Dec. 9, 1958 G. HARRISON 2,863,188

METHOD AND MEANS FOR CASTING SLUGS

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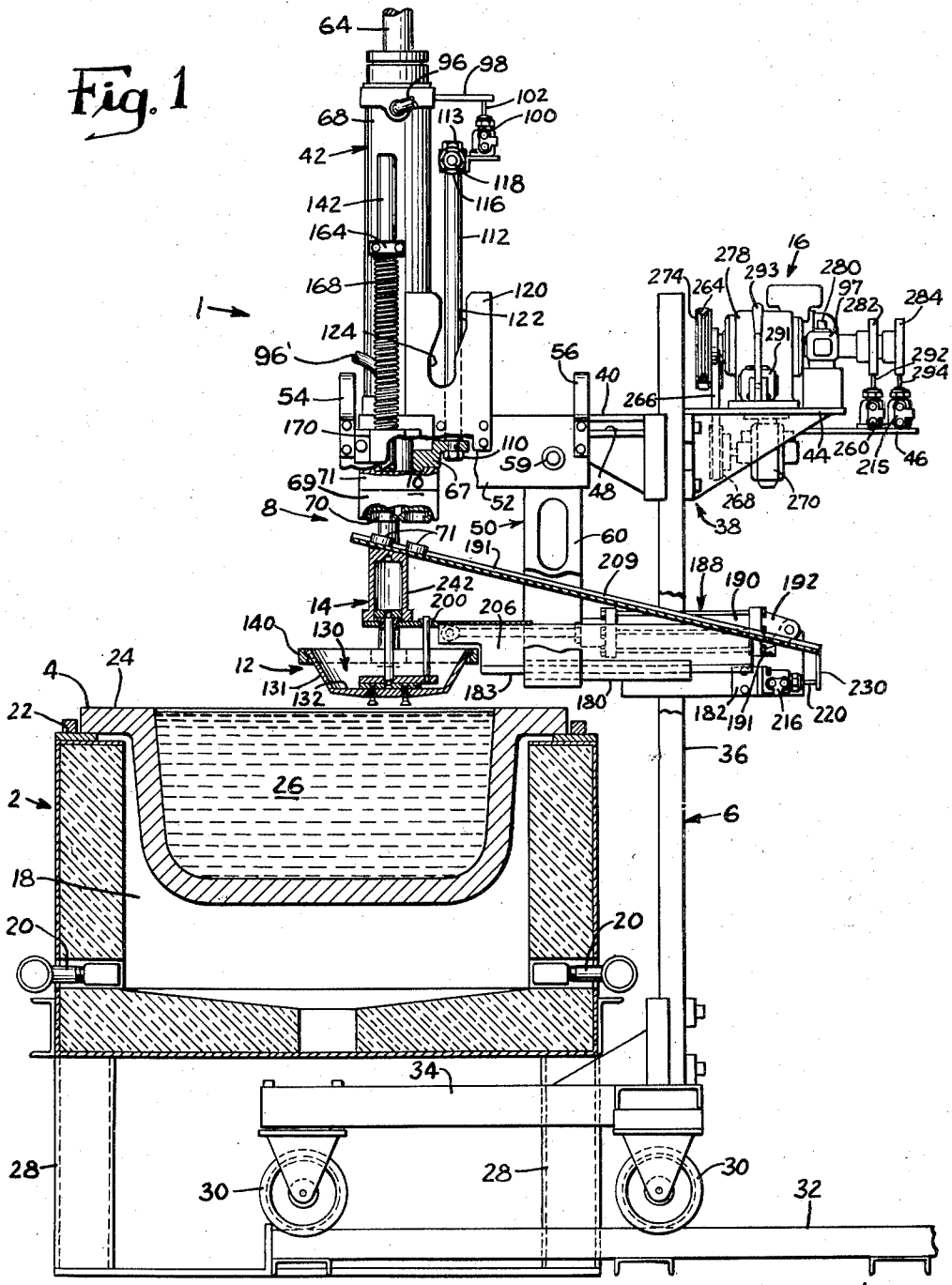
Fig. 1



Inventor
GEORGE HARRISON
by: Morris Spector
Atty.

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METHOD AND MEANS FOR CASTING SLUGS

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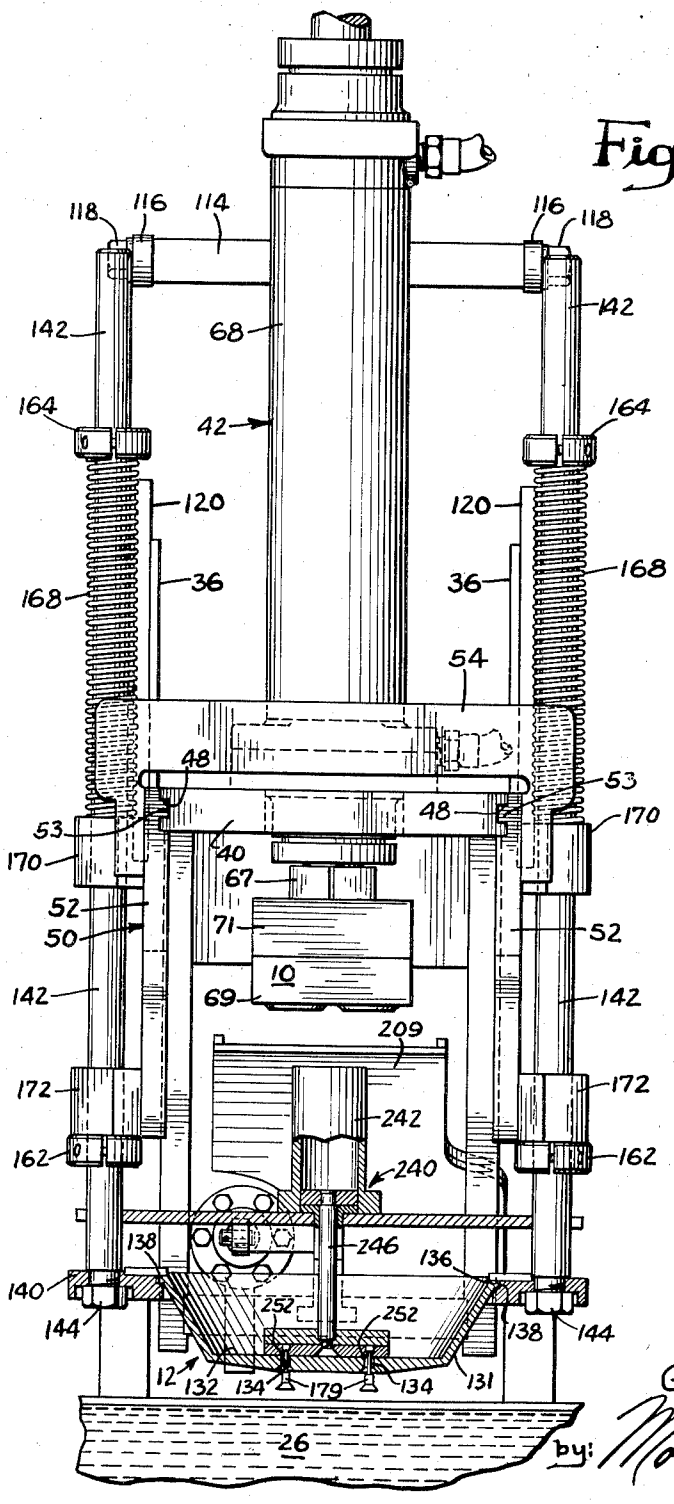
Fig. 2



Inventor
GEORGE HARRISON
by: Morris Spector
Atty.

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METHOD AND MEANS FOR CASTING SLUGS

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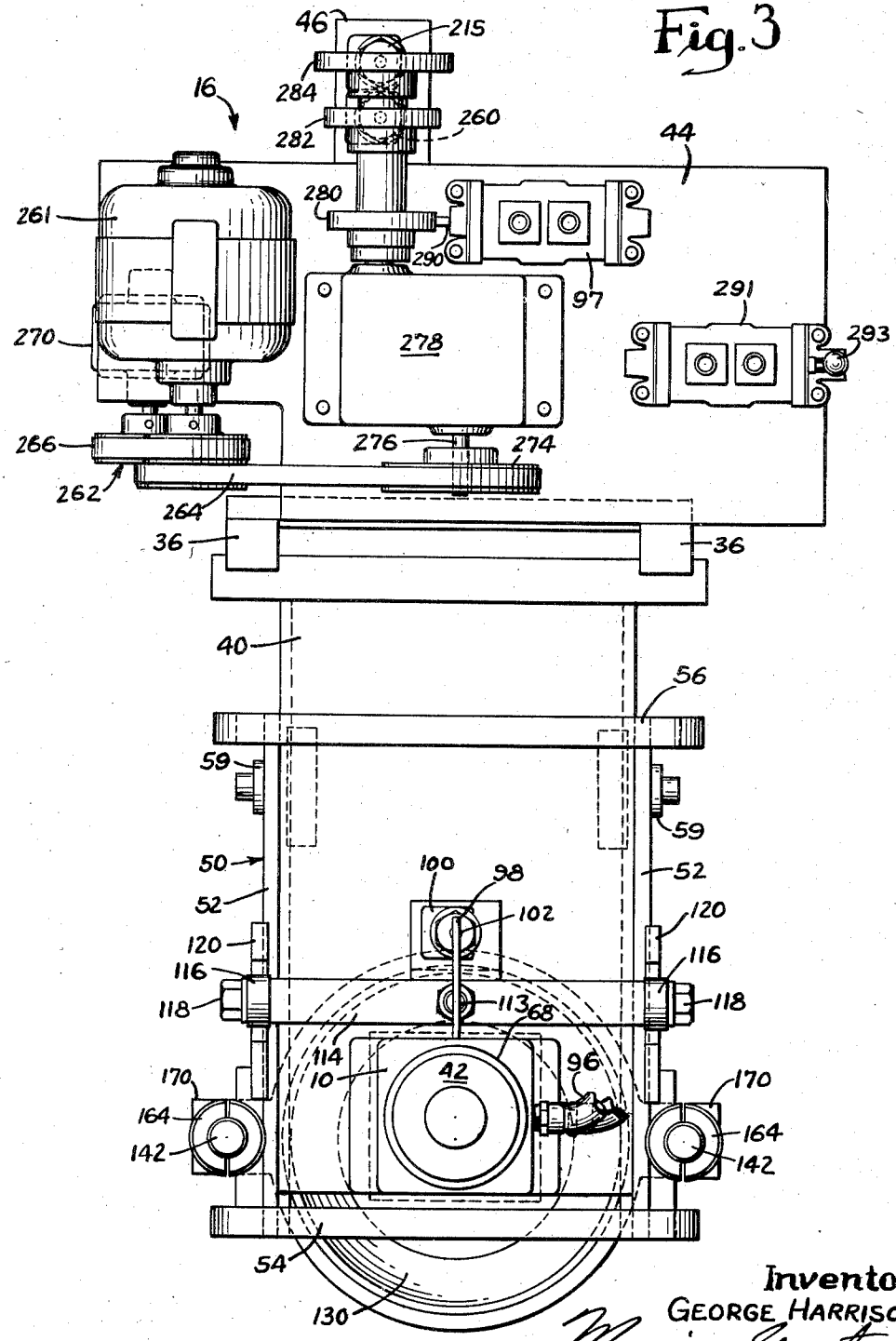
Fig. 3



Inventor
GEORGE HARRISON
by: Morris Spector
Atty.

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METHOD AND MEANS FOR CASTING SLUGS

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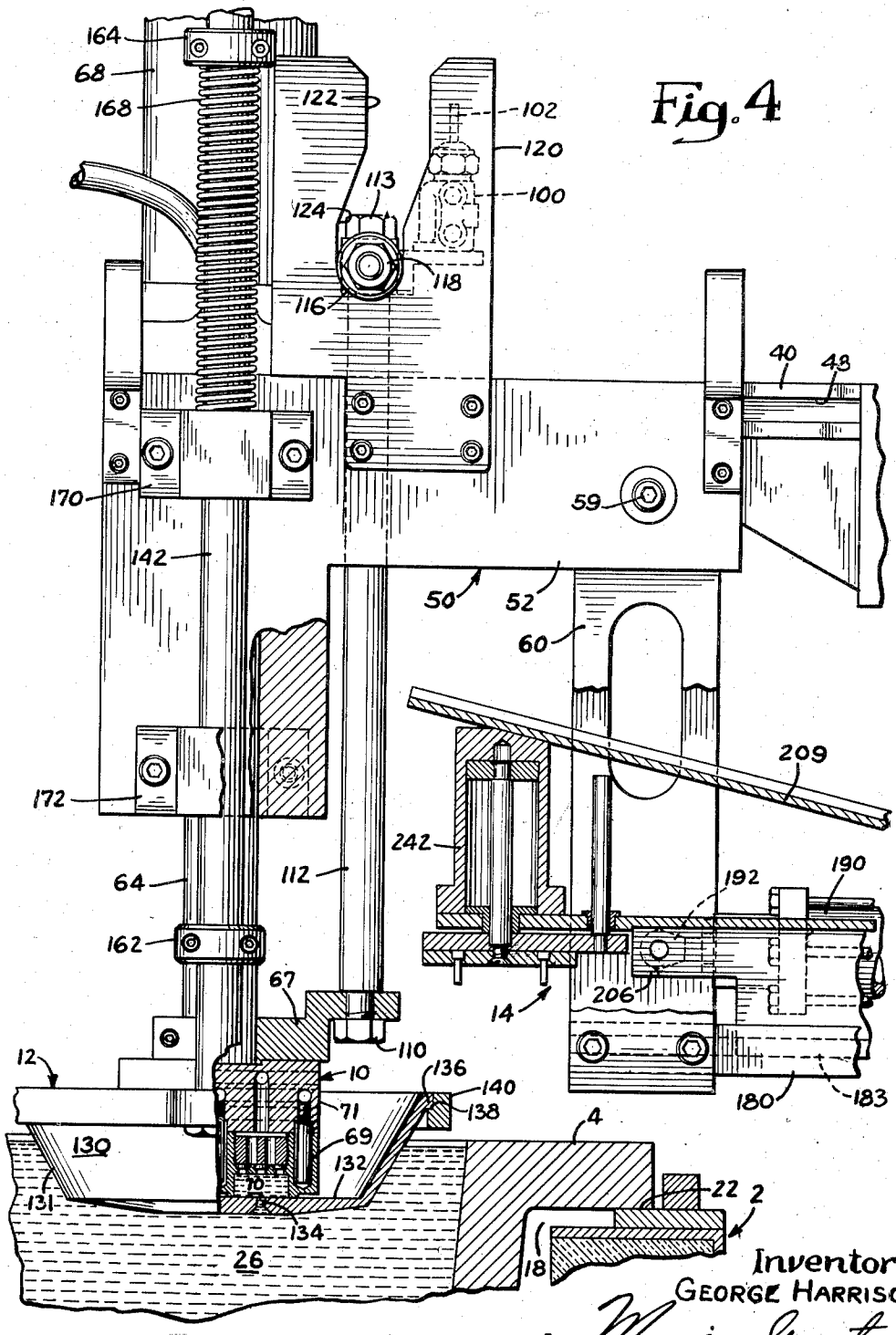
Fig. 4



Inventor
GEORGE HARRISON
by: Morris Spector
Atty.

Dec. 9, 1958 G. HARRISON 2,863,188

METHOD AND MEANS FOR CASTING SLUGS

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Fig. 5

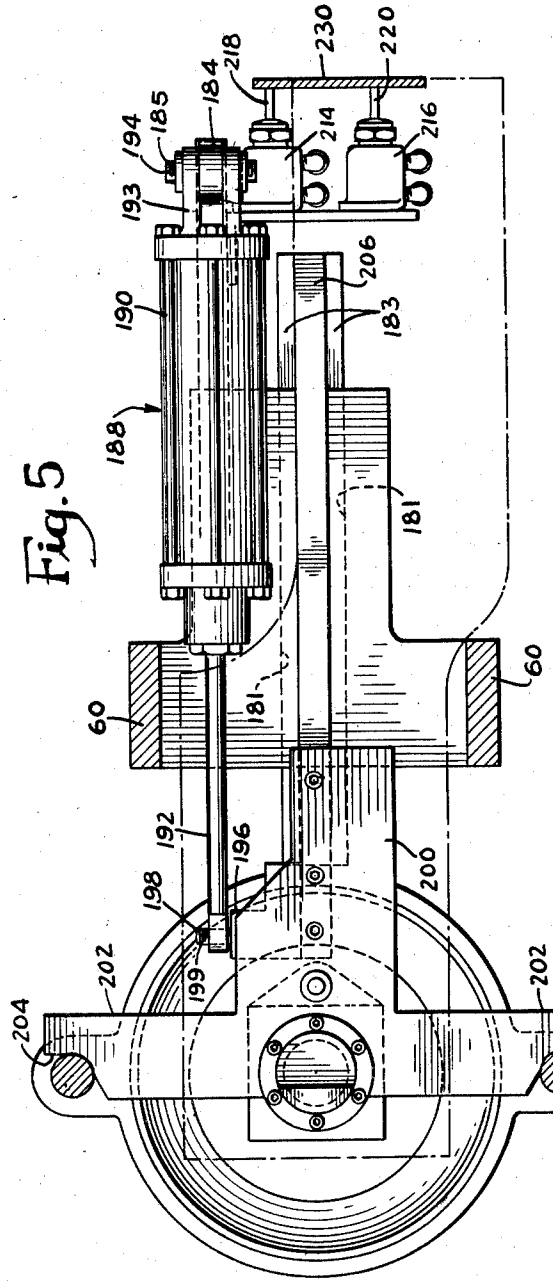
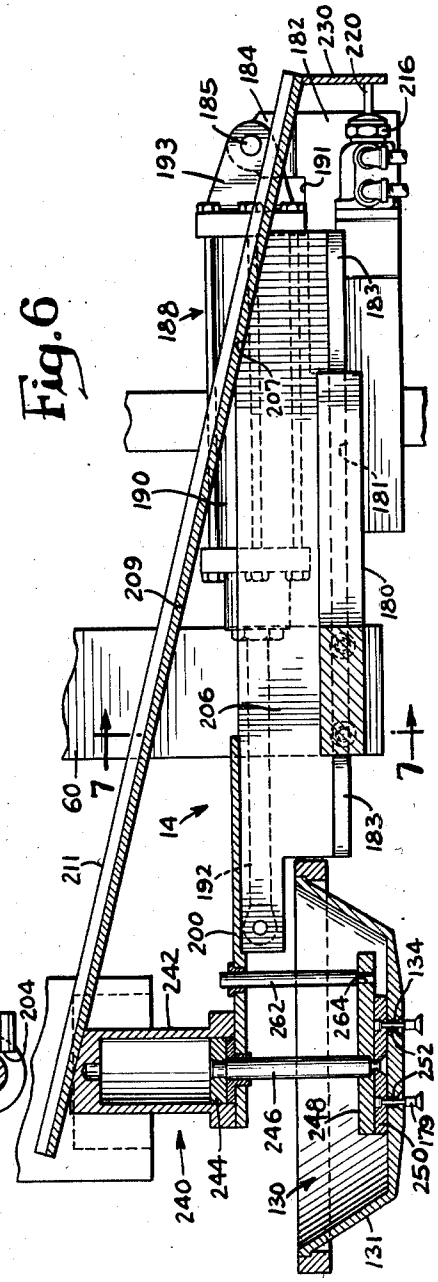


Fig. 6



Inventor
GEORGE HARRISON
by Morris Spector
Atty

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Fig. 8

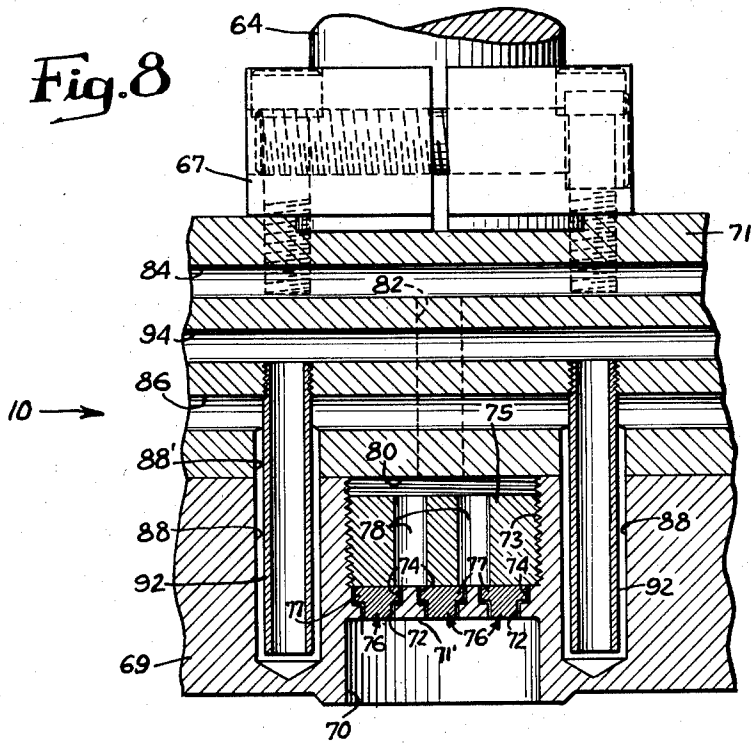


Fig. 8A

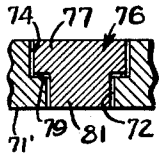
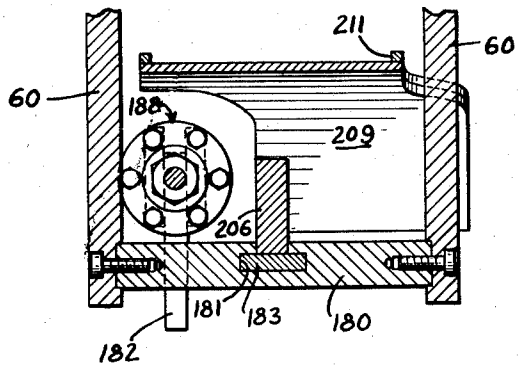


Fig. 7



INVENTOR.
GEORGE HARRISON
BY Morris Spector
Attys.

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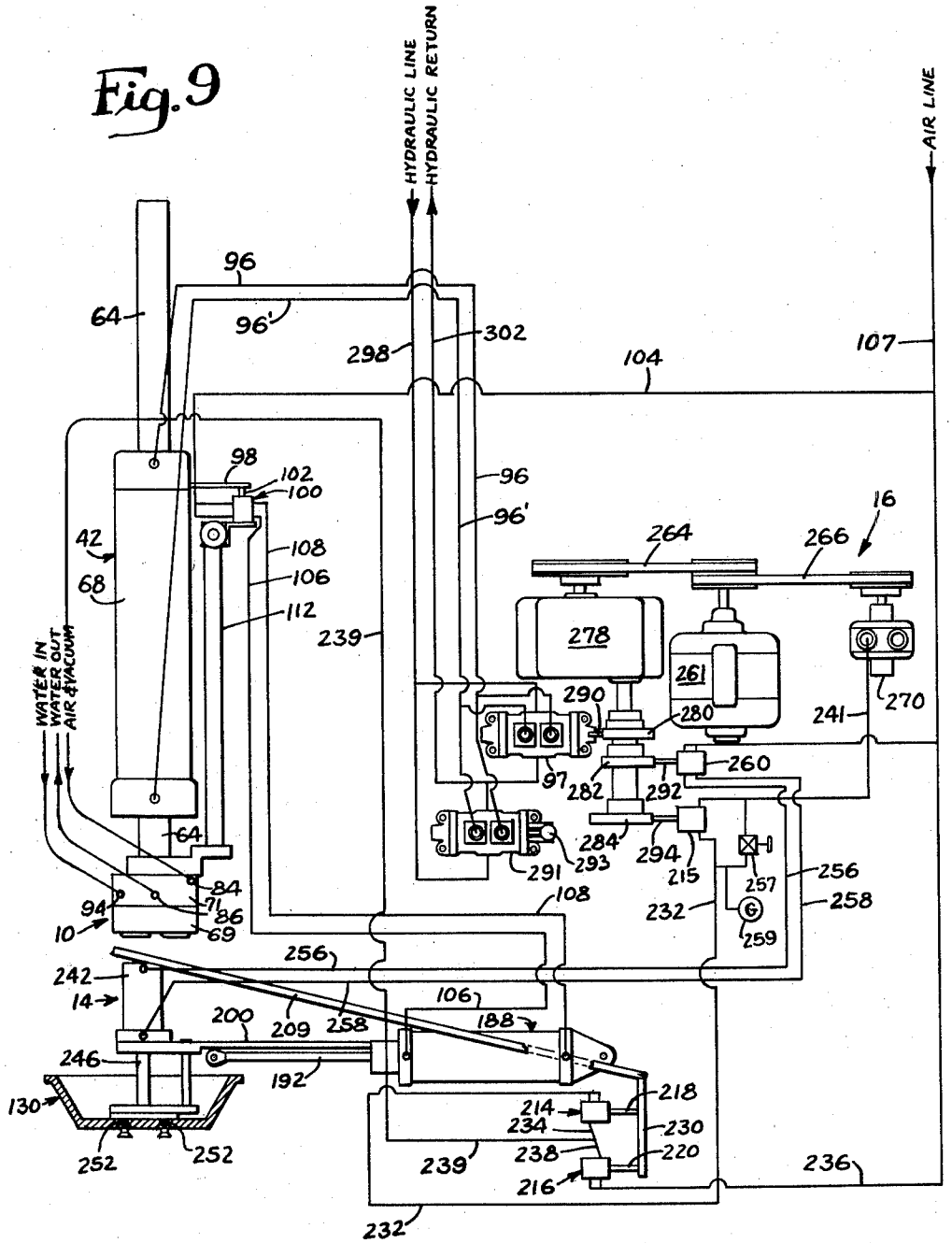
Fig. 9



INVENTOR.
GEORGE HARRISON
BY Morris Spector
Atty.

Dec. 9, 1958 G. HARRISON 2,863,188

METHOD AND MEANS FOR CASTING SLUGS

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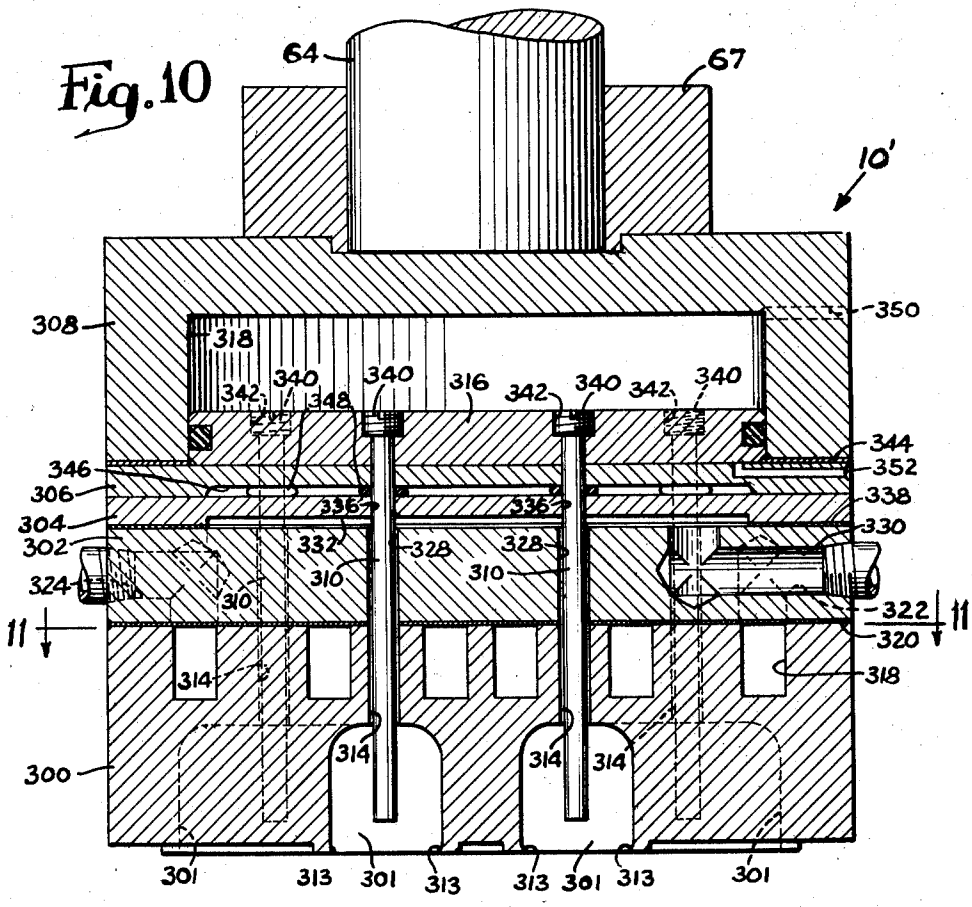
Fig. 10



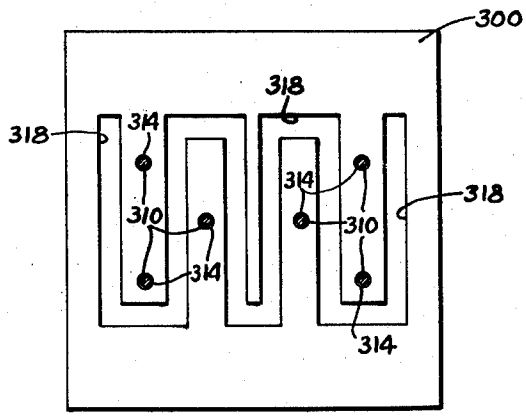


Fig. 11

INVENTOR.
GEORGE HARRISON
BY Morris Spector
Atty.

United States Patent Office 2,863,188 Patented Dec. 9, 1958

2,863,188

METHOD AND MEANS FOR CASTING SLUGS

George Harrison, Chicago, Ill.

Application November 23, 1953, Serial No. 393,537

17 Claims. (Cl. 22—73)

This invention relates to a method of, and apparatus for, making metal castings.

The invention has particular utility in the casting of metals and alloys having high melting points, such as aluminum and its alloys, wherein the prior art has experienced great difficulty in providing suitable, completely automatic, highly efficient, die casting machines. The invention has application, however, to the casting of metals having low melting points as well.

In the metal arts, many finished products are made originally from a slug of metal which is of a precise size and weight. It is one of the objects of the present invention to provide a method of casting such slugs which will result in a product of uniform composition and size.

It is another object of the present invention to provide a method of casting wherein the molten metal enters the cavity rapidly but yet with a minimum of turbulence. This reduces the tendency for separation of the ingredients of the metal. As a result, the composition is so uniform throughout the entire mass of the casting that the casting may be used as a standard of comparison, as in spectrum spark analysis.

It is a further object of the invention to provide a casting machine wherein the dies are moved into position above a crucible of molten material to be cast and are filled by submerging the bottom of the die assembly into the molten material. It is a further object to provide a die casting apparatus of this type where the portion of the machine which contacts the molten material in the crucible is periodically and automatically removed during each casting cycle to minimize the possibility of deterioration by the hot molten material.

It is a still further object of the invention to provide a method and apparatus for casting wherein the die assembly remains in a position to continue to receive molten material from the crucible during solidification, and wherein the solidifictaion progresses toward the entry-way in the bottom of the molding die assembly.

In one embodiment of the present invention the casting is made in a cold mold, which is water cooled to keep it cold during the molding operation. To facilitate cooling of the water cooled mold the mold body, with the exception of one face thereof, is made of copper or other suitable high heat conductivity metal. The one face, which is not water cooled, is the bottom of the mold. The gate for the entry of liquid metal into the mold is in this bottom face, which is maintained hot during the molding operation. Liquid metal to be cast is introduced into the mold at a controlled rate of flow to prevent turbulence and consequent splashing of molten material onto the cold mold walls which would produce voids and irregularities at the casting surface. Preferably the mold is dipped into a body of molten material to be cast and the air in the mold is evacuated at a controlled rate to draw molten material into the mold. The rate of exhaustion varies with the material being cast and is adjusted to provide as high a rate of flow of material into the mold as is possible without creating undesirable turbulence.

The rate of exhaustion of the mold is preferably the main determinative factor in the control of the rate of filling of the mold, rather than the hydrostatic pressure head of the molten material above the mold entry-way, so that the height of the unfilled portion of the mold does not materially affect the rate of flow of molten material therein.

As the liquid enters the mold and touches the water cooled side walls of the mold it solidifies. The rising mass of liquid metal is therefore solidifying from the outside of the mold inwardly, and in the filled mold from the top of the mold downwardly, while the metal at the bottom of the mold is cooling much more slowly and therefore remains in its liquid stage longer. This is accomplished by the cooling of the side walls of the mold cavity while maintaining the areas surrounding the entry-way heated by contact with the hot molten material in the crucible that supplies the molten metal to the mold cavity. Because of the progressive solidification of the metal toward the entry-way any shrinkage of the solidifying metal results in drawing additional molten metal into the mold cavity so that upon ultimate solidification of the metal the resulting casting is devoid of cavities.

Briefly, the preferred form of the invention utilizes a composite die assembly including an upper die element having an open bottom mold cavity, and a lower die element in the form of a pre-heated, open top, dish-shaped element which has a gate or entry-way in the bottom thereof. The upper die element is brought into engagement with the lower die element and the composite assembly is dipped into a body of molten material to be cast. The mold cavity (assuming there is only one mold cavity) is evacuated at a controlled rate which draws molten material at a fixed controlled rate into the mold cavity. This rate is preferably just short of the points where turbulence takes place. The upper die assembly is cooled to cause progressive solidification of the material in the mold cavity toward the entry-way while the die assembly remains in contact with a large body of hot molten material. Following the solidification of the metal in the mold cavity the die assembly is moved out of contact with the source of molten metal and the die elements are moved transversely of each other to shear the casting from the slug remaining in the entry-way of the lower die element. The upper die element is then raised from the lower die element, whereupon an ejecting apparatus is automatically moved into position between the separated die elements and the slug remaining in the entry-way of the lower die element is ejected. The casting remains in contact with the upper die element. A chute is moved beneath the upper die element and then the casting is released from the upper die element automatically at the proper time so as to drop onto the chute, where the casting is carried to a suitable disposal location.

The upper and lower die elements are moved by a hydraulic fluid operated piston device. The ejecting apparatus is moved by an air pressure operated piston device. Since the ejecting apparatus is moved between the upper and lower die elements following their separation, safeguards must be provided to prevent collision with the die elements due to any conditions which may tend to interfere with the proper timing of operation of these components. Specifically, a radical change in temperature or composition of the hydraulic fluid operating the piston device associated with the die assembly may change the speed at which the upper and lower die elements are moved toward and away from each other, and hence may cause a collision between the ejecting apparatus and die elements. To safeguard against this condition, the operation of the air pressure actuated piston device associated with the ejecting apparatus is controlled by a valve member which in turn is actuated by a control arm

which moves with the upper die element. The latter valve member is actuated to move the ejecting apparatus into or away from a position between the die elements only when the die elements are well separated from each other.

The attainment of the above and further objects of the present invention will be apparent from the following specification taken in conjunction with the accompanying drawings forming a part thereof.

In the drawings:

Fig. 1 is a side elevational view, in partial section, of the casting machine of the present invention in the ejecting position;

Fig. 2 is an enlarged fragmentary front view, in partial section, of the machine of Fig. 1;

Fig. 3 is an enlarged top view of the machine of Fig. 1;

Fig. 4 is an enlarged fragmentary side view of the machine of Fig. 1 showing the elements of the machine in the die casting position;

Fig. 5 is a top view of the ejecting apparatus in Fig. 1;

Fig. 6 is a side view, in partial section, of the ejecting apparatus of Fig. 5;

Fig. 7 is a vertical section of the apparatus of Fig. 6 taken along section line 7—7;

Fig. 8 is a detailed, enlarged, vertical section of a part of the upper die assembly;

Fig. 8*a* is an enlarged detail of a portion of the upper defining wall of a mold cavity in the upper die assembly;

Fig. 9 is a diagrammatic view of the hydraulic, vacuum, and air line circuits which control the operation of the casting machine;

Fig. 10 is a view corresponding to Fig. 8 and showing a modified die assembly; and

Fig. 11 is a sectional view taken along the line 11—11 of Fig. 10.

Reference may now be had more particularly to the drawings where like reference numerals indicate like parts throughout.

The casting machine **1** there shown, briefly, includes a movable frame support member **6** which carries a composite die assembly **8** comprising relatively movable upper and lower die elements **10** and **12**, respectively, between which the castings are formed, ejecting apparatus **14** which ejects slugs from the lower die element **12**, and control and timing apparatus **16** which controls in part, the sequence of operations of the various aforementioned elements of the casting machine.

The casting machine is associated with a furnace **2** which carries a crucible **4** of hot molten material to be cast. The stationary furnace **2** comprises a raised, open-top, heat-insulated compartment **18**. The lower portion of the compartment is filled with burning gases fed thereto by gas lines **20** communicating therewith. The furnace element **2** includes an upper annular shoulder **22** on which rests a peripheral supporting flange of the crucible **4**. The crucible extends down into the compartment **18** of the furnace. Metal **26** in the crucible is maintained in a liquid state by the heat of the flames in the bottom of the furnace compartment. The furnace **2** is raised from the floor by the legs **28**.

The frame supporting member **6** of the casting machine **1** is mounted on wheels **30** that ride on rails **32** extending beneath the furnace **2** so that the entire machine can be moved from an operative position over the crucible **4** to an inoperative position away from the crucible. The wheels **30** are secured to the bottom of a lower base member **34**, from which extend a pair of vertical, upright, supporting members **36**. A bracket **38** is mounted on the two upright members **36** adjacent to the top thereof and supports a horizontal frame base **40** which extends forwardly of and between the upright members **36**. The frame base **40** supports a hydraulic device **42** which includes a piston that actuates the die assembly **8**. The bracket **38** also supports horizontal support members **44** and **46** that hold the control and timing apparatus to be hereinafter described.

A movable frame assembly **50** is horizontally slidable in horizontal grooves **48** in the sides of the frame base **40** and includes side frame members **52** that are joined by front and rear bridge brackets **54** and **56**, respectively, so that the connecting bridge brackets and the side frames constitute a unitary structure that slides back and forth on the frame base **40**. The side frames **52** include inwardly projecting rails **53** which engage the walls defining the grooves **48**.

A pair of dependent side plate members **60** are secured to the side frame members **52** by bolts **59**. The ejector apparatus **14** is mounted to the bottom of the plate members **60** between and forwardly of the upright supporting members **36**.

The upper die assembly **10** includes a die block **69** and a water-air-vacuum distribution block **71**. This assembly is mounted on the bottom of a vertically movable piston rod **64** that projects from the bottom of a hydraulic cylinder **68** of the hydraulic device **42**. The blocks **69** and **71** are bolted together and to a split-sleeve bracket **67**, which bracket is clamped to the piston rod **64**.

The die block **69** is made of a suitable highly heat-conductive metal, for instance, copper. It has, on the bottom face thereof, a plurality of open bottom die or mold cavities **70** which conform to the shape of the articles to be cast. In the example illustrated in the drawings, the articles are cylindrical disks.

Means is provided in the die block for applying vacuum to the mold cavities to control the rate of flow of molten material thereinto and for applying air pressure thereto to aid in ejecting the finished castings from the die block. This includes the threaded bores **73** which are formed in the block **69**, one above each mold cavity **70**, in each case leaving a dividing wall **71'** between the cavity and the bore **73**. Vertically extending cylindrical holes **72** are formed in the wall **71'**, each hole **72** having a counterbored upper portion **74** in which the head **77** of a plug **76** is located. The plug head **77** is spaced from the side walls of the counterbore **74** and has circumferentially spaced nibs or projections **79** depending from the bottom thereof to provide small spaces or passageways for the flow of air between the head **77** and the wall defining the bottom of the counterbore. Each plug **76** has a shank **81** that fits within a hole **72** and terminates flush with the bottom of the wall **71'**. The clearance between the shank **81** and the wall defining the hole **72** is small so that air, but not molten metal, may flow therebetween.

A plug **75** of copper or other material of high heat conductivity is threaded into each bore **73** in the upper surface of the die block **69**. Vertical bores **78** extend through the plugs **75**. The bores **78** slightly overlap the peripheries of the counterbores **74**. The top of each plug **75** terminates short of the upper portion of the die block **69** so as to leave a cavity **80** communicating with the bores in each plug **75**.

The distribution block is secured by screws to the top of the die block **69**. Bores **82** in the block **71**, each centrally located above a plug **75**, communicate at their bottom ends with the cavity **80**, and at their top ends with a horizontally extending air and vacuum channel **84**. By means of control valves and associated apparatus, to be described, alternate vacuum and air pressure are successively applied to each mold cavity **70** via the channel **84**, a bore **82**, a cavity **80**, bores **78** and the small clearance space between the plugs **76** and the holes **72** and **74**.

Means is provided for water cooling the block **10**. This consists of a series of vertical bores **88** extending from the top of the block **69** to adjacent the bottom thereof and surrounding each of the mold cavities **70** as closely as is possible. The block **71** has a number of bores **88'** extending upwardly from the bottom thereof and each

overlying and communicating at its bottom with a bore 88 in the block 69. The upper ends of the bores 88' are each connected to one or more manifolding or cross bores 86. Above the manifolding bores 86 there is formed a series of interconnecting parallel bores 94 which are incommunicable with the bores 86. Communication with the bores 94 is provided by a series of tubes 92 that extend through the bores 88' and are threaded at their upper ends to the block 71 and open in the bore 94. Each one of the tubes 92 extends into the bore 88 at its lower end with considerable clearance between it and the bore wall, and terminates short of the bottom of the bore 88. Cooling water, under pressure, is circulated through the water inlet duct 94 in the distribution block 71, thence through each of the tubes 92, thence through the space between the tubes 92 and the bores 88 and 88' to the water outlet bore 86. Water conduits or lines (shown diagrammatically in Fig. 9 to simplify the drawings) are connected to the ducts 86 and 94, respectively.

The piston rod 64 that carries the upper die assembly is moved vertically by a double acting piston in the hydraulic cylinder 68. Hydraulic lines 96 and 96' communicate, respectively, with opposite ends of the cylinder 68 under control of a cam controlled valve 97 to effect the reciprocation of the piston.

Apparatus is provided for accurately positioning the upper and lower die assemblies with respect to each other during the filling of the mold cavities and for moving them laterally of each other following the solidification of the castings to separate the castings in the upper die assembly from connection with the lower die assembly. This apparatus includes a vertically extending cam control rod 112 which is secured to the rear of the split-sleeve clamping bracket 67 by a nut 110, and has a cross bar 114 which is secured to its upper end as by a nut 113. Cam rollers 116 are connected to the ends of the cross bar by bolts 118 which are threaded into the cross bar. As the piston of the hydraulic device 42 reciprocates the upper die assembly 10, the rollers 116 are reciprocated therewith to actuate a pair of slotted cam plates 120 which are fixedly secured to the side frame members 52 of the horizontally movable frame assembly 50, thereby moving the cam plates and with them the frame assembly 50.

Each cam plate 120 includes a vertically extending slot 122 having a forwardly offset lower portion 124. When the hydraulic device 42 moves the upper die assembly 10 and cam rollers 116 downward, the cam rollers 116 enter the cam slots 122 and, as the rollers ride in the lower portion of the cam slots 122, the cam plates 120 are moved rearwardly by the cam rollers. In so doing, the cam plates guide the lower die assembly 12, which is carried by the movable frame assembly 50, into proper position relative to the upper die assembly.

When the upper die assembly 10 is in its lowermost position (Fig. 4), the cam rollers 116 rest on the bottom of the cam slots 122. In this position, the casting operation, to be described, is performed. Following the formation of solid castings, the hydraulic device 42 moves the cam rollers 116 upward, and the rollers 116 engage the upper portion of the cam slots 122. In so doing, the rollers push the cam plates 120 and the connected frame assembly 50 forwardly relative to the upper die assembly to separate the castings in the upper die assembly from connection with the lower die assembly. This operation will be described in more detail hereinafter.

The lower die assembly 12 includes a flat bottom pan 130, made of a suitable high melting point alloy, and having upwardly extending side walls 131 and a flat bottom 132. A plurality of gates or entry-ways 134 having outwardly flared bottom ends extend through the bottom 132 of the pan 130, and are spaced the same distance apart as the centers of the die cavities 70 in the upper die assembly 10. These entry-ways 134 constitute sprues for the die molds. The pan 130 includes a peripheral flange 136 which rests on an annular shoulder 138 in a pan support ring 140.

Pan guide bars 142 are provided on opposite sides of the hydraulic cylinder 68 and the bottoms thereof extend through apertures in diametrically opposite sides of the pan support ring 140. Nuts 144 are threaded about the lower ends of the pan guide bars 142 from the bottom of the cam support ring 140 to secure the pan guide bars 142 to the support ring.

Split collars 162 are secured to the bottom portions of the pan guide bars 142. A pair of similar split collars 164 are secured to the upper portions of the pan guide bars 142. The pan guide bars are supported in a normally upper position by compression springs 168 which surround the respective pan guide bars 142 and abut the bottoms of the split collars 164. The lower ends of the springs 168 rest against the upper surface of respective pillow blocks 170 which are secured to the side frame members 52 of the horizontally movable frame assembly 50. A pair of lower pillow blocks 172 are secured to the side frame members 52 and act as stops for the upwardly spring urged pan guide bars 142 by their abutment with the upper faces of the split collars 162. The compression springs 168 normally bias the pan guide bars into a position where the bottom of the pan 130 is supported above the top of the crucible 4, as shown most clearly in Figs. 1 and 2.

Before the machine is initially put into operation, the pan 130 is heated red hot, as by dipping the bottom thereof into the molten metal for a time sufficient to accomplish such heating. The machine is then ready for the initiation of the automatic casting operations. These operations include the submerging of the bottom portion of the die assembly into the body of molten material in the crucible 4 where the mold cavities are filled with molten material rapidly and without turbulence, and where the metal is caused to progressively solidify toward the gates or sprues in the bottom of the assembly; and the subsequent raising of the die assembly out of the crucible 4 and the removal of the finished castings from the die assembly in a manner such that the castings are free of burrs and other undesirable irregularities.

In the mold cavity filling operation, it is desirable that the rate of flow of molten material into each mold cavity be determined mainly by the rate of exhaustion of each mold cavity rather than by the hydrostatic pressure head of the body of molten material above the bottom of the unfilled portion of each mold cavity. In the latter instance, the rate of flow of molten material into each mold cavity would vary with the depth of submergence of the bottom of the mold cavity below the surface of the molten material in the crucible 4, and with the rising of the molten material within each mold cavity. Thus, where the rate of filling is determined mainly by the hydrostatic pressure head, and the rate of exhaustion of the mold cavities is adjusted to a point just short of the point creating turbulent flow when the mold cavities just begin to fill with molten material, the rate of flow of material into the cavities decreases as the mold cavities gradually fill so that much valuable time is lost and the process becomes inefficient. Therefore, to minimize the time required to fill the mold cavities and the effect of the depth of submergence of the die assembly in the crucible, the depth of submergence of the die assembly in the crucible is reduced to a value where the rate of exhaustion of the mold cavities primarily determines the rate of flow of the molten material therein. Where the mold cavities have a constant horizontal cross sectional area, as the cylindrical castings illustrated in the drawings, the rate of exhaustion of the mold cavities necessary to fill the cavities at a constant and rapid rate just short of creating turbulence is a fixed and constant amount for a given casting material. A variation in the viscosity and surface tension of the casting material varies the flow characteristics thereof and the rate of cavity ex-

haustion necessary to provide a rate of flow into the mold cavities just below the rate creating undesirable turbulence. In any particular case, this rate of cavity exhaustion may be determined experimentally by running several trial runs.

The casting operation performed by the machine is as follows:

The actuation of a cam controlled valve initiates the operation of the hydraulic device **42** to effect the downward movement of the die block **69** and the distribution block **71**. The die block **69** is moved downward first into engagement with the bottom of the pan **130** and, upon continued downward movement, moves the pan **130** downward against the force of the springs **168** into the molten material **26** in the crucible **4**. The upper portion of the pan **130** remains above the molten material. The engagement of the cam rollers **116** with the bottom of the slots **122** of the cam plates **120** accurately positions each of the die cavities **70** of the upper die assembly over one of the entry-ways **134** of the pan **130**. The molten material then enters each mold cavity through its entry-way **134** at a rate inhibiting turbulence as controlled by the rate of evacuation thereof by a source of low pressure connected to the top of each mold cavity through the clearance space between the plug **76** and the hole **72**. The molten material rises in each mold cavity as air is exhausted from the unfilled portion thereof. When the molten material reaches the top of each mold cavity, which is the bottom face of the wall **71'**, entry of molten material into the cavity comes to a halt since the molten material is unable to enter the small space between the plug **76** and the wall of the hole **72** in the top cavity wall **71'**.

The solidification of the metal is then effected while the mold assembly remains partly submerged below the surface of the molten material **26**. The molten metal filling each mold cavity solidifies progressively toward the entry-ways **134**, since the side and top mold walls are water cooled and the pan bottom is maintained in contact with the hot body of molten material **26**. Any shrinkage of metal in the cooling of the liquid metal will be taken up by the liquid metal beneath the solidified metal, which liquid metal is in turn replaced by metal drawn into the entry-ways **134** from the main body of molten material **26**. The progressive solidification of the metal in the mold cavities and the non-turbulent flow of liquid metal therein produces cast products of homogeneous composition.

After the metal solidifies through the entry-ways **134**, the hydraulic device **42** raises the composite die assembly out of the crucible **4**. In so doing, the cam plates **120** are moved forwardly by the cam rollers **116** as the rollers move into the upper portion of the cam slots **122**. This occurs prior to the separation of the die block **69** from the pan **130** so that the pan is moved laterally of the die block **69** to shear the castings **71** in the die block cleanly from the solid slugs **179** within the pan entry-ways **134**. The slugs and castings are separated along a horizontal plane which is coextensive with the flat bottom of the pan **130** so that the separated castings have a smooth bottom surface. This insures that the castings have a uniform shape and quantity of material.

Just prior to the separation of the die block **69** from the pan **130**, a very low pressure is applied to the top of the mold cavities to secure the castings to the die block **69** by suction so that upon separation of the die block from the pan the castings remain with the die block.

When the hydraulic device **42** has moved the die block **69** to its uppermost position, the control arm **98** projecting from the rear of the hydraulic cylinder **68** actuates the control rod **102** of a valve **100** which is secured to the movable cam control rod **112**. This initiates movement of the ejecting apparatus **14** into a position between the die block **69** and the pan **130**. The slugs **179** in the pan entry-ways **134** are then ejected and the castings removed from the die block **69**.

The avoidance of a collision between the ejecting apparatus **14** and the upper die assembly **10** is assured, since the movement of the ejecting apparatus toward the die assembly is controlled by the position of the upper die assembly. The speed of movement of the hydraulic apparatus **42** which moves the upper die assembly **10** varies somewhat with the viscosity of the hydraulic fluid so that collision between the upper die assembly and the ejecting apparatus is possible if the movement of the ejecting apparatus **14** is not controlled by the actual position of the upper die assembly.

The ejecting apparatus **14** includes a horizontal supporting base member **180** which extends between, and is bolted to, depending side plate members **60** of the horizontally movable frame assembly **50**. The ejecting apparatus thus moves as a unit with the pan **130** under the control of the cam plates **120** to insure a proper and constant orientation between the pan and the ejecting apparatus. The base member **180** has an inverted T-shaped slot **181** which slidably receives a rectangular shaped gib **183** in the bottom thereof. Extending into the slot **181** and secured to the top of the gib **183** is a chute support member **206** which has an inclined upper rear surface **207** on which rests a forwardly and upwardly inclined chute **209** secured for movement with the chute support member. The chute **209** has upwardly extending side walls **211** defining the sides of a channel for guiding completed castings dropped thereon from the upper die assembly **10** to a storage bin.

The front end of the chute support member **206** is connected to a piston rod **192** of the piston actuated device **188** by a plate **196** from which extends a stud **198**. The stud is received in an opening in the piston rod **192** and is held in place within the opening by any suitable means, such as by the cotter pin **199**. The plate **196** is bolted to the chute support member.

A cylinder mounting bracket **182** is secured to the ejector base member **180** and it has an upwardly extending arm **184** at the rear thereof. The arm **184** has an aperture to receive a pivot pin **185** projecting beyond the outer faces thereof. The air actuated device **188** has a cylinder **190** which is supported on the pivot pin **185** by means of spaced apertured ears or lugs **193** which straddle the arm **184** and receive the pin **185**. Longitudinal movement of the pivot pin **185** relative to the mounting bracket **182** is prevented by a cotter pin **194** extending through apertures in the ends of the pivot pin **185**. The cylinder **190** rests on a shoulder **191** on the mounting bracket **182** which insures a horizontal orientation of the piston rod **192** projecting forwardly from the front end of the cylinder **190**.

A piston is mounted within the cylinder **190** in a conventional manner and actuates the piston rod **192** and the gib **183**, chute support member **206**, and chute **209** forwardly and backwardly with it.

The device **188** is air actuated and the air inlet lines **106** and **108** (Fig. 9) associated with the valve **100** communicate with opposite ends of the cylinder to actuate the piston therein in opposite directions.

A carrier plate **200** is secured to the end of the chute support member **206** and it has laterally extending arms **202** projecting from opposite sides of the forward end thereof. The front, outer ends of the cross arms **202** are cut away at **204** to provide a curved abutment against which the pan guide bars **142** rest when the carrier plate **200** is in its forwardmost position, as shown in Figs. 5 and 6. This accurately positions the carrier plate **200** with respect to the pan **130**. An air actuated slug-ejecting device **240**, to be described, is supported from the front end of the carrier plate **200**.

When the upper die assembly **10** is in its uppermost position and the control arm **98** has depressed the control rod **102** of the valve **100**, air pressure is applied to the

right-hand end of the cylinder **188** (Figs. 1 and 5) via air input line **104** and air output line **108** and the piston **192** is moved to the left, thereby carrying the ejecting device **240** and the chute **209** with it into operative position between the upper and lower die assemblies **10** and **12**. When the die assembly **10** is in a position other than its uppermost position, the valve rod **102** is out of engagement with the control arm **98** and the air input line **104** is connected to the line **106** leading to the left-hand side of the cylinder **188** which moves the ejecting apparatus to the right out of the way of the upper die assembly.

The air actuated ejecting device **240** includes an air-operated cylinder **242**, a movable piston **244** therein, and a depending piston rod **246** which carries on the bottom thereof upper and lower ejector plates **248** and **250**. The upper and lower ejector plates are bolted together. The depending pin members **252** are secured to the lower ejector plate **250** and are spaced to overlie the respective apertures **134** at the bottom of the pan **130**.

Air input lines **256** and **258** (see Fig. 9) are connected, respectively, with the upper and lower ends of the cylinder **242** for reciprocating the piston **244** therein. Air under pressure is alternately applied to the air inlet lines **256** and **258** under the control of a cam operated air valve **260**, to be hereinafter described. At the appropriate moment following the positioning of the ejecting apparatus above the pan **130**, air is applied through the air line **256** to the upper part of the cylinder **242** to force the piston **244** downward, thereby carrying ejector pins **252** into the pan apertures **134**. The solid slugs **179** in the apertures **134** are thereby pushed into the crucible **4**, where they are re-melted.

To assure accurate orientation of the ejector pins **252** with respect to the pan apertures **134**, a guide rod **262** is secured to the ejector carrier plate **200** and it extends through a guide aperture **264** in the upper ejector plate **248**. The guide rod secures the ejector plates **248** and **250** against rotation about the axis of the piston rod **246** and thus it maintains the alignment of the pins **252** with the pan apertures **134**.

Following the ejection of the slugs **179**, the cam controlled air valve **260** shuts off the supply of air pressure to the air line **256** and applies pressure to the line **258**, thereby raising the piston rod **246** and attached ejector plates and pins out of the pan **130**. The ejecting apparatus is then retracted rearwardly of the machine and out of the path of movement of the upper die assembly as the valve apparatus, to be described, initiates another casting operation which begins with the downward movement of the upper die assembly **10**. Valve apparatus is provided for controlling the pressure in the die cavities. This apparatus includes valve members **214** and **216** which are secured to the ejector apparatus mounting bracket **182**. These valve members include movable control rods **218** and **220**, respectively, which, when the chute **209** is in its forwardmost position where it underlies the upper die assembly **10**, abut a movable control arm **230** depending from, and movable with, the chute **209**. This actuates the valves **214** and **216** to effect the interruption of the vacuum applied to the mold cavities **70** in the die block **69** and the application of a relatively high air pressure thereto to eject the solid castings. Since the actuation of the valves **214** and **216** is controlled directly by the control arm **230** moving with the chute **209**, ejection of the castings from the upper die assembly **10** occurs only when the chute **209** is in position to receive the castings.

Connected to the air valve **216** (see Fig. 9) is an air inlet line **236** and an air output line **238** connecting the die cavities **70** of the upper die assembly **10** via line **239**. The air input and output lines **236** and **238** are interconnected by the air valve member **216** to apply high pressure to the mold cavities when the control rod **220** thereof is in contact with the control arm **230**, which, as stated above, occurs when the chute **209** is moved beneath the upper die assembly.

A vacuum input line **232** and a vacuum output line **234** connect with the vacuum valve **214**. When the control rod **218** is removed from the control arm **230** by the rearward movement of the chute **209**, the vacuum valve **214** connects the vacuum input line **232** with the vacuum output line **234**. This applies low air pressure to the mold cavities of the upper die assembly **10** via the line **239** to exhaust the air in the mold cavities **70** to draw molten material therein, in a manner previously explained. The input line **232** is connected with a vacuum header line **241** and vacuum pump **270** through the valve **215** or, alternatively, through an adjustable bleeder valve **257** connected across the valve **215**.

The adjustable bleeder valve **257** may be a conventional needle-valve which may be adjusted in small incremental amounts between a position where the valve is almost completely closed and a position where the valve is completely open. In this manner the value of low pressure at the output side of the needle valve **257** may be adjusted between vacuum or the low pressure output of vacuum heater line **241** and, say, atmospheric pressure. The adjustable bleeder valve **257** determines the low pressure condition of the mold cavities **70** during the filling operation and so controls the rate of filling of these cavities in a manner previously explained. The vacuum valve **215** remains closed during the filling of the mold cavities so that the bleeder valve **257** will then control the pressure in the mold cavities. The needle valve is adjusted by a trial and error method, to a position where the rate of exhaustion of the air from the mold cavities causes a rate of flow of molten material therein which is just short of the point where the turbulence of the in-flowing molten material forms air holes and irregular surfaces in the finished castings.

A gauge **259** connected at the output of the bleeder valve **257** indicates the pressure at this point. The gauge will indicate when the mold cavities are full since the pressure will then suddenly drop due to the termination of the rise of molten material in the mold cavities.

The bleeder valve **257** is by-passed when the vacuum valve **215** is opened by the timing and control apparatus **16**. The opening of the vacuum valve **215** applies the lowest air pressure available in the header line **241** to the mold cavities to provide maximum suction so as to maintain the solid castings in the mold cavities following the separation of the upper and lower die assemblies.

As previously stated, the sequence of operations of the various parts of the casting machine thus far described is controlled by the timing and control apparatus indicated generally by the reference numeral **16**.

The timing and control apparatus **16** includes a synchronous motor **261** which is supported on the horizontal support member **44** associated with the bracket **38**. A vacuum pump **270** is supported on the member **46**. The motion of the shaft of the motor **261** is coupled to the shaft of a vacuum pump **270** by a belt **266** which engages the grooved wheels **262** and **268**, respectively connected to the shafts of the motor **261** and the vacuum pump **270**. The motion of the motor shaft is also coupled to a speed reducing device **278** by means of the belt **264** which engages the grooved wheel **262** and the grooved wheel **274**, connected to the shaft **276** of the speed reducing device **278**. Through suitable gearing within the speed reducing device **278** respective cams **280**, **282** and **284** are slowly rotated on a common shaft and actuate, respectively, the hydraulic control valve **97**, the air pressure valve **260**, and the vacuum valve **215**. Each of the valves includes respective control rods **290**, **292** and **294** which ride on the peripheries of the cams **280**, **282** and **284**. These cams are appropriately shaped so that during a single rotation of said cams, the control rods **290**, **292** and **294** are depressed for a predetermined portion of the casting cycle to properly control the sequence of operations of

the various movable elements of the casting machine. The cam **280** actuates the valve **97** which controls the movement of the upper die assembly.

The hydraulic control valve **97** (see Fig. 9) is coupled to a source of hydraulic fluid, such as oil, through a hydraulic input line **298**. The hydraulic lines **96** and **96'** are coupled between the output side of the valve **97** and the upper and lower portions, respectively, of the hydraulic cylinder **68**. To initiate the downward movement of the upper die assembly, the cam **280** depresses the control rod **290** which connects the hydraulic input line **298** to the hydraulic line **96** through the valve **97** to carry hydraulic fluid to the upper end of the hydraulic cylinder **68**, thereby moving the piston therein downwardly. The oil previously filling the bottom of the cylinder **68** is removed via the line **96'** and return line **302**.

When the piston has reached its lowermost position, the casting operation previously described is performed. At a given time after the initiation of the downward movement of the piston within the hydraulic cylinder **68**, said time occuring after the complete solidification of the molten material within each die cavity **70**, the cam **280** allows the control rod **290** of the valve **97** to move outwardly, thereby causing the hydraulic input line **298** to be connected to the hydraulic output line **96'**. The hydraulic fluid is then coupled to the bottom of the hydraulic cylinder **68** thereby moving the piston upward in the hydraulic cylinder **68** which moves the die block out of engagement with the pan **130** to terminate the casting operation. The hydraulic fluid in the upper portion of the cylinder **68** is removed via the hydraulic line **96** and return line **302**.

A hydraulic valve **291**, similar to the valve **97**, and having a hand-operated control rod **293**, is connected in parallel with the hydraulic valve **97** so that the die assemblies **10** and **12** can be gradually operated to lower the pan **130** into the crucible **4** where it is heated red hot (for reasons previously explained), before the machine is placed into automatic operation.

The cam **282** actuates the valve **260** which controls the operation of the slug-ejecting mechanism **240**. The air header line **107** connects with the input side of the air pressure valve **260**. When the ejecting device **240** has been moved to a position over the pan **130**, following the termination of a casting operation, the cam **282** actuates a control rod **292** of the valve **260** and the air line **107** is connected to the air line **256** leading to the upper end of the cylinder **242**, thereby moving the ejecting pins **252** downward. The cam **282** actuates the control rod **292** in the opposite direction following the ejection of the slugs from the entry-ways **134** of the pan **130**, by connecting the air header line **107** to the other air line **258**, which connects with the lower end of the cylinder **242** to raise the ejector pins **252** from within the pan **130**.

The cam **284** actuates the valve **215** to control the timing of the application of suction to the die cavities **70** to maintain the finished castings to the upper die assembly when the upper die assembly separates from the pan **130**. As previously stated, the valves **215** and **257** are in parallel, and together are in series with the valve **214** which connects with the line **239** leading to the air and vacuum channel in the distribution block **71**. When the molten material in the mold cavities **70** has solidified, and just prior to the separation of the lower and upper die assemblies, the cam **284** actuates the control rod **294** of the valve **215** to open the valve and connect the vacuum header line **241** directly with the line **232**. At that time, the control arm **230** has been removed from the control rod **218** of the vacuum valve **214**, so that the valve **214** couples the line **232** to the line **239** leading to the distribution block **71** where vacuum is applied to the upper portion of the mold cavities to secure the mold castings to the upper die assembly by suction.

A review of the sequence of operations of the various components of the casting machine is as follows: After the pan **130** has been heated red hot, and under the control of the cam-operated hydraulic valve **97**, the upper die assembly is moved downward to initiate a new casting operation. With the initiation of the downward movement of the die block **69**, the valve **100** is actuated by the removal of the control rod **102** from contact with the control arm **98** which causes air under pressure to be fed to the left hand side of the cylinder **190** associated with the ejecting apparatus **14**, to move the ejecting apparatus rearwardly or away from the pan **130**. The die block **69** then depresses the pan **130** into the molten material **26** in the crucible **4** in its downward movement, whereupon the mold cavities **70** begin to rapidly but without turbulence fill with molten material due to the evacuation of the mold cavities, the adjustable needle valve **257** having been previously adjusted to provide a maximum non-turbulent rate of flow of the molten material into the mold cavities. After the cavities have been filled and the casting material has solidified, the vacuum control valve **215** is opened which applies vacuum to the mold cavities. The hydraulic valve **97** is actuated by the cam **280** to move the die block upward. This carries the spring biased pan **130** upward with it. Then, as the cam rollers **116** engage the upper portion of the cam slots **122**, which occurs prior to the separation of the pan and the die block, the cam is shifted laterally with respect to the die block **10** to shear the castings from the slugs in the pan entry-ways **134**. When the die block **69** has been raised to its uppermost position, the control rod **102** of the valve **100** is depressed by the control arm **98**, which actuates the piston-operated device **188** to move the ejecting apparatus **14** into operative position between the die block **69** and the pan **130**. Valves **216** and **214** are then actuated and vacuum is removed from the mold cavities **70** and air pressure is applied to eject the castings from the mold cavities, which fall onto the chute **209** on which they slide, by gravity, from the machine. A new casting cycle is initiated by the cam **280** as it actuates the valve **97** to begin the downward movement of the die block **69**, following ejection of the slugs from the pan entry-ways and the removal of the castings from the die cavities **70**.

The vacuum method of retaining the solid castings to the upper die assembly **10** following the separation of the upper and lower die assemblies may be unsatisfactory where the solid castings are of appreciable weight or where the top surface of the castings are curved. In such case, the upper die assembly may be modified by providing an undercut portion in each mold cavity as by reducing the size of the bottom opening in each mold cavity to produce an annular shoulder or seat on which each casting sits. The ejection of each casting from the upper die assembly may be effected by means of one or more ejector pins which force each casting through the narrowed open bottoms of the die cavities.

Such a modified form of die assembly is shown in Figs. 10 and 11 to which reference should now be had. The basic elements of this modified upper die assembly **10'** include a lower die block **300** having mold cavities **301**, a pair of intermediate distribution blocks **302** and **304** which aid in directing cooling water, air pressure, and vacuum to the die block **300**, and a pair of upper cylindrical members **306** and **308** which together form an air-operated piston device which vertically reciprocates dependent ejector pins **310** into and out of the mold cavities **301** to eject the solid castings therefrom. All of these components are connected together and are secured to the piston rod **64** by the split sleeve **67**.

The mold cavities **301** are open at their bottoms and, in the illustrated embodiment, have non-circular cross-sections. The cavities shown have vertically extending side walls which flare inwardly slightly at the open bottoms of the cavities so that the mold cavities undercut

slightly the neck portions **313** defining the openings into the bottoms of these cavities. The width of the necks **313** should be of such a value or, in other words, the amount by which the upper portion of the mold cavities undercuts the open bottoms thereof should be such that shrinkage of the metal in the mold cavities upon solidification thereof provides a press fit between the outer vertical walls of the castings and the necks **313** so that the castings are secured to the necks **313** by the friction therebetween. The castings may then be readily ejected from the mold cavities by the downward movement of the ejector pins **310** against the tops of the castings.

The upper portion of the die block **300** has vertically extending bores **314** which communicate with the tops of the mold cavities **301** and receive the vertically movable ejector pins **310** depending from a piston **316** located in the upper portion of the upper die assembly. As illustrated, each mold cavity has several of these bores and ejector pins associated therewith. A small clearance is provided between the ejector pins **310** and the walls defining the vertical bores **314** so as to prevent the rise of molten material while allowing the passage of air therebetween. The bores **314** also serve as passageways for the application of vacuum to the mold cavities **301** to control the rate of flow of molten material thereto.

To effect the circulation of cold water through the die block **300**, an undulating horizontally extending slot **318** is cut in the upper face of the die block **300**, to provide a passageway for cold water which traverses the portion of the die block above the mold cavities **301**. A gasket **320** overlies the top surface of the die block **300** and covers the open tops of the slots **318** to provide a closed passageway for the circulation of the cooling medium. The gasket is provided with openings to receive the ejector pins **310**.

Above the gasket **320** is situated the lower distribution block **302**. The distribution block **302** includes water inlet passageway **322** which communicates with one end of the die block slot **318** through a suitably placed aperture in the gasket **320**. The lower distribution block also includes a water outlet passageway **324** which communicates with the other end of the die block slot **318** through an aperture in the gasket **320**. Cooling water is thus circulated through the upper die assembly via a path including the water inlet passageway **322**, the die block slot **318** and the water outlet passageway **324**. The die block **300**, as is the die block **69** previously described, is made of a highly heat conductive material such as copper, so that the walls of the mold cavities **301** are cooled to effect a progressive solidification of the molten material within the mold cavities toward the entry-ways in the pan **130** associated with the lower die assembly.

The lower distribution block **302** also includes vertical bores **328** which are in register with the bores **314** in the die block so as to receive the ejector pins **310**. A small clearance is provided between the ejector pins **310** and the walls defining the bores **328** to enable air to pass therebetween.

The lower distribution block **302** also includes an air receiving passageway **330** having open ends respectively in the side and top faces of the distribution block. The opening of the passageway **330** which communicates with the upper face of the lower distribution block **302** communicates with a cylindrical cavity **332** formed in the bottom face of the upper distribution block **304**. The cavity **332** is in communication with each of the bores **328** in the lower distribution block **302**.

The upper distribution block **304** also includes vertical bores **336** which slidably receive the ejector pins **310**. An annular gasket **338** is inserted between the peripheral abutting portions of the upper and lower distribution blocks to effect an air-tight seal therebetween.

The upper and lower distribution blocks thus provide together a plurality of communicating passageways which communicate with the top of the die cavities through the passageway **330**, cavity **332**, and bores **328** and **314**. The air and vacuum line **239** is connected to the inlet end of the passageway **330** in the lower distribution block **302**. The vacuum is thereby applied to the mold cavities **301** to exhaust the air from the mold cavities to effect the fiilling thereof in a manner similar to that previously explained in connection with the embodiment of Figs. 1 through 9. Air pressure is applied to the mold cavities via the same path during the ejection of the castings to remove any dust particles gathering in the spaces between the ejector pins **310** and the bores **328** and **314**.

The ejector pins **310** have enlarged heads **340** which are seated in and threaded to the walls defining the counterbores **342** in the upper face of the piston **316**. The piston **316** is vertically movable within a vertical cylindrical bore **318** formed in the hollow cylindrical member **308**. In the uppermost position of the piston **316**, the bottoms of the ejector pins are flush with the tops of their associated mold cavities. With the piston in its lowermost position, the bottoms of the ejector pins extend well down into the mold cavities as shown in Fig. 10.

The bore **318** is open at its bottom end. A gasket **344** is fitted between the bottom of the hollow cylindrical member **308** and a cylindrical plate or block **306**. The plate **306** and the gasket **344** have bores in registry which receive the shanks of the ejector pins **310**. The plate **306** rests on the upper distribution block **304**. A cylindrical recess **346** which is vented to the atmosphere is formed in the bottom face of the plate **306** and receives a plurality of annular gaskets **348** which surround the portion of the ejector pins extending therethrough and which abut the opposed faces of the plate **306** and the upper distribution block **304**. The gaskets are under compression and effect an air-tight seal with the adjacent walls of the ejector pins, plate **306** and the upper distribution block **304**. The gaskets prevent the leakage of air between the piston containing bore **318** and the cavity **332**.

The piston **316** is reciprocated by means of air pressure applied alternately above and below the piston **316** within the piston containing bore **318**. A passageway **350** in the side walls of the hollow cylinder **308** communicates with the upper portion of the bore **318**. A passageway **352** formed in the plate **306** communicates with the bottom of the bore **318**. The passageways **350** and **352** are connected to a cam operated valve driven by the motor **261** which applies air pressure at the appropriate times to the passageways **350** and **352** to alternately move the piston **316** upward and downward in the bore **318**. One of the passageways is connected by the valve to the atmosphere while the other passageway is connected to a source of air under pressure.

The operation of the casting ejecting portion of the upper die assembly is as follows:

The upper die assembly **10'**, with the ejector pin bottoms flush with the top wall of the mold cavities, is moved into engagement with the pan **130** and into the crucible **4** where the mold cavities **301** are filled by evacuating the air therefrom through the bore **314**. Following the filling of the mold cavities and the solidification of the molten material therein, the upper die assembly **10'** is raised from the pan **130**. The solid castings are maintained within the mold cavities by a tight fit between the necks **313** at the open bottoms of the mold cavities and the outer walls of the castings. The castings may then be readily ejected from the mold cavities by the downward movement of the ejector pins into the bottom of the mold cavities which forces the castings out of the open bottoms of the mold cavities. Following the ejection of the castings, the piston **316** is moved into the upper portion of the piston cylinder **318** and the above described process is repeated.

The invention thus provides a relatively simple and efficient method and apparatus for making a large number of smooth surfaced castings which are of uniform composition and shape throughout.

It should be understood that numerous modifications may be made of the preferred embodiments of the invention above described without departing from the broader aspects of the invention.

I claim:

1. Casting apparatus comprising a die assembly having separable upper and lower die elements adapted, when brought together into confronting relation, to define a mold cavity which conforms in shape to the article to be cast, means for supporting said die assembly above an open top container which holds a body of molten material to be cast, said lower die element being an open top, dish-shaped element with a flat bottom and upstanding side walls and having at least one aperture extending through the bottom thereof forming a mold cavity entry-way, said upper die element having a mold cavity portion open at the bottom and shaped to enable the ready removal of the article to be cast through the open bottom thereof, means for moving said upper die element into engagement with said lower die element with the open bottom of said upper die element abutting the bottom of said lower die element, with said entry-way communicating therewith, and for depressing said lower die element into the molten material in the container with the top of the side walls thereof being above the level of the molten material in the container, said last-mentioned means being adapted to move said upper die element out of engagement with said lower die element following the solidification of the molten material in said mold cavity, means for moving one of said die elements laterally with respect to the other to shear the slug in said entry-way from the remainder of the casting, means for retaining the solid casting in said upper die element following the separation of the upper and lower die elements, and means for removing the casting from the open bottom of the upper die element.

2. Casting apparatus comprising a frame member being adapted to overlie an open top container containing molten material to be cast, a die assembly depending from said frame member and including a lower die element having an apertured bottom and an upper die element having at least one mold cavity which is open at the bottom and being shaped to enable the ready removal of the article to be cast through the open bottom thereof, an aperture in the top of said mold cavity which is pervious to the passage of air but impervious to the passage of said molten material therethrough, first means for moving said upper die element into engagement with the lower die element with the aperture in the lower die element bottom communicating with the mold cavity, said first means being adapted to further move said lower die element downward into the molten material in the said container, second means for connecting a source of adjustable air pressure to said upper die cavity aperture to control the rate of flow of molten material into the said mold cavity, third means for separating said upper die element from the lower die element following the complete solidification of the material in said mold cavity, fourth means for retaining the solid casting within the cavity of the upper die element following the separation of the upper and lower die elements, and fifth means for removing said casting from the open bottom of said upper die element mold cavity following the separation of said die elements.

3. Casting apparatus comprising a frame member being adapted to overlie an open top container containing molten material to be cast, a separable die assembly depending from said frame member and including a lower die element having an apertured bottom and an upper die element having at least one mold cavity which is open at the bottom and being shaped to enable the ready removal of the article to be cast through the open bottom thereof, an aperture in the top of said mold cavity which is pervious to the passage of air but impervious to the passage of said molten material therethrough, first means for moving said upper die element into engagement with the said lower die element with the aperture in the lower die element bottom communicating with the mold cavity, said first means being adapted to further move said upper die element and lower die element downward into the molten material in the said container, second means for connecting a source of air pressure to said upper die cavity aperture in the top of said die element mold cavity to control the rate of flow of molten material into the mold cavity, third means for moving said upper die element from the lower die element following the complete solidification of the material in said mold cavity, fourth means for connecting a source of very low pressure to said aperture in the top of said mold cavity prior to the separation of said die elements and following the solidification of the molten material in the die cavity to retain the solid casting within the cavity of the upper die element by suction, and fifth means for disconnecting said source of very low pressure from said upper mold cavity aperture to release the solid casting therefrom following the separation of said die elements.

4. A casting machine comprising separable die elements which, when brought into engagement, define a mold cavity having an entry-way extending through the bottom of one of the die elements and communicating with the mold cavity, first means for moving said separable die elements from a position wherein the elements are displaced from one another and are out of contact with a body of molten material, into a position wherein the die elements are in engagement and the bottom of the assembly is immersed into a body of molten material, said first means also being adapted to remove said die assembly from contact with the body of molten material and to separate the die elements from each other following the solidification of the molten material in the mold cavity and said entry-way, an ejecting device for ejecting slugs from said entry-way, a finished casting receiving member, second means for moving said ejecting device and finished casting receiving member from a position displaced from said die elements to a position between the separated die elements with the ejecting device adjacent to the die element having said entry-way and said finished casting receiving member adjacent to the other die element, third means for maintaining the solid casting secured to said latter die element following the separation of said die elements, first control means responsive to the separation of said die elements to cause said second means to move said ejecting device and finished casting receiving member between the separated die elements, said first means also being responsive to the movement of said die elements toward each other to cause said second means to move said ejecting device from between the separated die elements, second control means responsive to the position of said finished casting receiving member opposite said other die element to cause said third means to eject a solid casting from said other die element, third control means for periodically actuating said first means to move said die elements into the body of molten material and for causing said first means to raise said die assembly from the body of molten material and to separate said die elements following the solidification of the molten material in said die cavity, and fourth means responsive to the upward movement of said die assembly from the body of molten material for moving one of said die elements laterally with respect to the other die element to shear the main body of the solid casting from the slug remaining in said entry-way.

5. The casting machine of claim 4 wherein one of the die elements constitutes an upper die element having an entry-way extending through the top thereof for com-

munication with the die cavity and the other die element constitutes a lower die element having said first mentioned entry-way therein, a source of very low pressure for connection to said entry-way at the top of the upper die element to retain the solid casting in said upper die element, said second control means including a relatively stationary control element and a removable control element which is movable with said finished casting receiving member, said latter control elements making engagement when the finished casting receiving member has been moved opposite the upper die element to thereby disconnect said source of low pressure from said entry-way at the top of said upper die element to cause ejection of the solid casting previously retained thereby by the suction applied by the source of low pressure.

6. A casting machine comprising a mold having mold elements movably mounted with respect to each other and defining an enclosed mold cavity therebetween, an entry-way to said mold cavity in one of said mold elements, means for bringing said mold elements together and for dipping said mold into a body of molten material with said entry-way immersed therein, means for filling said mold cavity through said entry-way, means for raising said entire mold out of said body of molten material and for separating said mold elements, means for severing the solidified main casting body from the solid slug remaining in said entry-way, means for removing the main solid casting body from said mold, and means for ejecting the said solid slug in said entry-way following the separation of the mold elements.

7. A casting machine comprising a mold having separable mold elements defining an enclosed mold cavity therebetween, an entry-way to said mold cavity in one of said mold elements, means for filling said mold cavity through said entry-way, means for severing the solidified main casting body from the solid slug remaining in said entry-way, means for separating said mold elements following solidification of the mold cavity contents, and for bringing said mold elements together, means for removing the main solid casting body from said mold, means for ejecting the said solid slug in said entry-way, means responsive to the actual separation of said mold elements for automatically moving said ejecting means into position adjacent to said entry-way, and means for automatically moving said ejecting means out of the way of said mold elements prior to the engagement thereof.

8. In a casting machine where the mold is inserted directly into a body of molten material to be cast, the improvement comprising a mold having an open-top, dish-shaped outer mold body including sides and a bottom wall, the side walls being sufficiently high to project above the surface of the said body of molten material, an entry-way in the bottom wall of said outer mold body which communicates with the bottom of a mold cavity within the mold, a mold cavity-forming member within said outer mold body having walls defining the sides and top of said mold cavity which are made of a highly heat conductive material, at least the side walls of said latter member having a cooling medium circulating therein to cool the walls of the mold cavity other than the bottom wall thereof, the wall defining the bottom of said mold cavity being said bottom wall of said outer mold body which is heated by virtue of its direct contact with the body of molten material.

9. In a die casting machine having a die element with an open bottom mold cavity, and wherein said mold cavity has a portion undercut a small amount for retaining the finished casting therein, an ejector pin for ejecting the casting from the mold extendable downward into the said mold cavity through an opening in the walls of the die element to force a solidified casting out of the open bottom thereof, said ejector pin being spaced from the walls defining said opening, and a source of low pressure coupled with the mold cavity through the said space between the ejector pin and the said walls of said opening to effect the exhaustion of the air in the mold cavity so as to draw molten material into the mold cavity to fill same.

10. Casting apparatus comprising a die assembly having separable upper and lower die elements adapted when brought together to define a mold cavity therebetween which conforms in shape to the article to be cast, said lower die element being an open-top, dish-shaped element having a filling hole extending through the bottom thereof, said upper die element having an open bottom mold cavity which is closed by the lower die element but with the filling hole communicating with the cavity, means for positioning said lower die element alternately in and out of contact with a body of molten material with the top of the side walls thereof extending above the level of the molten material and for positioning said upper die element over and in engagement with the bottom of said lower element, means for raising said upper die element out of said dish-shaped lower die element following the solidification of the material in the mold cavity while maintaining the filling opening in the same location with respect to the mold cavity that it occupied during the flow of liquid metal through the opening into the cavity, and means for shearing solidified casting metal in the filling hole from the solidified casting metal in the mold cavity by shifting one die element with respect to the other die element.

11. In a casting machine, a pair of relatively movable mold elements adapted to define a mold cavity therebetween, one of said mold elements having an entry-way into the mold cavity through which molten material enters the cavity, means for severing the solidified main casting from the slug remaining in said entry-way prior to removal of the casting from the mold, said means including means for moving one of said relatively movable mold elements in a direction transverse to the outlet end of said entry-way to shear the entry-way slug from the main casting body, and means for automatically moving said mold elements into their mold cavity defining position, and for moving the same into a position to expose the solid casting within one of the mold elements to permit removal thereof from the mold.

12. In a casting machine, a pair of relatively movable mold elements adapted to define a mold cavity therebetween, one of said mold elements having an entry-way into the mold cavity through which molten material enters the cavity, means for severing the solidified main casting from the slug remaining in said entry-way prior to removal of the casting from the mold, means for automatically moving said mold elements into their mold cavity defining position, and for moving the same into a position to expose the solid casting within one of the mold cavity elements to permit removal thereof from the mold, means for ejecting the solid slug remaining in said entry-way, means for moving said slug-ejecting means opposite the mold element containing said entry-way when said mold elements are in said latter position, and means for operating said slug-ejecting means when in said last-mentioned position to eject slugs from said entry-way.

13. Casting apparatus comprising vertically separable upper and lower die elements defining a mold cavity therebetween, said lower die element having an aperture therethrough which forms an entry-way to the mold cavity, said upper die element having a mold cavity open at the bottom and shaped to enable the ready removal of the article to be cast through the open bottom thereof, first means for moving said upper die element into and out of covering engagement with said lower die element, means for bringing the aperture portion of the lower die element and a source of liquid metal together for the flow of liquid metal into the mold cavity through the aperture, and means for moving one of said die elements laterally with respect to the other to shear the slug

remaining in said entry-way from the remainder of the casting following the solidification of the casting material in said mold cavity, and means for retaining the solid casting in said upper die element following the separation of the upper and lower die elements.

14. Casting apparatus comprising an upright support member, a horizontally extending frame member supported from said upright support member and being adapted to overlie an open top container containing molten material to be cast, an assembly supported from said frame member and movable in a horizontal direction relative thereto, said assembly including a pan support member carrying an open top pan having an apertured bottom, a resilient member for holding said pan support member in an upper position with said pan removed from the molten material in said container, a vertically movable die element carried by said frame member and having at least one mold cavity which is open at the bottom and being shaped to enable the ready removal of the article to be cast through the open bottom thereof, first means for moving said die element downward into engagement with the bottom of said pan with the pan bottom closing the open bottom of the mold cavity in said die element and said aperture in the pan bottom communicating with the mold cavity, said first means further moving said die element and pan downward into the molten material in said container with the top of said pan above the surface of the molten material in said container, second means for laterally displacing said pan and die element following the completion of the casting operation and prior to the separation thereof for shearing the slugs remaining in said pan aperture from the remainder of the casting, third means for separating said die element from the pan following the complete solidification of the material in said mold cavity, fifth means for ejecting the slugs from said pan aperture following the separation of said pan and die element, and sixth means for moving said fifth means into operating position over said pan following the separation of said die element from said pan, and for moving said fifth means away from said pan following the ejection of the slugs and prior to the engagement of the said die element with the pan.

15. The casting machine of claim 14 wherein one of the die elements constitutes an upper die element and the other die element constitutes a lower die element, and the lower die element having said entry-way therein, and said first control means includes a relatively stationary control element and a movable control element that is movable with said upper die element, said control elements making contact to actuate the first control means when said upper die element has been moved upward from said lower die element to move said ejecting device between said die elements, the separation of said latter control elements occurring when the upper die element is moved downward toward the lower die element to actuat said first control means to move said ejecting device from between the separated die elements.

16. A metal casting machine comprising separable die elements which, when brought into engagement, define a mold cavity having an entry-way for the flow of metal thereinto through the bottom of one of the die elements, first means for moving said separable die elements into a position wherein the die elements are in engagement and the bottom of the assembly is immersed in a body of molten material, said first means also being adapted to remove said die assembly from contact with the body of molten material and to separate the die elements from each other following the solidification of the molten material in the mold cavity and said entry-way, an ejecting device for solidified casting metal from said entry-way, second means for moving one of said ejecting device and die elements to a position where the ejecting device is in operative position between the separated die elements adjacent to the die element having said entry-way, third means for removing the main solid casting from the die element containing said entry-way upon separation of said die elements, first control means responsive to the separation of said die elements to actuate said second means, and second control means for periodically actuating said first means to move said die elements into the body of molten material and for causing said first means to raise said die assembly from the body of molten material and to separate said die elements following the solidification of the molten material in said die cavity.

17. A casting machine comprising a mold having separable mold elements defining an enclosed mold cavity therebetween, an entry-way to said mold cavity in one of said mold elements, means for filling said mold cavity through said entry-way, means for bodily moving said separable mold elements together to bring the mold element containing said entry-way into and out of a body of molten material, means for severing the solidified main casting body from the solid slug remaining in said entry-way following the removal of the mold from the body of molten material, means for separating said mold elements following solidification of the mold cavity contents and the removal of the mold from said body of molten material, and for bringing said mold elements together, means for removing the main solid casting body from said mold, and means for ejecting the said solid slug in said entry-way following the separation of said mold elements.

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