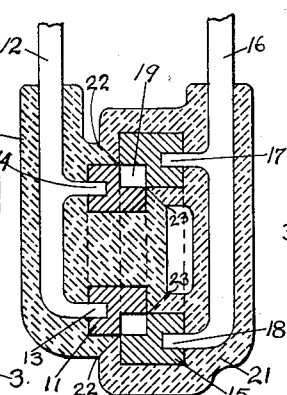


Fig. 2.

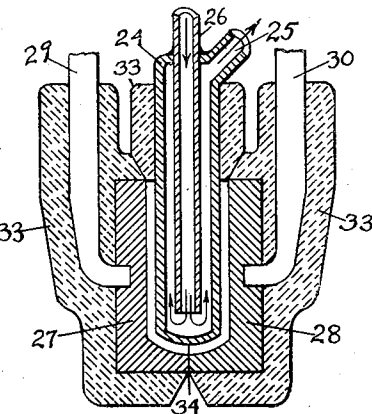


Fig. 3.

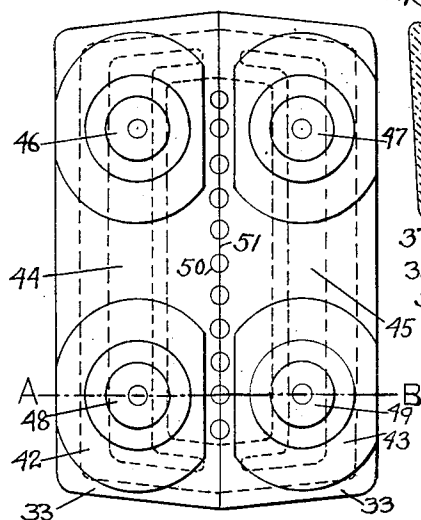


Fig. 5.

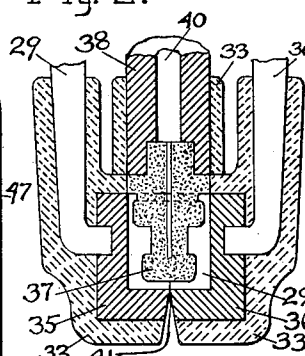


Fig. 4.

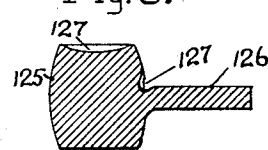


Fig. 22.

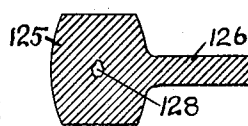


Fig. 23.

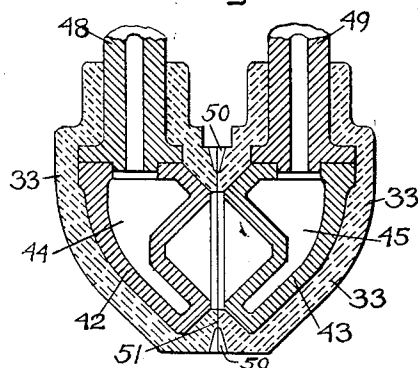


Fig. 6.

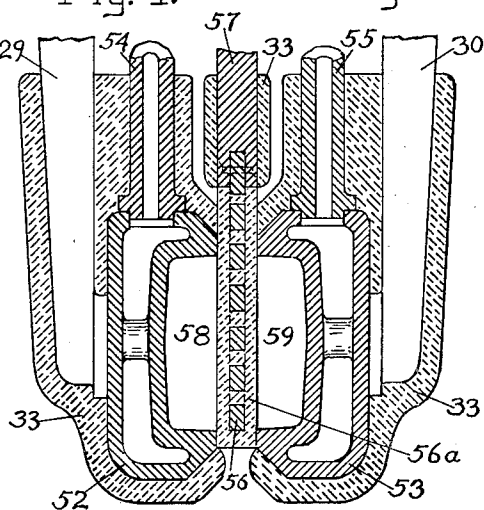


Fig. 7.

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3 Sheets-Sheet 2

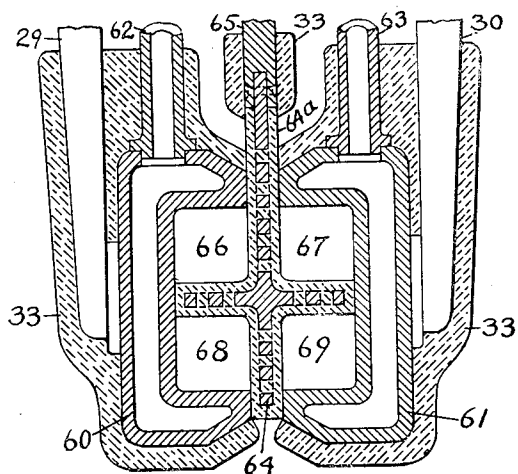


Fig. 8.

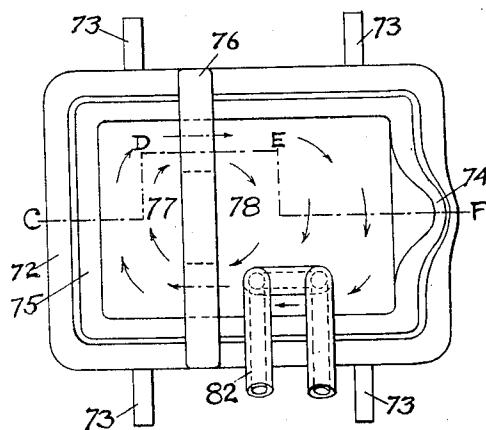


Fig. 9.

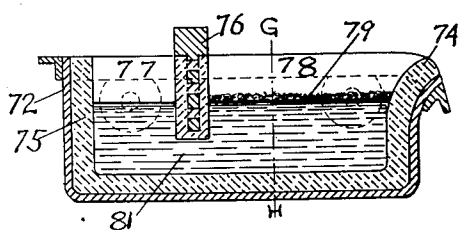


Fig. 10.

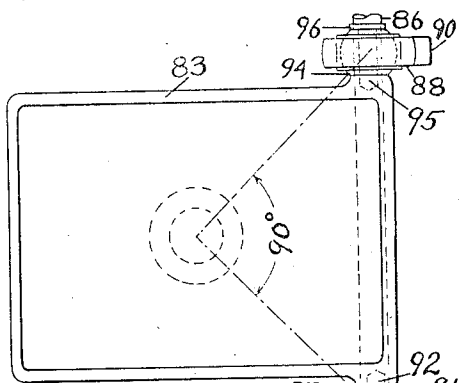


Fig. 12.

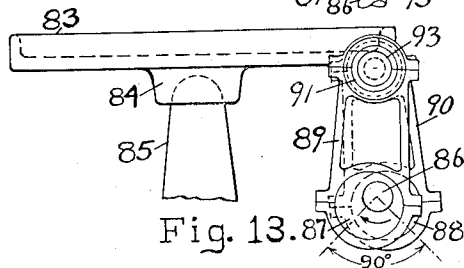


Fig. 13.

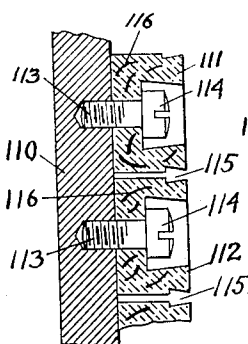


Fig. 18.

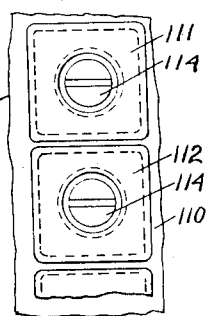


Fig. 19.

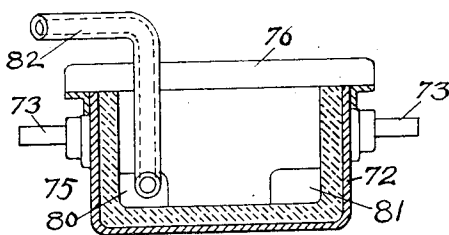


Fig. 11.

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3 Sheets-Sheet 3

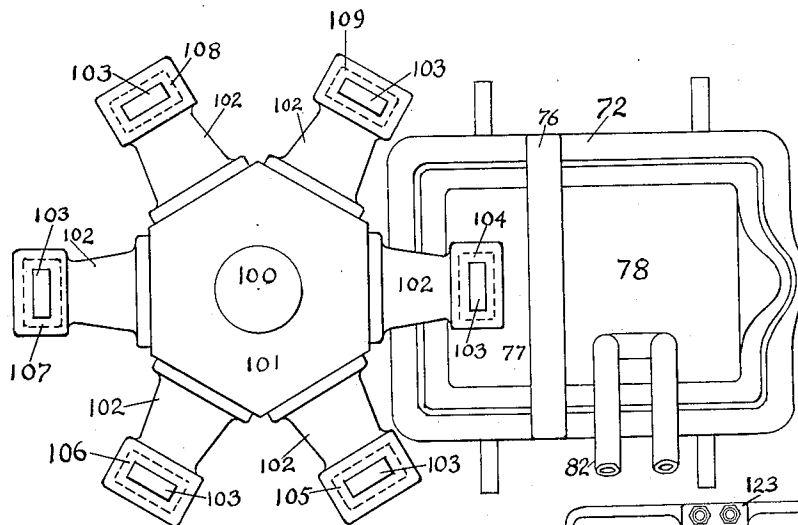


Fig. 14.

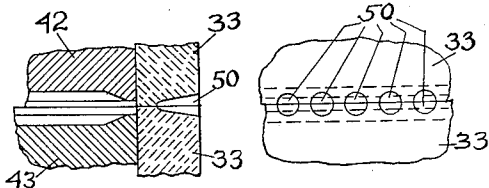


Fig. 16.

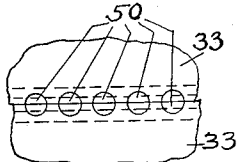


Fig. 17.

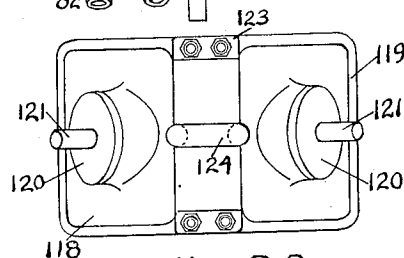


Fig. 20.

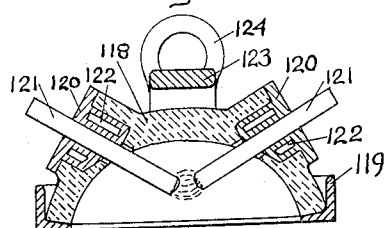


Fig. 21.

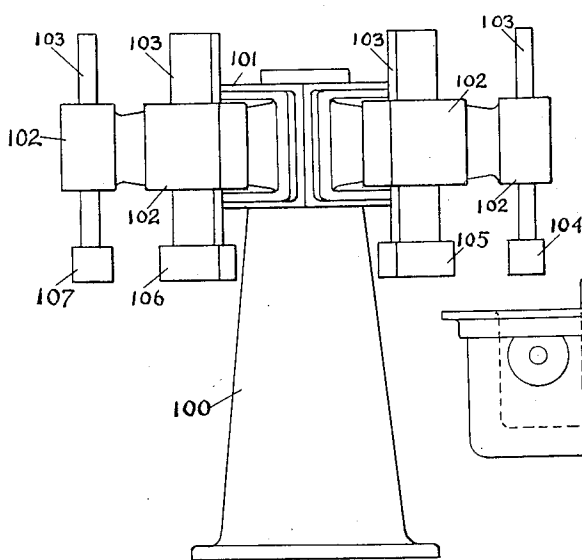


Fig. 15.

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UNITED STATES PATENT OFFICE

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APPARATUS FOR AND PROCESS OF
CASTING METALS

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Application October 30, 1930, Serial No. 492,253

8 Claims. (Cl. 22—210)

This invention relates to improved methods and means for producing metal castings and more especially castings made through the use of permanent or semi-permanent molds. The process and appliances therefor are particularly well suited to the production of castings of metals having high temperature melting points, as iron, steel, nickel, copper, bronze, etc.

My invention contemplates the provision of means for overcoming many of the difficulties which prevail today in the art of casting metal. It may be pointed out that under the customary methods of producing castings, the temperature of the pouring metal must be high in order that it may run freely and reach the most remote corners of the mold. Inasmuch as early solidification takes place in the restricted sections of the mold, shrinkage defects usually occur. With high temperature pouring conditions moreover the cooling is necessarily slow, particularly with sand molds, and results in coarse grain. This invention discloses a method and apparatus wherein it is feasible to form castings under conditions where the metal is at a relatively very low temperature, above the plastic or semi-fluid state, practically eliminating shrinkage defects.

An important aim of the invention is the making of castings having smooth surfaces, which are free from scale and true to form, irrespective of their size. An added object is to effect fine-grained structure, as compared with castings produced by the more usual methods, together with freedom from blow-holes, inclusions and other defects. A still further object is to bring about economy in manufacture and greater uniformity in product.

In the carrying out of my invention, I employ a mold or die having separable portions which may be constructed of metal alone, or a combination of metal and refractory materials. The mold when joined, i. e., when closed on itself, is plunged into a properly prepared molten metal bath to a depth below its dross surface portion, after which it is opened to allow entry of the molten material. The mold is then quickly closed, lifted with its contents out of the bath, opened after the necessary time has elapsed to permit the metal to freeze and the casting ejected.

While in its broad aspects a like procedure employing metal molds was used many years ago for casting soft metals, I have devised and incorporated therein certain features designed to effect greater speed in casting, higher precision and uniformity and economy in manufacture in order to render the method more suited to present-day

high-temperature requirements and needs. To characterize the improved process I have termed it "dip-casting".

Briefly described, the method of making dip-castings according to my improved process includes means for shielding the exterior surfaces of the mold for their protection against early deterioration, the freezing of metal thereto and also to avoid undue loss of heat from the bath as the result of excessive chill from the mold. It includes combinations of permanent and porous cores to allow the casting of intricate shapes and also means for accelerating, retarding or otherwise controlling the cooling of one portion of the mold or casting relative to another, thereby facilitating perfection of castings as to form and quality. These and other equally important features of novelty, such as means for controlling the temperature of the casting metal within a desired low range for the prevention of undue shrinkage in cooling, are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention and the advantages possessed by it, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described various embodiments of my invention.

In the drawings:

Fig. 1 is a view in sectional elevation of one form of divided mold construction with co-operating elements, which I may employ.

Fig. 2 is a view in sectional elevation of a divided mold construction suited to the casting of ring blanks.

Fig. 3 is a view in sectional elevation of a divided mold construction embodying a water-jacketed metal core.

Fig. 4 is a view in sectional elevation of a divided mold employed in combination with a sand core.

Figs. 5 and 6 are views in plan and sectional elevation respectively of a water-jacketed divided mold designed for the casting of ingots.

Fig. 7 is a view in sectional elevation of a water-jacketed divided mold designed for the simultaneous production of two billets.

Fig. 8 is a view in sectional elevation of a water-jacketed divided mold designed for the simultaneous production of four billets or ingots.

Figs. 9, 10 and 11 are views in plan, sectional side, and sectional front elevation, respectively, of a dipping tank.

Figs. 12 and 13 are views in plan and elevation respectively, of a tilting table designed to pro-

mote circulation of molten metal in the dipping tank.

Figs. 14 and 15 are views in plan and elevation respectively of a construction suited to the production of castings under automatic or semi-automatic operation.

Fig. 16 is a view in side sectional elevation showing the position of the refractory on the divided mold and Fig. 17 is a front view of the same.

Figs. 18 and 19 are views in side sectional and front elevation, respectively, of refractory tiles or blocks show-method of attaching same to the mold.

Fig. 20 is a plan view and Fig. 21 is a view in sectional elevation of an electric arc heating device which may be employed in combination with the dipping tank of Figs. 9, 10 and 11 for the purpose of raising the temperature of the metal therein.

Figs. 22 and 23 are views illustrating the location of shrinkage cavities under different methods of casting.

Referring to Fig. 1, the separable parts 1, 2 of a metal mold or die, which fit closely together along relatively narrow parting faces designated as 3, each have recessed portions forming a cavity 4 designed for the casting of a body of disk form, all as shown in sectional elevation. Permanently attached to the parts 1 and 2 are the short arms of a pair of tongs 5, 6. Refractory coatings 7, 8 of graphite, fire clay, asbestos fibre or other suitable material are attached to and surround as far as possible the mold itself which is submerged in a molten metal bath 9 contained in a crucible 10, as shown in section.

Preliminary to the use of the apparatus of Fig. 1, the mold should be preheated, before inserting in the bath, to a degree sufficient to insure its freedom from moisture. It will however be understood that the mold will always be at an elevated temperature after the production of castings is under way. In the process of forming the castings the closed mold is inserted in the metal 9 in such manner that the recessed portion 4 will be well below that surface region of the bath 9 where dross may be expected to be present. Then the mold is opened by means of the tongs 5, 6 whereupon the molten metal has free access to its relatively cool inner surfaces and parting faces. A slight amount of metal will immediately freeze thereon to form a thin coating of solid metal, whereupon the mold is again closed to retain an amount of liquid metal sufficient to entirely fill the recess 4. As the next step, the mold is withdrawn from the bath, leakage of metal therefrom being effectually prevented by the thin chilled coating of solid metal at the parting faces 3 welding together. After a proper interval of time has elapsed so as to permit freezing of the metal in the cavity 4, the mold is opened and the casting ejected.

In Fig. 2 I show in sectional elevation a mold of somewhat more complex form, which is designed for the casting of ring blanks. Referring to Fig. 2, an annular metal mold portion 11 mounted upon a metal carrying arm 12 having lugs 13, 14 which are secured to such mold portion 11 at points 180° apart, coats with an annular metal mold portion 15 mounted upon a metal supporting arm 16 which has lugs 17, 18 which are secured to the portion 15 at points likewise 180° apart. The two mold portions 11 and 15 are so positioned relative to each other that when they are in contact there is an annular region 19 formed which is designed for receiving molten metal in the

process of casting. Surrounding the mold portions 11 and 15 respectively and a portion of the carrying arms 12 and 16 therefor, are refractory coatings 20, 21 which coat at parting faces designated as 22, 23. The supporting arms 12 and 16 are connected with an operating mechanism, not shown, by means of which the mold portions 11 and 15 are brought together or separated.

The process of forming a casting through the use of the construction shown in Fig. 2 is entirely similar to that described in connection with the construction of Fig. 1.

In Fig. 3 I show in sectional elevation a divided permanent mold arrangement, which is designed for casting a cylinder having one closed and one open end, in combination with a metal core which is water-jacketed to control temperature. Referring to Fig. 3, a tubular metal cylinder 24 which is closed at one end and has a vent 25 eccentrically disposed at the other, surrounds a concentrically disposed pipe 26 passing through its end and connecting to a source of water supply not shown. The cylinder 24 and pipe 26 unite to form a water-jacketed core. The divided mold portions 27, 28 are attached to operating arms 29, 30. Mold portions 27, 28, operating arms 29, 30, and that portion of the core 24 which is exterior to the mold are lagged with refractory material 33. The space between the cylinder 24 and the divided metal portions 27 and 28 receives the casting metal. The parting faces of the mold are indicated at 34.

The cylinder 24 and pipe 26 are supported by outside means, not shown, the latter being connected at its upper end to a source of fluid supply in such manner that the fluid passes through pipe 26 into cylinder 24 at its lower end, thence up and about the annular space between such cylinder 24 and the outside walls of the pipe 26 as indicated by the arrows to emerge through the vent 25, which is connected to a drain system not shown. The supporting means for the cylinder 24 and the pipe 26 are in fixed relation to the mold operating means so that such cylinder shall properly seat when the mold is closed.

The operation of the appliance of Fig. 3 is similar to that of the appliances of Figs. 1 and 2, except that when the mold is closed after receiving its metal the cylinder 24 is flushed inwardly by the cooling fluid so as to cause it to shrink away from the casting for the purpose of facilitating the ejection of the latter.

Under some conditions it is desirable to use cores of sand or the like and in Fig. 4 I show in sectional elevation a divided mold arrangement which employs a core in combination with a suction device, the latter for the dual purpose of holding the core in place during the forming of the castings and to draw off gases formed when the casting metal strikes such core. Referring to Fig. 4, mold portions 35, 36, secured to operating arms 29, 30, have interiorly a sand core 37 which is socketed at its upper end into a metallic tubular head 38 supported by outside means not shown, the mold and core coating to provide a space 29 designed for the casting of a conventional type automobile piston. The bore 40 of the tubular head 38 is connected to a vacuum pump system, not shown, in such manner that the core 37 is held in place by suction. Operating arms 29, 30, the exterior surfaces of the mold portions 35, 36 and the tubular core head 38, are lagged with refractory material 33. The parting faces are indicated at 41.

The operation of forming castings by means of

the mold of Fig. 4 is similar to those previously described, the supporting means for the tubular head 38 having a fixed relation to the mold operating means so that the core 37 shall be in proper position when the mold is closed.

In Figs. 5 and 6 I show in plan and sectional elevation respectively a water-jacketed divided mold designed for the casting of ingots. Referring to Figs. 5 and 6, in which Fig. 6 represents a section along the line A—B of Fig. 5, extended hollow divided mold portions 42, 43 are fastened to, at their respective end regions, and supported by, tubular operating arms 46, 47, 48 and 49 which serve also for the ingress and outlet of a cooling fluid which passes through the interiors 44 and 45 of the respective mold portions 42 and 43. For example, mold portion 42 has fluid ingress and outlet through arms 46 and 48 respectively, while mold portion 43 has corresponding fluid ingress and outlet through arms 47 and 49 respectively. Lagging 33 of refractory material is applied to cover the whole exterior portion of the mold and those portions of the tubular arms which would contact with the molten metal in the process of forming a casting.

It will be noted, in connection with the construction disclosed in Fig. 6, that the refractory material is so disposed that when the mold is closed the refractory in effect forms a part of the mold itself and determines the thickness of the casting, 51 designating here the parting faces. Conical holes 50 along the vertical parting lines serve to facilitate escape of surplus metal as the mold is closed.

It is practicable by the method of my invention to produce more than one casting in a single operation and in Fig. 7 I show a view in sectional elevation of one end of a divided mold designed for casting billets or slabs consisting of hollow mold portions 52, 53 fastened to and supported by operating arms 29, 30. It will be understood that additional similar pairs of operating arms are required where the cast object is of considerable length, as in the case of slabs, etc. 56 is a partition, preferably of metal and coated with a refractory material 56a, which is secured to and supported by a member 57 in such manner that it will be central to the mold when the latter is closed. The partition 56 runs longitudinally to provide similar interior regions 58, 59 for the reception of molten metal. A tubular connection 54 giving access to the hollow interior of the mold portion 52 provides for the ingress of a cooling fluid while a similar tubular connection, not shown, provides for the egress of such fluid. In like manner the tubular connection 55 provides for the ingress of cooling fluid to the hollow interior of mold portion 53 while a similar tubular connection, not shown, provides for the egress of such fluid. 33 is the refractory. It will be clear that the operation of forming castings through the use of the construction of Fig. 7 differs in principle in no way from those previously described.

The construction shown in Fig. 7 combining the jacketed system, for rapid cooling, offers a peculiar advantage in that due to the cooling taking place more rapidly at one region of the cast body than another quite some control over the location of impurities may be had. For example, in forming such bodies as slabs by the use of this construction, the impurities in the casting metal are segregated in that region of the slab which cools last, i. e., at or near the surface bordering on the partition 56.

In Fig. 8 I show a view in sectional elevation of one end of a water-jacketed mold construction designed for the casting of four square-sectioned billets or ingots in the one operation. Referring to Fig. 8 hollow mold portions 60, 61 are fastened to and supported by operating arms 29, 30 at one end region while similar operating arms not shown are fastened to and support the other ends of such molds. A tubular connection 62 giving access for the cooling fluid at one end of the hollow interior of the mold portion 60 provides for ingress, while a similar tubular connection at the other end provides for egress. Similarly, the tubular connection 63 provides for ingress of the cooling fluid at one end of the hollow interior of the mold portion 61, while a similar tubular connection, not shown, provides for egress. 64 is a partition of cruciform shape, preferably of metal and coated with a refractory 64a, while is secured to and supported by a member 65 and runs centrally throughout the mold to provide four spaces 66, 67, 68, 69 for the reception of the casting metal. 33 is the protective refractory. The method of forming castings by the construction shown in Fig. 8 differs in no way from those previously described with a like advantage as in the construction of Fig. 7 with regard to the localization of impurities by control of the cooling conditions.

While in connection with Fig. 1 I have shown the liquid casting metal as contained in a crucible I do not limit myself to such construction as it will be apparent that the container of the metal to be cast may have many forms. I may point out that the high speed production of castings of good quality calls for many precautions being taken not only to insure uniform temperature of the liquid metal, but also that it be homogeneous in character. To this end I have devised a so-called "dipping tank" which has many advantages, as is disclosed in connection with Figs. 9, 10 and 11, showing plan, part sectional side and part sectional front elevation respectively.

Referring first to Fig. 10, which represents a sectional side elevation along the line C—D—E—F of Fig. 9, a metal container or tank 72 having lifting lugs 73 and a pouring lip 74 is lined on the inside with refractory material 75 and contains liquid casting metal brought thereto by means of a ladle or other convenient method. A partition 76 arranged as shown is provided to divide the dipping tank into two portions 77, 78. The metal in one of these portions 78 has its surface protected by flux or slag 79 to prevent oxidation or undue radiation while the metal in the other portion 77, is free of surface flux and is designed to receive the mold. To provide for free passage of metal between the two portions of the dipping tank the partition 76 is cut out at its lower corners as indicated at 80, 81 in Fig. 11, which is a front sectional elevation along the line G—H of Fig. 10. A pipe loop 82 for circulating a cooling medium is provided as shown, this being for the purpose of maintaining the liquid metal at a temperature sufficiently low to obviate undue shrinkage in the finished casting.

In the use of the dipping tank illustrated in Figs. 9, 10 and 11, it is highly important that the liquid metal be held at a uniform temperature in dipping space 77 and this is best met by providing means for insuring free circulation. To this end I have designed a tilting table upon which the dipping tank just described may be mounted and which is illustrated in Figs. 12 and 13 in plan and elevation respectively.

Referring to Figs. 12 and 13, a table or plat-

form 83 designed to support the tank 72 of Figs. 9, 10 and 11, has on its under side a centrally located boss 84 provided with a semi-circular recess which engages the semi-spherical end of a supporting pillar 85, the arrangement forming a universal joint bearing. A shaft 86 supported in pedestal bearings not shown, is fitted at or near either end with eccentrics 87 and 88 which are keyed at 90° with respect to each other. A connecting rod 89 engages at one end with eccentric 87 and at the other end with a spherical bearing bushing 91, which is secured to the table 83 by means of a pin 92 having a head 93. Similarly, a connecting rod 90 engages at one end with eccentric 88 and at the other with a spherical bearing bushing 94 secured to the table 83 by means of a pin 95 having a head 96.

The connecting rods 89 and 90 are attached at points 90° apart in a horizontal plane with respect to the center of the table 83. Since the eccentrics 87 and 88 are also spaced 90° apart, as described, it follows that when the shaft 86 is rotated clockwise, as designated by the arrow in Fig. 13, there results a series of four vertical oscillations of the table 90° apart which produces a true gyratory motion of the liquid metal in the tank 72, as illustrated by the arrows of Fig. 9.

My invention lends itself well for mass production of castings under automatic or semi-automatic operation and in Fig. 14 I show in plan and in Fig. 15 in elevation a multiple-head turret casting machine for this purpose in combination with a dipping tank similar to that illustrated in Figs. 9, 10 and 11. It will be understood that the design of the casting machine can be varied many ways, particularly with regard to the operation mechanisms. In order not to confuse the description of the main invention, the casting machine is represented diagrammatically.

Referring to Figs. 14 and 15, a pedestal 100 supports a turret 101 having extensions 102, supporting operating heads 103 terminating in molds 104, 105, 106, 107, 108, 109. As will be seen, each mold may in turn be brought into position for immersion in the tank 72, the control of the turret, operating heads and molds being effected by mechanical, hydraulic, pneumatic or electrical means or a combination of several or all. In the position shown, mold 104 is ready to dip, 105 is in a position to drop its casting, which latter may be conveyed off by suitable means, while molds 106, 107, 108 and 109 are open to inspection, the insertion of new cores, etc.

I have pointed out in this specification that my improved process for the making of castings includes means for shielding the exterior surfaces of the mold for its protection against early deterioration, freezing of metal thereto and to obviate too rapid loss of heat from the molten contents and I have described in this connection the preferred constructions of using the refractory material toward these ends. In connection with the construction of Fig. 1 the refractory material completely surrounds the mold when the latter is closed for the purpose of taking up the molten material. In Figs. 5 and 6 a construction is disclosed in which the refractory forms part of the closed mold and in Figs. 16 and 17 I show this method of construction in greater detail.

Referring to Figs. 16 and 17, Fig. 16 shows a view in section of a mold joint similar to that of Figs. 5 and 6 while Fig. 17 is a view in elevation wherein the divided mold portions are designated as 42, 43, as before, and 33 is the refractory. This refractory is formed so that when the

mold is closed there is presented a series of conical holes 50 extending part way through such refractory and serve for the purpose of facilitating the escape of surplus liquid metal as the mold is closed. The use of refractory material as a parting face promotes the making of castings true to size as there is no tendency of the liquid metal to chill on such refractory. When the parting faces are of metal, as for example in the construction shown in Figs. 1 and 3, the thickness of the casting will vary with the thickness of the chilled film formed on such faces. Allowance for this may be made in designing the mold, but absolute uniformity of size of the castings will depend to an extent upon the skill and judgment of the operator.

It is important that the refractory be of considerable mechanical strength combined with such minimum thermal conductivity as will prevent molten metal adhering thereto. Such refractory may be a mixture of graphite, fire clay, asbestos fibre and the like. Although the refractory can be applied over the mold and its cooperating parts while in a plastic state, pieces of reinforcing material such as nichrome or other heat-resisting metal should be interspersed therein. It is frequently desirable to apply such refractory in segments or blocks, providing means for attachment as shown in Figs. 18 and 19. Referring to Figs. 18 and 19 in which 18 is a side sectional view and 19 a front view, the outer wall section of a mold or die 110 to which tiles or segments of refractory material 111, 112 are attached by means of screws 113 is shown, the refractory being countersunk to receive the screw heads 114. Also, the segments 111, 112 have, as shown, grooves about their outer edges so that when assembled there is provided a dove-tail opening 115 between adjacent segments. This dove-tail opening and the undercut countersinking for the screw heads should be filled with an elastic refractory cement. The segments 111, 112 are preferably constructed with reinforcement consisting of short pieces of heat-resisting metal 116 imbedded therein.

In connection with the use of the dipping tank illustrated in Figs. 12 and 13, it may be advisable under some circumstances to provide means for maintaining the temperature of its liquid contents constant, or for the purpose of increasing such temperature. This can be done in various ways, through the use of electric resistance, electric arc, gas or oil-fired devices. For the purpose I preferably employ an electric arc heating unit, as illustrated in Figs. 20 and 21, wherein Fig. 20 is a plan and Fig. 21 a sectional elevation view of a unit designed to fit over the reservoir portion 78 of the dipping tank 72 of Figs. 9, 10 and 11. Referring specifically to Figs. 20 and 21, a body 118 of refractory material having an inner arched dome based upon a metal frame 119 is provided with guide bushings 120 of heat resistant material through which project carbon electrodes 121. The electrodes 121 are so positioned that when connected to a source of power supply and an arc is struck, such arc will be at the focal point of the arched dome, the latter being designed to be approximately parabolic in shape, so that the maximum heat will be reflected downward. The bushings 120 are cored to provide inner annular spaces 122, as shown, to permit of water or other cooling. A fixed bail 123 having an eye 124 is provided to permit ready handling of the heating unit.

For a more complete understanding of my

process and the advantages to be gained by it, it is important to consider the transition changes accompanying the solidification of molten metal. If the cooling is slow the ensuing crystal structure is of large grain size which is conducive to weakness. Moreover the structure is variable as to composition, that portion of the casting which has solidified last usually carrying the unavoidable metal impurities in concentrated form. All substances expand when heated and contract upon cooling. In liquids the volumetric change is greater than in solids. It therefore follows that if a liquid metal can be poured into a mold at a temperature near its freezing point, the tendency for shrink cavities to form will be much less than when pouring takes place at high temperatures. Accompanying solidification there is volume expansion or contraction. In cast iron, for example, solidification causes expansion. If the metal has been poured at too high a temperature the contraction in the mold may exceed the expansion which occurs in solidification, thus causing shrink holes. Under the usual conditions of forming castings the pouring temperature must necessarily be high. In my dip-casting method such temperature however may be quite low, as pointed out.

While the melting of the metal is no part of my invention I would point out that the temperature of the furnace must be high enough so that all the ingredients of the bath are thoroughly melted and amalgamated. Also, that all reactions are completed before the molten metal is poured into the dipping tank. Generally a temperature which satisfies these requirements is too high to avoid harmful shrinkage. Therefore, as a preliminary to casting and dipping I reduce the temperature of the metal. For example with reference to the dipping tank of Figs. 9, 10 and 11 I employ the pipe loop 82 for circulating a cooling medium. This is a more desirable method of reducing temperature than the common one of dissolving scrap and the like, which introduces oxides and causes inhomogeneity. The temperature is reduced to a point, experimentally determined, which is dependent upon the composition of the metal and the size, shape and nature of the castings to be made. In this connection it will be noted that I provide means for heating as well as cooling the metal in the dipping tank of Figs. 9, 10 and 11.

The molds which I employ have refractory coatings on their exterior surfaces. When such molds are immersed in the bath, at a depth where clean and homogeneous metal is to be found, upon opening, the metal will rush in from all sides filling up the space between the parted mold portions almost instantaneously. As the metal encounters the comparatively cold surfaces of the mold interior it will chill on the respective faces in the form of a thin solidified sheet. The mold should then be closed quickly, before the heat from the bath proper causes redissolving of such chilled metal. If the timing is correct, this chilled metal protects the faces of the mold from eddies and erosive action as the surplus metal is squeezed out. Upon closing of the mold a seal is provided as the solidified sheets meet at the parting faces, and due to these welding together they retain the correct amount of metal.

It has been indicated that divided molds used in connection with a liquid metal bath have been used hitherto. However, such molds were unprotected by a refractory and it was necessary to let them remain in the bath until they reached

approximately the bath temperature, otherwise the mold itself would be coated upon its exterior surfaces with metal which would prevent its being opened later for the ejection of the casting. When protected by refractory material, the mold will remain at a much lower temperature than when unprotected, while at the same time it is protected from erosive action. In fact, it would be practicable by the use of refractory protection and adequate cooling to employ a copper mold for the making of steel castings under my process.

It will thus be seen that by my improved method the metal flows without restriction and from many directions, having only a short distance to travel. These advantages, combined with the lower pouring temperature and possibility of cooling from all surfaces largely eliminates the possibility of shrinkage cavities. If such occur, and this is at times unavoidable, they are to be looked for in the central interior of the casting where the harmful effects are least, instead of near or at the surface region. This is well illustrated in connection with Figs. 22 and 23 showing a cast body having a massive portion 125 combined with an extension of smaller section 126. With reference to Fig. 22, 127 represents shrinkage cavities which may be expected under the usual process employing a sand mold, while 128 of Fig. 23 represents a single cavity of small size, located much more favorably as far as harmfulness is concerned, which may occur under the dip-casting method.

In some cases it is desirable to employ means for keeping the mold relatively cool, where the casting is large in size relative to the mold itself. For such purpose I prefer to employ a jacketed mold as described, in connection with the construction disclosed in Figs. 6, 7 and 8. Such means for controlling the temperature of the mold are also applicable in the control of the cooling of the casting itself and offers a method of localizing the segregation as indicated in the discussion of the construction disclosed in Figs. 7 and 8. Here the means described causes the segregation to locate in the vicinity of a surface, which can be readily planed away, resulting in less loss than would occur through the cropping necessary under the usual methods of casting ingots.

It is important in the case of ingots or billets that cavities of all kinds be guarded against. I therefore may employ compression at times, particularly in combination with the construction illustrated in Figs. 5 and 6. The operation of forming a casting using power compression is as follows: The mold is lightly closed and after a short period has been allowed to intervene to permit of formation of a rather thick shell on the mold parting faces, an elastic follow-up pressure is applied by means of the operating arms. This is carried out by means of pneumatic, hydraulic or electrical means or the like, to compress the casting as fast as the contraction or expansion of the metal allows.

Under some conditions, especially for the mass production of small commercial castings, the interior of the mold faces may have inserts of a refractory for the purpose of retarding the cooling of thin sections of the castings; or the entire matrix may be lined with a refractory. However, such refractory should be hard and wear resisting, of the nature of fused quartz, graphite-crucible material and the like, which are not easily destroyed by coming in contact with hot liquid metal.

Under the dip-casting process as described, castings can be made equal in surface finish to drop forgings and practically equal thereto in

strength, with the further advantages that the process is applicable to intricate shapes and to materials not sufficiently malleable for forging.

While in accordance with the provision of the statute I have disclosed and explained the best forms of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the modes of operation and forms of apparatus disclosed without departing from the spirit of my invention, and that certain features of the invention may sometimes be used without a corresponding use of other features.

I claim:

1. The process of casting metals of high melting point which comprises submerging a cooled separable mold in a liquid metal bath, opening the submerged mold to receive the metal, conducting heat from the liquid metal within the mold to the mold at a relatively quick rate to cause solidification of the metal within the mold while hindering flow of heat to the mold from metal surrounding the mold to prevent solidification of the metal exterior to the mold, closing the mold, and withdrawing the mold from the bath.

2. The process of casting metals of high melting point which comprises submerging a cooled separable mold in a liquid metal bath, opening the submerged mold to receive the metal, conducting heat from the liquid metal within the mold to the mold at a relatively quick rate by passing cooling fluid in heat exchange relation with the interior part of the mold while hindering flow of heat to the mold from metal surrounding the mold by heat insulating the exterior part of the mold, closing the mold, and withdrawing the mold from the bath.

3. The process of casting metals of high melting point which comprises submerging a cooled separable mold in a liquid metal bath, opening the submerged mold to receive the metal, conducting heat from the liquid metal within the mold to the mold, hindering flow of heat to the mold from the metal of the bath surrounding the mold, closing the mold lightly, withdrawing the mold, and applying pressure to the mold as the metal therein cools.

4. The process of casting metals of high melting point which comprises submerging a cooled separable mold in a liquid bath, opening the submerged mold to receive the metal, closing the mold, cooling the interior parts of the mold in variable degree while hindering flow of heat to the mold exteriorly thereof to prevent cooling and solidification exteriorly of the mold, and withdrawing the mold from the bath.

5. A mold structure for submersion in a molten

metal bath comprising separable parts including metal members and adapted to be brought together to form a closed chamber, means connected to the mold parts whereby the mold structure may be lowered into a metal bath and whereby the mold structure may be opened to allow metal to flow therinto and whereby the mold structure may be closed to isolate metal within said chamber, and means comprising heat-insulating material entirely covering the outsides of said metal members to hinder transfer of heat from molten metal surrounding said mold structure to said mold structure to permit the mold structure in cooled condition to cause solidification of metal within the same without substantial cooling of molten metal exterior thereto.

6. A mold structure for submersion in a molten metal bath comprising separable parts including metal members and adapted to be brought together to form a closed chamber, means connected to the mold parts whereby the mold may be lowered into a metal bath and whereby the mold structure may be opened to allow metal to flow therinto and whereby the mold structure may be closed to isolate metal within the mold structure, means to cool the interior surface of said metal members, and heat-insulating means entirely covering the exterior surfaces of said metal members.

7. A mold structure for submersion in a metal bath comprising separable parts including metal members and adapted to be brought together to form a closed chamber, means connected with the mold parts whereby the mold structure may be lowered into a metal bath and whereby the mold structure may be opened to allow metal to flow therinto and whereby the mold structure may be closed to isolate metal therein, and refractory material entirely covering the outside surfaces of said metal members and forming the parting surfaces between the mold parts.

8. A mold structure for submersion in a metal bath comprising separable parts including metal members and adapted to be brought together to form a closed chamber, means connected with the mold parts whereby the mold structure may be lowered into a metal bath and whereby the mold structure may be opened to allow metal to flow therinto and whereby the mold structure may be closed to isolate metal therein, refractory material entirely covering the outside surfaces of said metal members and forming the parting surfaces between the mold parts, and means to supply cooling fluid to said metal members.

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