

March 4, 1941.

E. G. FAHLMAN

2,233,405

METHOD OF AND APPARATUS FOR CASTING CYLINDER HEADS

Filed Dec. 27, 1938

6 Sheets-Sheet 1

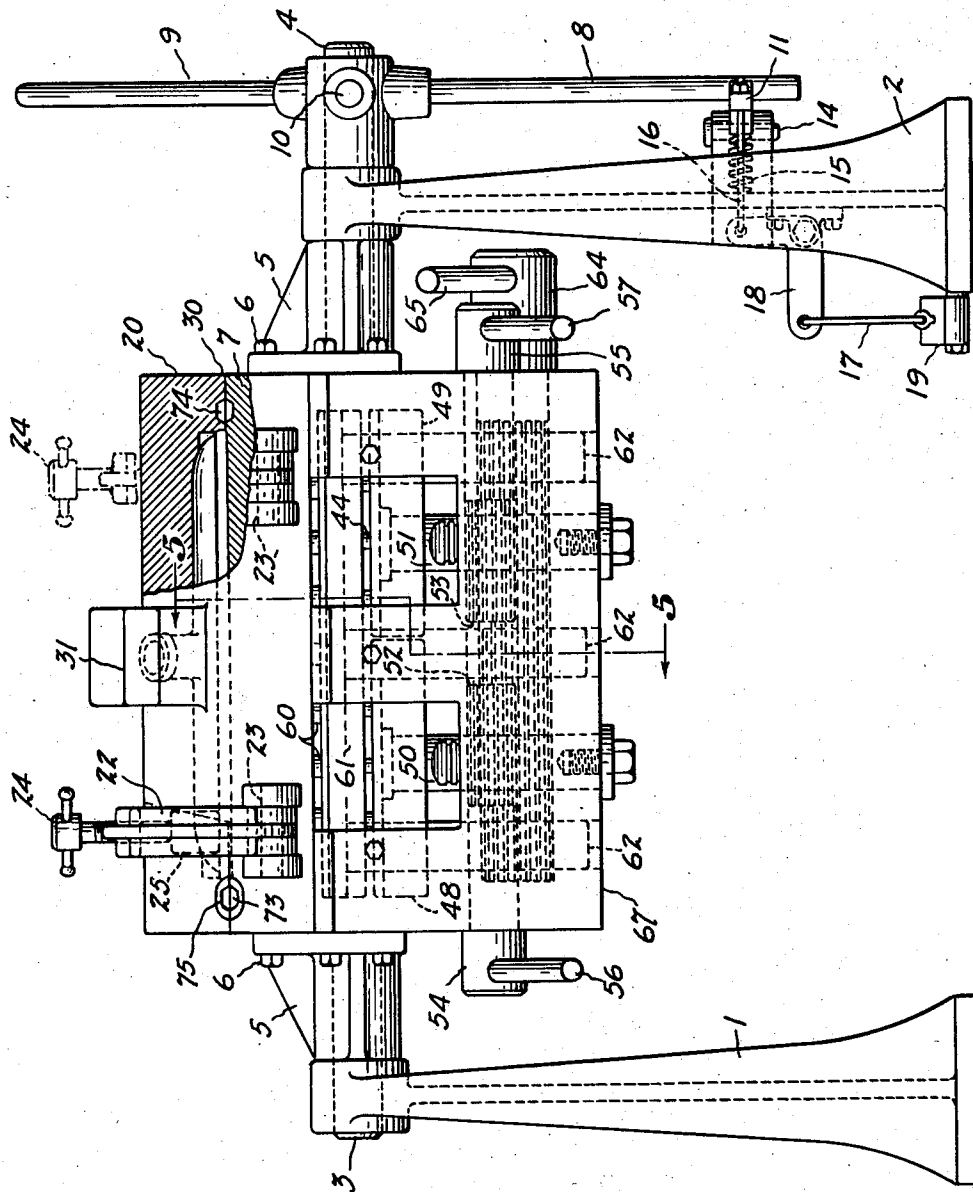


Fig. 1

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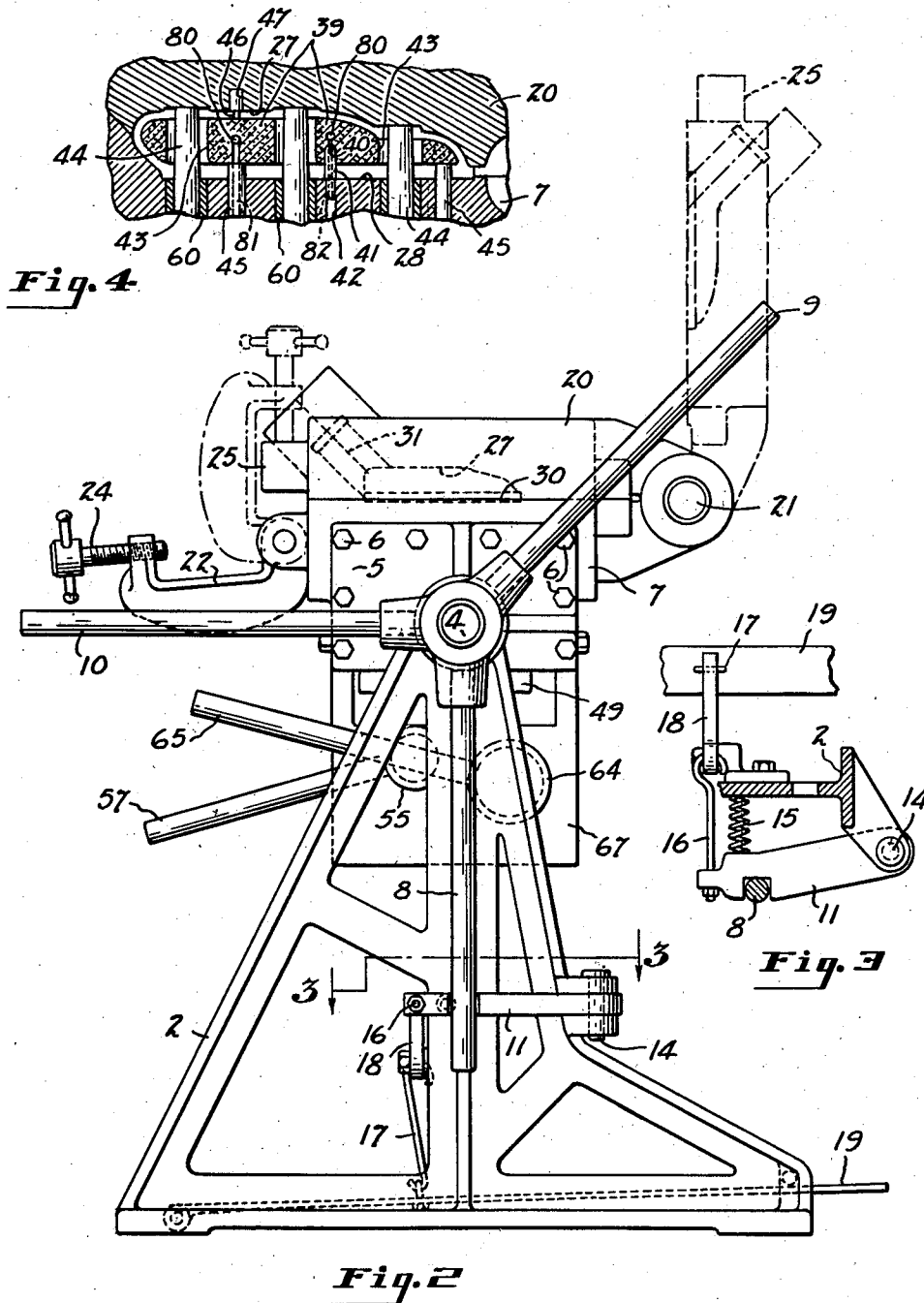
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METHOD OF AND APPARATUS FOR CASTING CYLINDER HEADS

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6 Sheets-Sheet 2



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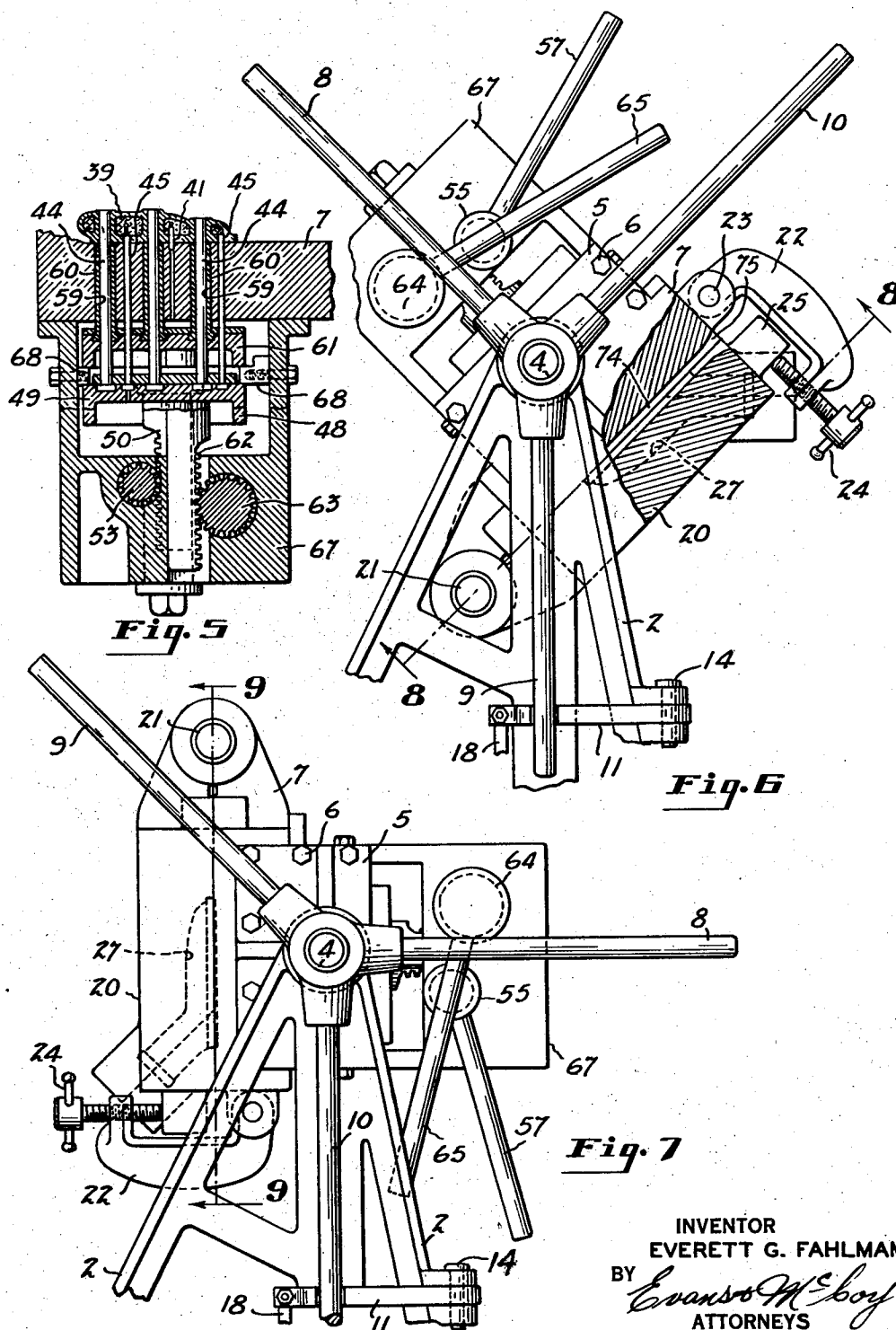
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METHOD OF AND APPARATUS FOR CASTING CYLINDER HEADS

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METHOD OF AND APPARATUS FOR CASTING CYLINDER HEADS

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6 Sheets-Sheet 4

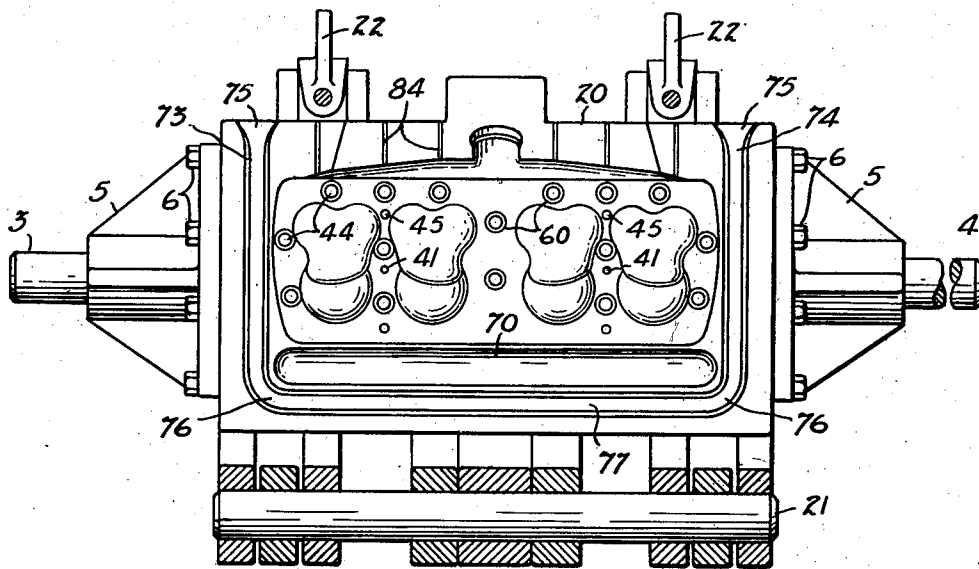


Fig. 8

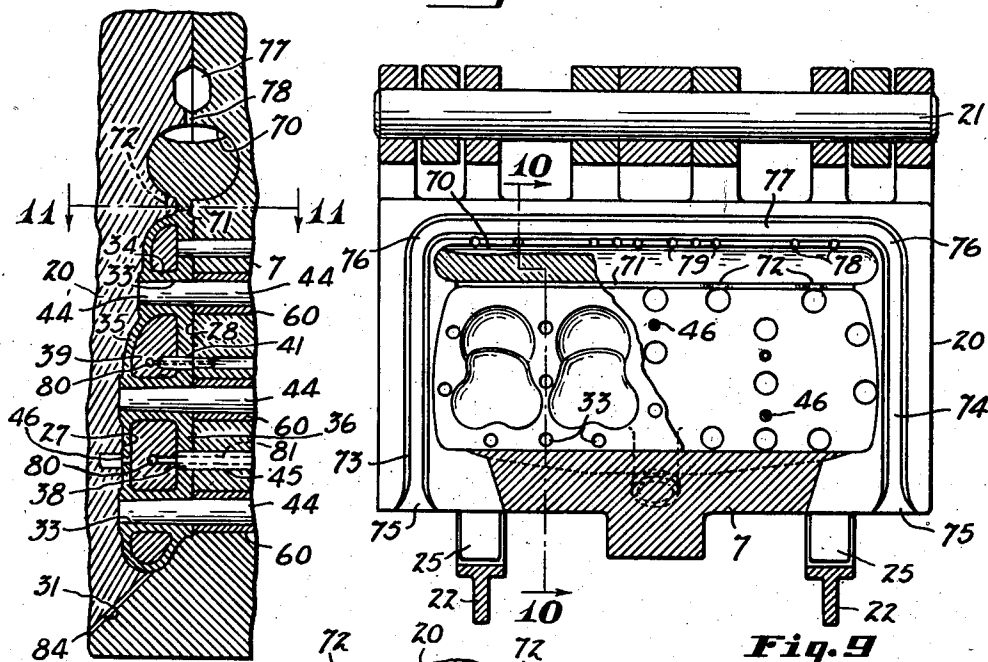


Fig. 9

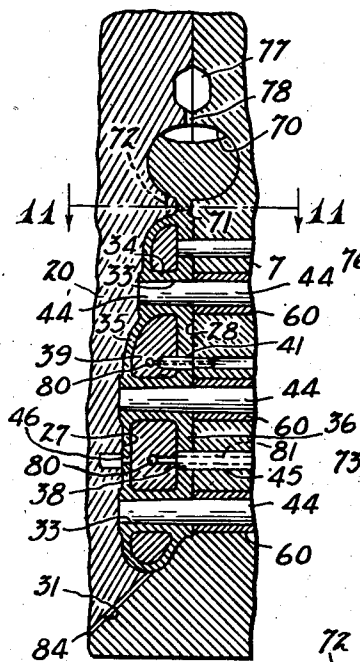


Fig. 10



Fig. 11

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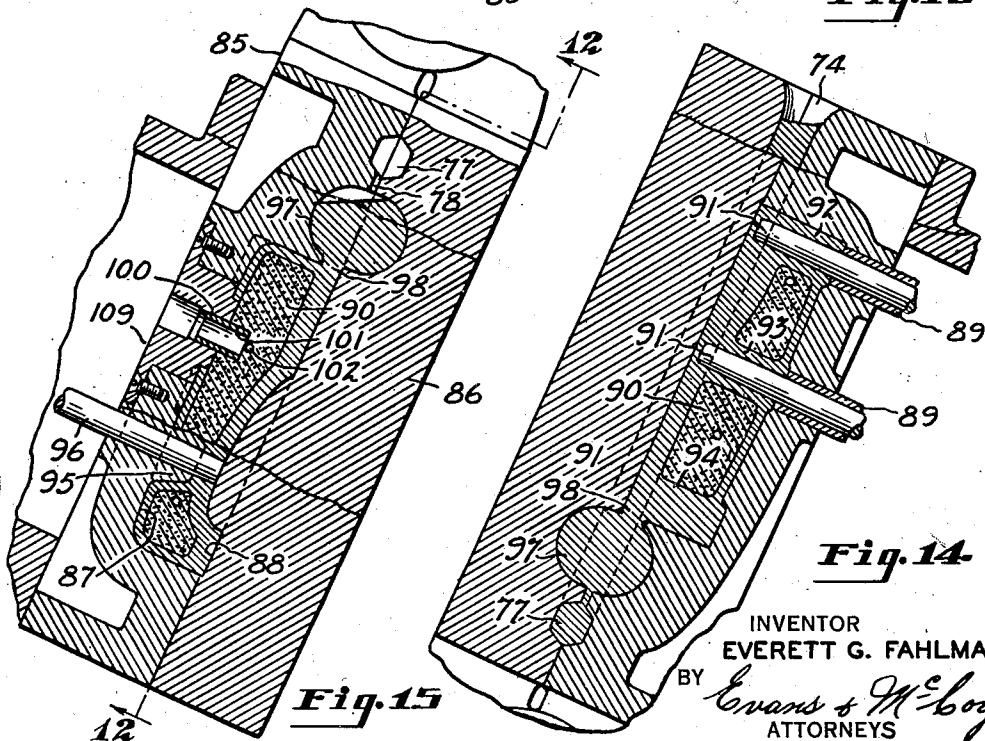
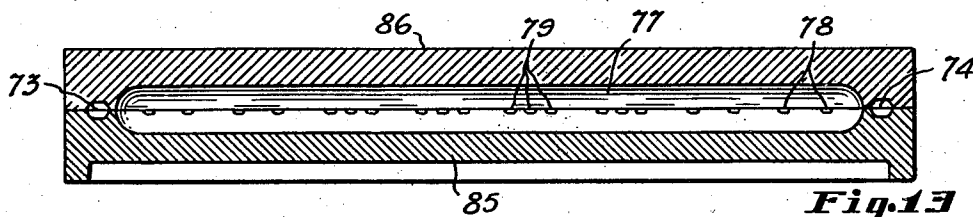
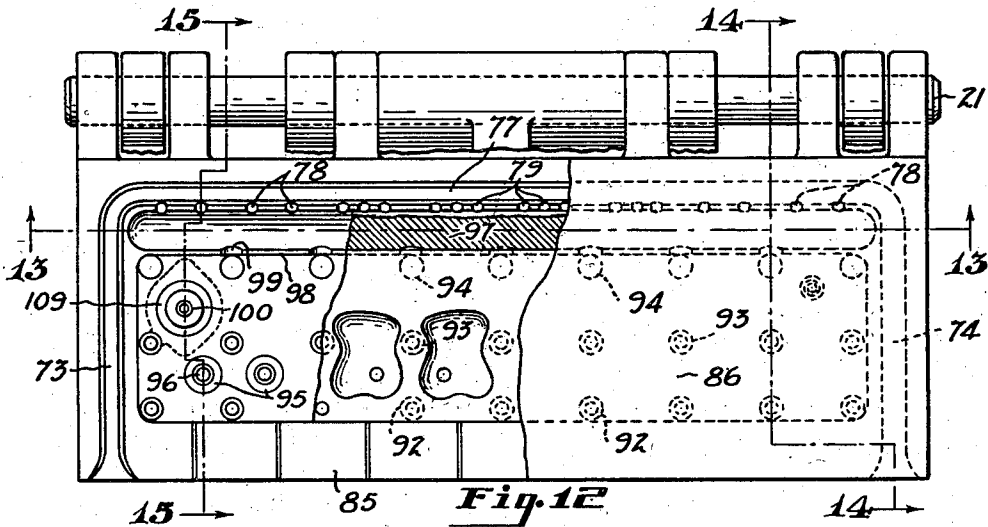
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METHOD OF AND APPARATUS FOR CASTING CYLINDER HEADS

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6 Sheets-Sheet 5



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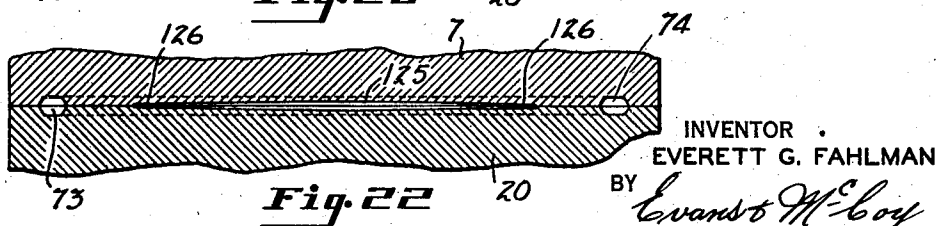
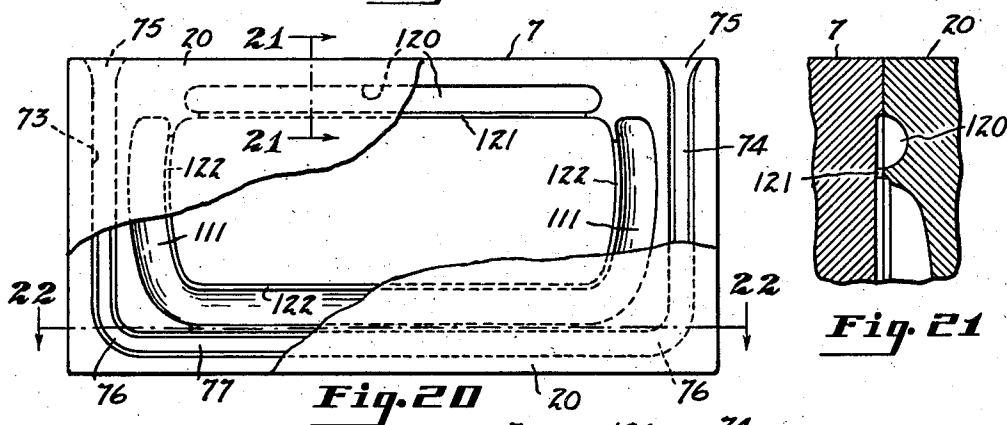
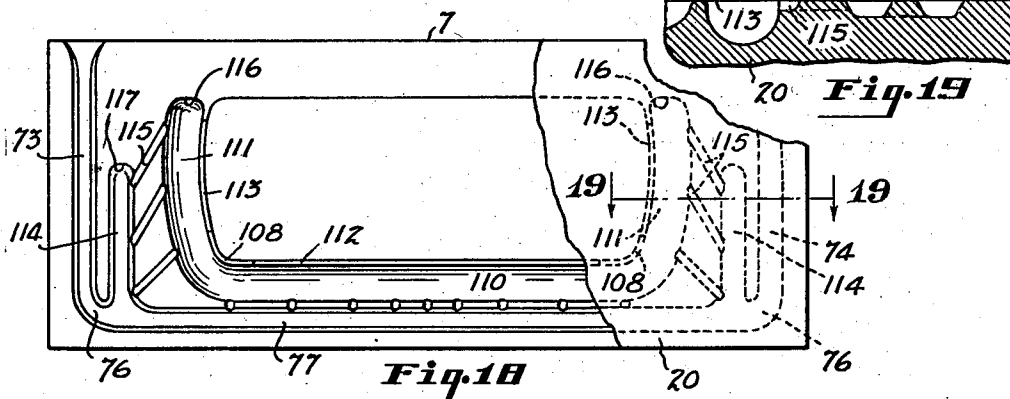
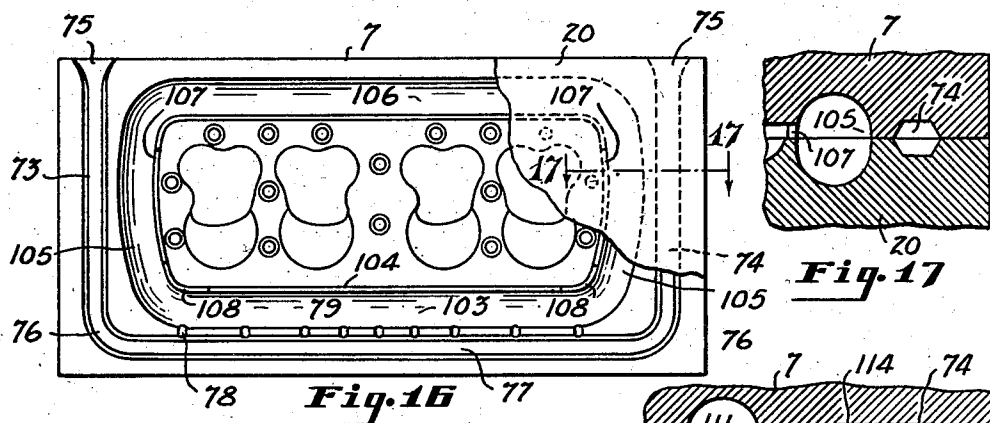
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METHOD OF AND APPARATUS FOR CASTING CYLINDER HEADS

Filed Dec. 27, 1938

6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE

2,233,405

METHOD OF AND APPARATUS FOR CASTING
CYLINDER HEADSEverett G. Fahlman, Lakewood, Ohio, assignor to
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Application December 27, 1938, Serial No. 247,872

26 Claims. (Cl. 22—91)

This invention relates to permanent molds for casting aluminum alloys, and a method of casting such alloys, and particularly to molds for and a method of casting aluminum heads for internal combustion engines.

In the art of casting aluminum and its alloys it is an accepted fact that castings made in permanent molds are superior to those made in sand. One of the advantages of permanent molds is that they allow closer tolerances in the castings and increased strength is obtained because of the greater density produced by the chilling effect of the metal of the permanent mold during the solidifying of the molten metal.

Aluminum and other light alloy cylinder heads have been used on internal combustion engines for many years. However, such cylinder heads have not met with complete commercial success for various reasons such as their high cost. Such cylinder heads have been cast in permanent molds, but because of limitations in the permanent mold art in its present state of development, considerable scrap loss usually resulted, giving rise to the relatively high manufacturing cost mentioned. Furthermore, in adapting conventional permanent molding practice to the casting of cylinder heads, the mold designers have resorted to numerous modifications and alterations. The castings produced have not exhibited the usual advantages of increased strength, smooth surface, and freedom from porosity customarily found in permanent mold castings as compared with sand mold castings.

One of the problems in connection with the use of permanent molds for aluminum alloy castings of non-uniform cross-sectional form or of intricate design results from the fact that, due to the rapid freezing or solidification of the molten metal in the mold, it is difficult to flow the metal into the mold cavity in such manner that defects in castings are not formed by reason of imperfect filling of the mold on account of trapped air or blocking of parts of the cavity by freezing metal.

A prime difficulty in connection with the use of permanent molds for making aluminum and aluminum alloy castings of intricate design and non-uniform cross-sectional form is the chilling effect of the mold sections on the cast metal. The relatively faster freezing or solidifying of the aluminum or like alloy in a metal or permanent mold, makes it difficult to flow the metal into the mold in such a manner as to prevent voids or other types of misrun, by reason of the imperfect filling of the mold on account of trapped air or the blocking of parts of the mold cavity

by premature freezing of the casting metal. Castings of intricate design and which have metal sections of different thickness tend to cause uneven heating of the various sections or parts of the mold, and this uneven heating of the mold sections aggravates the difficulty of properly introducing the metal into the mold without misruns and premature freezing.

Another problem to be overcome in the casting of intricate designs having portions of different thickness is the elimination of surface depressions and internal voids. The high crystallization shrinkage of aluminum and its alloys results in the drawing of molten metal by the relatively thin, faster freezing portions from heavier or thicker sections of the casting, which, because of their higher heat content, freeze or solidify more slowly than the thin sections. Accordingly, when the solidification of the thick or heavy section portions of the casting takes place, there is insufficient metal to completely fill the cavity and the deficiency is made up either by surface depressions, known as "sinks," or internal voids. Where internal voids occur, the resulting casting is unsound and of decreased strength. Furthermore, the porosity of the casting increases the possibility of fluid leakage through the metal of the casting, a defect which is quite objectionable in cylinder heads for internal combustion engines.

Where heavy portions of the castings are along parting lines of the mold it has been common practice to provide riser cavities of relatively large volume in the meeting faces of the mold sections adjacent the heavy sectioned portions of the casting cavity. Such risers are so disposed that metal may be drawn into the casting cavity from the risers during freezing of the metal to supply adjacent portions of the casting with the amount of metal required to make up for the shrinkage.

Cylinder heads for liquid cooled internal combustion engines are of quite intricate designs and numerous substantial variations in the cross-sectional area of the casting occur throughout the length thereof, making it difficult both to fill a permanent mold properly with metal and to prevent defects in the casting due to shrinkage.

The present invention has for its principal object the provision of a mold for and method of casting aluminum or aluminum alloy cylinder heads or the like, which is so gated for the feeding of the molten metal that the flow of the metal into and through the mold cavity is of such uniform and even nature that air in the cavity is eliminated or pushed out ahead of the flow of the

metal, thus avoiding air traps and occlusions, a more specific object being to provide a mold of this type in which the path of flow of the molten metal is such that the mold at the points of ingress of metal is hotter than more remote portions of the mold, so that this feature, in combination with the method of operation, is such that metal is supplied to feed shrinkage in the casting during its freezing, the freezing occurring progressively from the coldest or most remote portions of the mold to the hotter portions of the mold and subsequently to the external metal supplied for compensation of all the metal shrinkage that occurred in the casting.

A further object of the invention is to provide a mold of the character mentioned, which is vented to permit escape of gases arising from the sand core, so as to avoid blows which cause voids in the casting due to the trapping of such gases within the metal in the casting cavity.

When casting a hollow object by means of a permanent mold a frangible sand core is employed to form the chamber or cavity within the casting. The core is subsequently removed in the usual manner after the metal has solidified or frozen. The use of a baked sand core in combination with a permanent mold gives rise to the generation of gas in the sand core, caused by the heat of the molten metal around and in contact with the sand core. Some of the core gas may be generated at the surface of the sand core and, unless the mold is properly designed, commingles with the molten metal to an objectional degree as the latter flows over the core in filling the casting cavity. After the sand core is surrounded by the hot molten metal and during the solidification of the latter, gas is usually generated internally of the core and unless released builds up a considerable pressure therein. In some instances such pressure is sufficient to force the gas through the solidifying or partly molten metal even to the extent of blowing metal out the sprues and risers of the mold. Where the gas forces its way out of the core into the solidifying metal it causes what is known as a blow hole. The resulting casting is either useless as such or of such defective character that the advantages expected from the use of a permanent mold are lost and no material advantage is obtained over sand castings. The present invention aims to provide a method and apparatus for making castings of aluminum and its alloys of intricate design, such as cylinder heads, wherein provision is made for the escape of core gas during the filling of the mold and while the molten metal is freezing and solidifying.

A further object of the invention is to provide a mold for cylinder heads or the like which requires in the casting operation an amount of metal only slightly in excess of that required to fill the casting cavity.

A further object is to provide a mold of simple design made up of a minimum number of parts from which castings can be quickly and easily removed and which can be quickly assembled for the casting operation.

With the above and other objects in view, which will become apparent as the description proceeds, the invention may be said to comprise a mold such as illustrated in the accompanying drawings, hereinafter described and particularly set forth in the appended claims, together with such variations and modifications thereof as will be apparent to one skilled in the art to which the invention appertains.

Reference should be had to the accompanying

drawings forming a part of this specification, in which:

Figure 1 is a front elevation of a permanent mold embodying the invention;

Fig. 2 is a side elevation of the mold;

Fig. 3 is a detail view partly in section and with parts removed, showing the latch for holding the mold in various positions of adjustment taken substantially on the line 3—3 of Fig. 2;

Fig. 4 is a fragmentary transverse section through the casting cavity and sand core;

Fig. 5 is a section with parts removed taken substantially on the line indicated at 5—5 of Fig. 1;

Fig. 6 is a fragmentary side elevation with parts removed showing the mold in pouring position;

Fig. 7 is a fragmentary side elevation with parts removed showing the mold in inverted freezing position;

Fig. 8 is a section taken substantially on the line indicated at 8—8 in Fig. 6, looking toward the bottom section of the mold;

Fig. 9 is a section taken substantially on the line indicated at 9—9 in Fig. 7, looking toward the top section of the mold;

Fig. 10 is a fragmentary transverse section with parts removed through the mold in freezing position and taken substantially on the line 10—10 of Fig. 9;

Fig. 11 is a fragmentary longitudinal section showing the gate from the feeding cavity into the casting cavity and taken substantially on the line 11—11 of Fig. 10;

Fig. 12 is a view partly in section and with parts broken away, showing a slightly modified form of mold and corresponding to Fig. 9 of the first mold illustrated. In this view, which is taken substantially along the line 12—12 of Fig. 15, a portion of the top mold section is broken away to show the casting and feeding cavities and the sprue or pouring passages;

Fig. 13 is a longitudinal section taken substantially on the line indicated at 13—13 in Fig. 12;

Fig. 14 shows the mold of Figs. 12 and 13 in pouring position with parts broken away;

Fig. 15 is a section with parts removed taken substantially on the line indicated at 15—15 in Fig. 12 and enlarged with respect thereto, and showing the mold in freezing position;

Fig. 16 is a diagrammatic illustration showing a modification of the invention, in which the feeding cavity is annular in extent and extends completely around the periphery of the casting cavity;

Fig. 17 is a sectional view taken substantially on the line 17—17 of Fig. 16;

Fig. 18 is a diagrammatic illustration of a modification of the invention, in which the feeding cavity extends on three sides of the casting cavity and receives molten metal from supplementary pouring passages or sprues;

Fig. 19 is a sectional view taken substantially on the line 19—19 of Fig. 18;

Fig. 20 is a diagrammatic illustration of a modification of the invention, in which an overflow cavity is provided for receiving metal which is discharged from the casting cavity after pouring through the latter during the casting operation;

Fig. 21 is a sectional view taken substantially on the line 21—21 of Fig. 20; and

Fig. 22 is a sectional view taken substantially on the line 22—22 of Fig. 20 showing a modified type of gate through which the molten metal flows from the pouring passage into the feeding cavity.

A mold constructed in accordance with the

present invention is mounted for pivotal or turning movement from a pouring position to an inverted freezing position, applying the principle of the invention disclosed in my Patent No. 1,982,424 granted November 27, 1934 to molds for the casting of cylinder heads for motor vehicle engines or other castings of similar form.

As shown in the accompanying drawings, in which like parts throughout the several views are indicated by the same numerals of reference, the mold of the present invention is rotatably supported upon a pair of spaced upright standards 1 and 2 by means of horizontal trunnions 3 and 4 journaled in the tops of the standards and extending from brackets 5 which are attached by means of bolts 6 to the opposite ends of bottom section 7 of the mold. The trunnion 4 extends beyond the journal in the standard 2 and is provided with angularly spaced radially extending arms 8, 9, and 10, which are adapted to be successively engaged by a latch 11 carried by the adjacent standard 2 near the bottom thereof. The arms 8, 9, and 10 may be used to rotate the mold and when successively engaged by the latch 11 hold the mold in the three positions which it occupies during operation. The arm 8 when engaged by the latch 11 holds the mold in assembling position, as shown in Figs. 1 and 2. The arm 9 holds the mold in pouring position as shown in Fig. 6, and the arm 10 holds the mold in freezing position as shown in Fig. 7. The latch 11 is a notched bar connected to the standard 2 by a vertical pivot 14 and is urged outwardly toward engaging position by a spring 15. The latch 11 is connected by links 16 and 17 and a bell crank lever 18 to a treadle 19 so that when the treadle is depressed the latch 11 is drawn inwardly against the spring 15 to releasing position and the mold can be turned from one position to another during operation.

A top mold section 20 is connected along its rear edge to the rear edge of the bottom section 7 by hinge bar 21. The mold is held in closed position by means of clamps 22 connected by pivots 23 to the lower sections 7. The clamps 22 are of U-shape pivoted at one end and carrying screws 24 at their free ends which are adapted to be screwed down upon lugs 25 projecting from the front edge of the upper section 20.

The confronting or meeting faces of the mold sections are formed to cooperatively define an elongated casting cavity having its long axis substantially parallel to the rotational axis of the trunnions 3 and 4. The face of the upper mold section 20 has a recessed surface portion 27 which conforms to the configuration of the outer surface of the outside or exposed part of the cylinder head to be cast. Face portion 28 of the bottom mold section 7 conforms to the configuration of the outside surface of the compression wall of the cylinder head and may be provided with metallic core pads or chills 29 to form the combustion chamber recesses in the cylinder head which overlie the cylinder of the engine. As shown in Fig. 4, the casting cavity defined by the surfaces 27 and 28 and the pads 29 is formed primarily in the upper mold section 20.

The meeting faces of the mold sections 7 and 20 are flat around the margin of the casting cavity, forming a parting line 30 which preferably lies in a substantially horizontal plane along the side and rear edges of the mold when the mold is in assembling position (Figs. 1 and 2). Along the front edge of the mold the meeting

faces are inclined upwardly intermediate the ends of the mold to provide an upwardly inclined parting line 31. The parting line 31 is along the center line of water outlet 32 of the particular cylinder head for which the mold is designed.

The cylinder head casting is hollow substantially throughout its length to provide a chamber for circulation of cooling liquid or water and has bolt receiving apertures 33. The apertures 33 are formed in bosses 34 which are integral with outer wall 35 and compression wall 36 of the cylinder head and extend transversely through the cooling liquid chamber of the head.

The casting is also provided with apertures 38 in the bottom or compression wall 36 through which communication is established between the interior or cooling liquid chamber of the cylinder head and the water jacket or jackets of the engine. A sand core 39 is disposed in the casting cavity between the surfaces 27 and 28 of the mold sections 20 and 7 respectively, and is shaped to conform to the desired interior cavity or cooling liquid chamber of the casting. This sand core has apertures therethrough of a diameter corresponding to the external diameter of the bosses 34 which form the tubular walls of the bolt apertures 33 within the cooling chamber of the head. The side of the core 39 toward the mold section 7 is provided with a number of recesses 40 adapted to receive positioning pins 41 which have reduced diameter and portions frictionally retained in drilled holes 42 formed in the face 28 of the mold section 7.

The lower section 7 of the mold carries a series of slidably mounted core pins 44 which are adapted to be projected through holes in the cavity face 28 substantially entirely across the mold cavity, centrally of the openings in the sand core which define the bosses 34, thus serving to form the apertures 33 through the head. Another series of core pins 45 slidably mounted in the lower section 7 are adapted to be projected through the face 28 of the mold section into the casting cavity a distance corresponding to the thickness of the bottom or compression wall 36 of the casting and into abutting engagement with the sand core to serve as supports for the latter and to define the cooling liquid inlets 38. Suitable chaplets 46 may be provided and are received in spaced holes 47 in the face 27 of the top mold section. These chaplets extend into the casting cavity to engage the core 39 when the mold is closed and retain the core in proper spaced relation with respect to the mold surface 27.

Beneath the bottom section 7 there are mounted a first pair of movable heads 48 and 49 disposed in end to end relation and each extending one-half the length of the casting cavity. To these heads are attached the core pins. Racks 50 and 51, attached to the bottoms of the heads 48 and 49 and projecting at right angles thereto, are engaged by pinions 52 and 53, respectively, on shafts 54 and 55 which are operated by means of handles 56 and 57.

Surrounding the core pins 44 and slidable in apertures 59 in the bottom section 7 are tubular knockout pins or sleeves 60 which are attached at their lower ends to a head 61. Racks 62 are secured to the head 61 and are engaged by pinions 63 on a shaft 64 having an actuating handle 65.

The pin supporting heads and their actuating racks are mounted in a housing 67 secured to the

under side of the mold section 7. The heads 48, 49, and 61 are guided by the rack bars in the housing 67 and are movable toward and away from the mold section 7 by means of the racks and pinions actuated by the handles 56, 57, and 58, respectively. Stops 68 secured to the housing 67 engage the heads to limit the movement thereof. The heads 48 and 49 seat against the stops 68 when the core pins are fully projected into the casting cavity, substantially in the position shown in Fig. 4. The stops engage the head 61 when the ejector sleeves or hollow pins 60 are flush with the surface 28 of the casting cavity. After each casting operation, the handles 56 and 57 may be actuated to withdraw the pins 44 and then the handle 65 may be actuated to free the casting from the bottom mold section after the mold is opened.

Along the rear edge of the casting cavity the meeting faces of the mold sections are recessed to provide a feeder cavity 70 which preferably is connected throughout substantially its length with a relatively narrow ingate 71, as shown in Fig. 11, the cross-sectional area of the ingate being enlarged at intervals along the length thereof as shown at 72 to provide freer flow of metal into portions of the casting adjacent the bosses 34 which are located near the marginal edge of the casting. The increased flow of hot metal around the marginal core pins induced by the enlarged gate portion retards the freezing of the adjacent portions of the casting and promotes a more uniform freezing of the metal across substantially the entire length of the casting. It is important that the freezing of the molten metal initiates at the side of the casting remote from the feeding cavity 70 and progresses relatively uniformly across the width of the casting toward the feeding cavity. In this manner, as crystallization shrinkage occurs, molten metal is fed into the casting cavity through the ingate 71 from the body of molten metal in the feeding cavity 70. The provision of an increased flow of hot metal by means of the increased area ingate portions 72 through those portions of the casting cavity wherein freezing normally starts and occurs at a relatively rapid rate, tends to reduce such early freezing and delay the freezing of the metal along the edge of the casting cavity adjacent the feeding cavity 70, until the portions of the metal in the casting cavity more remote from said feeding cavity freeze. Accordingly, entrapment of bodies or portions of molten metal in the interior of the casting cavity, by premature freezing of marginal portions of the casting, is avoided.

Recesses are formed in the meeting faces of the mold sections to define pouring passages or sprues 73 and 74 which extend from inlet openings 75 in the parting line 31 at the front edge of the mold along opposite ends of the casting cavity beyond the feeding cavity 70. Along the rear edge of the mold the ends 76 of the pouring sprues are joined by a connecting passage or sprue 77 which substantially parallels the feeding cavity 70 on the opposite side thereof from the casting cavity and is formed by mating recesses in the meeting faces of the mold section. The passage 77 is connected to the feeding cavity 70 at intervals by suitable end gate apertures 78 and central gate apertures 79. As shown in Fig. 9, the apertures or gates 79 which provide the inlets from the connecting sprue passage 77 to the feeding cavity 70 adjacent the central portion of the passage 77 are spaced closer together than the

end gate passage 78 to provide for flow into the feeding cavity 70 through an inlet, the cross-sectional area of which per unit of length gradually increases in the direction of flow of molten metal in the passage 77 from the ends of the feeding cavity 70 to the center thereof, so as to insure uniform filling of the feeding cavity and flow into the casting cavity substantially simultaneously and evenly along the full length of the ingate 71, and uniform upward flow into the casting cavity, except for the increased flow through the ingate enlargements 72 which effects a somewhat lateral flow of the metal in the casting cavity above these points of ingress towards both ends of the cavity.

In operation the mold previously heated to the proper temperature and with the casting cavity surfaces suitably treated with "dope" in the usual manner, is first placed in assembling or first position with the upper section raised as shown in dotted lines in Fig. 2. The handles 56 and 57 are operated to raise the heads 48 and 49 to their uppermost positions to project the core pins through the bottom section 7. The handle 65 is operated to retract the ejector sleeves 60 and the core positioning pins 41 are set in the holes 42 in the bottom mold section. The sand core 39 is then placed on the section 7 upon the tops of the supporting core pins 45 with the positioning pins 41 projecting into the recesses 40 thereof and the core pins 44 projecting centrally through the apertures 43 of the sand core. The chaplets 46 are positioned in the holes 47 of the top mold section 20 and the latter is then swung to closed position and locked by means of the clamping screws 24.

A network or maze of interconnecting passages 80 are provided internally of the sand core 39 and communicate with the atmosphere through passages 81 and 82 formed in the supporting core pins 45 and positioning pins 41. In this manner, core gas generated in the core 39 during the casting operation and while the aluminum metal is solidifying, is permitted to escape freely from within the core, passing to the atmosphere through the passages 80 in the core and the passages 81 and 82 in the core supporting members. Thus is prevented the building up of a pressure of core gas within the core which would otherwise be apt to force itself through the molten or solidifying metal and cause a misrun or other imperfect casting. The latch 11 is released and the closed mold is moved to second or pouring position, shown in Fig. 6. In this position of the mold the pouring passages 73 and 74 have their open or inlet ends 75 up, and the connecting passage 77 and feeding cavity 70 are wholly below the casting cavity.

Two operators, one at each end of the mold, pour metal from ladles into the inlets 75 of the sprue passages 73 and 74. This pouring is continued until the level of the molten metal rises to the top of the pouring passages. The molten metal flows down the passages 73 and 74, into the connecting sprue passage 77, through the openings 78 and 79, upwardly into the feeding cavity 70 and then upwardly through the gate 71 into the casting cavity. The molten metal rises uniformly in the casting cavity through the passages around the core members until the casting cavity is filled completely. The reversal of direction of flow prior to entry into the feeding cavity 70 and the mold or casting cavity and the restriction of the inlet toward the ends of the feeding cavity insures the filling of the passage 77 and

cavity 70 prior to flow of metal into the casting cavity of the mold so that turbulence is quieted prior to flow into the mold and flow into the mold cavity is governed solely by hydrostatic pressure, the cross-sectional area of the passages being such that the level of the molten metal in the pouring passages 73 and 74 rises substantially evenly with the level of the metal within the mold cavity. During the pouring of the molten metal, with the mold in its pouring position shown in Fig. 6, the pouring passages 73 and 74 are inclined to the vertical about 45°. Hence the metal being introduced into the mold flows smoothly and evenly down the side walls of the pouring passages without a free drop, which would be apt to produce a splattering of the metal. Accordingly, the metal flows into the connecting passage 77 from the opposite ends 76 thereof in smooth homogeneous streams free from entrapped or occluded air.

The metal flowing upwardly into the casting cavity through the ingate 71 takes a divided course. One portion of the inflowing metal passes upwardly through that part of the casting cavity which defines the heavy sectioned compression wall 36 of the cylinder head disposed between the sand core and the casting cavity surface 28 of the bottom mold section 7. Another portion of the incoming metal flows upwardly through that part of the casting cavity which defines the outer or thin sectioned wall 35 of the cylinder head and is disposed between the sand core and the surface 27 of the top mold section 20. However, due to the rotation of the mold the relatively flat casting cavity is inclined to the vertical and the top mold section is disposed beneath the bottom mold section, during the pouring of the metal, and the thin sectioned portion of the casting cavity is beneath the sand core and under the heavy sectioned portion of the casting cavity, the latter being disposed above the sand core.

The positioning of the mold so that the portions of the casting cavity which define the relatively thin sectioned top and side wall portions of the cylinder head are below the portions of the casting cavity which define the relatively thick sectioned portions of the cylinder head promotes a more even and uniform flow of the metal upwardly through the casting cavity on the opposite sides of the sand core. The top and side walls of the cylinder head casting are thinner than the bottom wall so that, if the pouring were done with the mold vertical, the metal would flow upwardly more readily through the wider passages in the cavity in which the bottom wall of the casting is formed and into which the gate 71 opens directly. The mold is therefore inclined in the direction in which the cavity in the mold section 20 partially underlies the mold section 7, in which position upward flow through the thinner top wall forming passages of the mold cavity is favored. The degree of inclination desirable can readily be estimated for a casting of a given configuration or the most effective inclination may be found by trial. The resistance to the flow of the molten metal is greater through the thin portions of the casting cavity than through the thick portions of the casting cavity and inclining the mold so that the thin sectioned portion is lowermost provides the additional hydrostatic pressure required to effect a substantially uniform flow up the opposite sides of the sand core. This feature is of considerable advantage in assuring that the several portions of metal flowing upwardly through the mold rise

on opposite sides of the same core at substantially a uniform even rate so as to meet one another at substantially the parting line 31 which is uppermost during the pouring operation. Thus is prevented the flow of metal through the thick section portion of the casting cavity at a faster rate than through the thin section portion so that the spilling of metal over the uppermost edge of the sand core from one side thereof to the other is avoided.

Air which is displaced by the incoming metal is forced out of the casting cavity through a multiplicity of relatively fine vent grooves 84 formed in the face of one of the mold sections along the side thereof opposite the feeding cavity 70 and 15 communicating with the atmosphere along the parting line 31. The grooves 84 thus extend upwardly from the uppermost edge of the casting cavity when the mold is in pouring position so that the displaced air is vented through the top 20 of the casting cavity.

As soon as sufficient metal has been poured into the mold the latch 11 is tripped and the mold is swung to the third or freezing position shown in Fig. 7. In this position the open ends of the passages 73 and 74 face downwardly. As the mold swings over, the two operators swing their ladles to a position to catch the molten metal which flows by gravity out of the pouring sprue passages 73 and 74, leaving these passages empty. The molten metal in the feeding cavity 70, however, is trapped and as the casting freezes in the inverted position metal from the feeding cavity 70 is drawn downwardly through the gate 71 and the enlargements 72 thereof into the passages 35 around the internal core members to compensate for shrinkage during the freezing of the casting. It has been found that the body of metal in the feeding cavity 70 extending along the whole length of the casting cavity and above the same, and which remains molten until after solidification of the metal in the casting, satisfactorily supplies all metal needed to compensate for freezing. After a sufficient time has been allowed for the freezing of the casting the mold is turned to the assembling or first position. The upper section 20 of the mold is lifted, the core pin heads 48 and 49 are moved downwardly to retract all of the core pins and the head 61 is moved upwardly to elevate the tubular ejector pins 60 which free or lift the casting off the bottom mold section so that it can be readily removed.

When the casting is removed, the knock-out pins are retracted and the core pins raised to their uppermost position, whereupon the mold is ready to receive another sand core for repetition of the cycle.

The core pins 44 act as chills to cause relatively rapid freezing of the tubular connecting portions or bosses 34. The bosses in the portions of the casting near the ingate 71 are retarded in their freezing because of the heating of the core pins extending therethrough effected by the heavy flow of molten metal through the ingate enlargements 72.

The projection of the sand core 39 which forms the interior of the water passage 32 extends to the parting line 31 of the mold and provides an outlet for the vent passages 80 of the sand core.

The housing 50 and mechanism mounted therein serves as a counterbalance for the mold to facilitate turning of the mold about the axis of the trunnions.

In Figures 12 to 14 the invention is shown applied to a mold for casting a cylinder head of the "straight-eight" type. In this adaptation of the invention bottom section 85 of the mold has a cavity defining surface 87 which conforms to the top and side and end faces of the head. Face 88 of top section 86 is shaped to conform to the base of the head. A sand core 90 is positioned within the mold cavity between the faces 87 and 88. The bottom section 85 carries retractable core pins 91 and ejector sleeves 89 which serve the same purpose and correspond to, the core pins and ejector sleeves 44 and 60, respectively, in the mold first described. In this modification, however, the core pins are provided only for stud bosses 92 and 93 which are remote from feeding cavity 97 and stud bosses 94 adjacent the feeding cavity are without core pins. Members 95 on the bottom mold section 85 form depressions in the top of the cylinder head casting for receiving the spark plugs of the engine. Retractable core pins 96 movable through the mold portions 95 form the apertures in the casting for the spark plugs. The feeding cavity 97 extends the full length of the casting cavity along one edge thereof and feeds through continuous ingate 98 upwardly into the casting cavity during pouring, with the mold supported in the inclined pouring position shown in Fig. 14. The ingate 98 is widened at 99 opposite each of the thick sectioned portions of the casting cavity which form the solid stud bosses 94. The pouring passages and connecting passage are similar to those described in connection with Figs. 1 through 11.

As shown in Fig. 15, one or more tubular core members 100 may be provided for venting the sand core 90. The core member 100 extends into a recess 101 in the sand core and the sand core may be provided with passages 102 to conduct gases to the outlet provided by the tubular core member. Preferably, one of the tubular core venting members 100 extends through a member 109 secured in an aperture of the mold section 85. The member 109 is arranged to form water outlet passage 118 of the cylinder head.

As shown in Fig. 14 and Fig. 15, the ingate 98 opens into the casting cavity at the side thereof which forms the relatively thick base portion of the casting. The inclination of the mold in the pouring position, Fig. 14, is such as to favor flow through the thinner passages of the casting cavity, and as shown in Fig. 15, the inclination of the mold in the freezing position is such as to favor flow to the thicker portions of the casting.

In Figs. 16 through 22 are diagrammatically illustrated modifications of the invention. In these figures the modifications have been shown as applied to a mold for casting a cylinder head of the character illustrated in Figs. 1 through 11. It is to be understood, however, that these variations or modifications can be adapted to other cylinder heads such as the cylinder heads shown in Figs. 12 through 15.

In Fig. 15 the feeding cavity is shown as being of annular extent and is disposed around the peripheral edges of the relatively flat casting cavity. In the casting operation the molten metal is poured into the inlets 75 of the pouring sprues 73 and 74, flowing downwardly therein between the meeting faces of the mold and thence into the horizontally disposed connecting sprue or passage 77. The molten metal then rises or flows upwardly through the gates 78 and 79 into receiving portion 103 of the feeding cavity, which extends substantially horizontally and is

located between the connecting passage 77 and the casting cavity. While the mold is in pouring position the receiving portion 103 is the lowermost portion of the feeding cavity and is below the casting cavity. A substantially continuous ingate 104 connects the feeding cavity 103 to the casting cavity and corresponds to the ingate 71 previously described. The ends of the receiving portion 103 of the feeding cavity are continuous with end portions 105 of the feeding cavity, which are disposed at opposite ends of the casting cavity. The ends of the portions 105 of the casting cavity remote from the receiving portion 103 are continuous with a side portion 106 of the feeding cavity, which extends along the side of the casting cavity opposite the receiving portion 103 and in parallel relation therewith. As the molten metal rises in the casting cavity, the end portions 105 of the feeding cavity receive molten metal from the ends of the portion 103. Metal from the end portions 105 flows laterally into the casting cavity through substantially continuous gates 107 (Fig. 17). If desired, the gates 107 may be continuous with the gate 104 around the entire bottom and side edges of the casting cavity to promote a more uniform flow of metal into the cavity during the pouring operation. However, for practical purposes in connection with the machining and finishing of the casting, it is preferable that the corners of the casting cavity be blocked off as indicated at 108, so that at these points the feeding cavity does not communicate with the casting cavity.

Between the uppermost edge of the casting cavity and the portion 106 of the feeding cavity there is no ingate. The feeding cavity portion 106 carries heat to the portions of the mold remote from the receiving portion 103 of the feeding cavity and in this manner tends to equalize the temperature of the mold and to promote a more uniform and even freezing of the metal in the casting cavity when such is desired. The portions 103, 105, and 106 of the feeding cavity shown in Fig. 16 are of substantially uniform cross-sectional area around the entire periphery of the casting cavity. It is to be understood, however, that the cross-sectional area may be suitably varied to produce the desired heating effect on the several portions of the mold.

Fig. 18 illustrates a modification of the invention in which the feeding cavity has a substantially horizontal receiving portion 110 disposed between the connecting passage or sprue 77 and the casting cavity. End portions 111 of the feeding cavity are continuous with the receiving portion 110 and extend across opposite ends of the casting cavity. A substantially continuous ingate 112 corresponding to the ingates 71 and 104, previously described, connects the receiving portion 110 of the feeding cavity with the casting cavity. Ingates 113 (Fig. 19) which correspond to ingates 107 shown in Figs. 16 and 17, connect the end portions 111 of the feeding cavity with the opposite ends of the casting cavity. In this modification the pouring sprues 73 and 74 are spaced from the ends of the casting cavity a sufficient distance to provide room for sprues 114 which extend in substantially parallel relation to the pouring sprues between the latter and the end portions 111 of the feeding cavity. One end of each of the sprues 114 communicates with the connecting passage or sprue 77 adjacent one of the ends 76 of the latter and the opposite end of each of the sprues 114 is closed to prevent the discharge of metal therefrom upon inverting the

mold to freezing position. A plurality of short sprues 115 connect the sprues 114 to the end portions 111 of the feeding cavity. Thus, after the portion 110 of the feeding cavity is filled by molten metal flowing through the gates 78 and 79 and the filling of the casting cavity is commenced, molten metal is fed into the end portions 111 of the casting cavity through the sprues 114 and 115 without first flowing through the receiving or horizontal portion 110 of the feeding cavity. Thus it may be said that after the filling of the casting cavity through the bottom has commenced, metal is "short circuited" into the feeding cavity and casting cavity through the sprues 114 and 115 and the end feeding cavity 111, all of which are formed in the meeting faces of the mold sections. Excessive heating of the portions of the mold adjacent the receiving portion 110 of the feeding cavity is thus avoided so that all portions of the mold are maintained at more nearly uniform temperatures.

Upon inverting of the mold, gated as shown in Fig. 18, the molten metal is trapped within the casting cavity and feeding cavity by closed ends 116 of the feeding cavity and portions 111 and closed ends 117 of the sprues 114.

Fig. 20 illustrates a modification of the invention in which the feeding cavity has the receiving and end portions 110 and 111 respectively described in connection with Fig. 18, in combination with an overflow chamber 120. This chamber extends along the edge of the casting cavity opposite the receiving portion 110 of the feeding cavity and communicates with the casting cavity throughout substantially its entire length through a relatively narrow gate 121 (Fig. 21). During the filling of the mold illustrated in Fig. 20, the metal which first flows upwardly through the casting cavity may entrain therein particles of sand or the like from the core and also air or core gas, or both. Such foreign substances are carried upwardly by the flowing metal into the overflow chamber 120, leaving in the casting cavity pure metal free from occluded gases and sand particles. While the overflow chamber 120 may be of any suitable cross-sectional area, it has been found sufficient if the area is about one-half that of the cross-sectional area of the feeding cavity.

The receiving and end portions of the feeding cavity shown in Fig. 20 communicate with the casting cavity through a continuous ingate 122 which extends entirely around three sides of the casting cavity adjacent the receiving and end portions 110 and 111, respectively, of the feeding cavity. Thus the feeding cavity is in continuous or uninterrupted communication with the casting cavity across the bottom edge and up the ends of the latter when the mold is in pouring position. This type of continuous ingate forms a more uniform and even flow of metal into the casting cavity and if desired may be adapted to the modifications or embodiments previously described.

In the embodiments of the invention illustrated in Figs. 20 through 22, all of the metal introduced into the feeding and casting cavities flows through a continuous slot gate 125 (Fig. 22) which connects the passage or sprue 77 and the receiving portion 110 of the feeding cavity throughout substantially the entire length of the latter. The slot 125 tapers toward its ends 126 so that the latter are of materially less width than the central portion of the slot. In this manner the flow of molten metal into the feeding

cavity is regulated so as to be at a substantially uniform rate throughout its entire length. The relatively narrow end portions 126 of the slot 125 tend to retard the flow of metal from the ends of the connecting passage directly into the ends of the feeding cavity and cause the incoming metal to flow horizontally in the connecting passage 77 toward the center thereof and to flow into the feeding cavity through the relatively wider center part of the slot 125. The tapered slot 125 thus may be employed as an alternative to the gates 78 and 79 for producing the desired uniform upward flow of molten metal into the feeding cavity and casting cavity.

It is to be noted that in Figs. 16 and 20 while the feeding cavity is shown as extending across the lower side and ends of the casting cavity when the mold is in pouring position, all of the metal flowing into the casting cavity must enter through the receiving portion of the feeding cavity which is disposed along the lowermost side of the casting cavity, the metal thus dividing in the feeding cavity to flow up the opposite end portions thereof.

The invention has been illustrated as applied to the casting of cylinder heads for automobile engines. It is to be understood, however, that the present invention is applicable to the casting of various articles with or without sand cores in which non-uniform cross-section of the casting along the length thereof requires a considerable amount of metal to compensate for crystallization shrinkage. It should be noted that very little metal is required for the sprues, a portion of the excess metal being returned to the ladle upon inversion of the mold. The parting lines are along the side edges of the casting so that the smooth surface provided by freezing against metal extends throughout the top and bottom of the casting.

While the invention has been illustrated and explained as exemplified in a mold into which metal is poured by two men who simultaneously feed the molten aluminum from the ladles into the pouring sprues or passages 73 and 74, it is to be understood that the invention is also applicable to molds having but a single pouring sprue. For example, in the molds illustrated in the drawings, castings can be satisfactorily produced by the filling of the mold from a single ladle, the operator pouring the entire quantity required for filling the mold through either the pouring sprue 73 or the pouring sprue 74. It is desirable, however, in such cases to modify the gates 78 and 79 so that the relatively closely spaced gates are remote from the pouring sprue through which the metal is introduced into the mold, while the gates more widely spaced are adjacent the pouring sprue. In this manner the flow of metal into the feeding cavity is regulated so as to be substantially uniform throughout the entire length of the feeding cavity. Thus the flow of molten metal longitudinally through the feeding cavity during the pouring operation is minimized. In the event that when using a single man pour a continuous gate, such as shown at 125 in Figs. 20 and 22, is employed, the narrow end of the gate will be disposed adjacent the single pouring sprue and the gate will widen progressively as the distance from the pouring sprue increases.

In all of the embodiments of the invention the flow of the molten metal into the casting cavity is such that it rises therein at a uniform rate in all portions so that the air and gases in the casting

cavity are forced out ahead of the metal. Thus if gas is liberated or released from the sand core upon initial contact of the molten metal therewith, such core gas mingles with the air in the mold cavity and rises upwardly and is forced out of the mold by the incoming metal, there being a minimum opportunity for entrapment of the core gas by the casting metal.

Furthermore, it is to be understood that the particular forms of apparatus shown and described, and the particular procedures set forth, are presented for purposes of explanation and illustration and that various modifications and substitutions are contemplated and can be made without departing from my invention.

What I claim is:

1. The method of casting elongated aluminum alloy cylinder heads or the like in a permanent mold which comprises positioning the mold with the casting cavity extending horizontally and with the side edges of the cavity at the top and bottom, filling the cavity by causing molten metal to flow upwardly from below the casting cavity into the lower longitudinal edge of the cavity substantially throughout the length thereof, turning the mold to a freezing position in which the longitudinal edge of the casting cavity through which the metal entered is uppermost, and compensating for shrinkage of the metal during freezing by feeding metal downwardly from above the cavity through said longitudinal edge substantially throughout the length thereof.

2. The method of casting a hollow elongated aluminum alloy head for a multiple cylinder engine in a permanent mold having separable sections with meeting faces recessed to provide a cavity conforming to the exterior of said head, which comprises assembling the mold with a sand core which conforms to the interior of the head in said casting cavity, positioning the mold with a longitudinal edge of the casting cavity lowermost and substantially horizontal, filling said cavity with the mold so positioned by causing molten metal to flow upwardly into the casting cavity along said lowermost longitudinal edge, reversing the position of the mold with respect to a horizontal axis and subsequently feeding metal downwardly into the uppermost edge portion of the casting cavity along substantially the full length thereof during freezing to compensate for shrinkage in the casting.

3. The method of casting a hollow elongated aluminum alloy head for a multiple cylinder engine in a permanent mold having separable sections with meeting faces recessed to provide a cavity conforming to the exterior of said head, which comprises assembling the mold with a sand core which conforms to the interior of the head in said casting cavity, in a position to provide the casting with a base wall thicker than the side and top walls thereof, positioning the mold with a longitudinal corner at the juncture of the base and side wall forming portions of the casting cavity lowermost and substantially horizontal, and with the base forming wall of the casting cavity inclined to the vertical and partially overlying the casting cavity, filling the casting cavity by causing molten metal to flow upwardly into the casting cavity along said longitudinal corner, shifting the mold angularly with respect to a horizontal axis to bring the base of the casting to a position inclined to the vertical and partially underlying the casting cavity, and feeding metal downwardly into the base of the casting along substantially the full length there-

of during freezing to compensate for shrinkage in the casting.

4. The method of casting a hollow elongated aluminum alloy head for a multiple cylinder engine in a permanent mold having separable sections with meeting faces recessed to provide a cavity conforming to the exterior of said head, which comprises assembling the mold with a sand core which conforms to the interior of the head in said casting cavity, positioning the mold with a longitudinal edge of the casting cavity lowermost and substantially horizontal, filling said cavity with the mold so positioned by feeding molten metal upwardly into the casting cavity substantially simultaneously and uniformly along substantially the entire length of said lowermost longitudinal edge and subsequently feeding metal downwardly into the uppermost portion of the casting cavity along substantially the full length of said edge during freezing to compensate for shrinkage in the casting.

5. The method of casting elongated aluminum alloy articles of non-uniform cross-sectional form in the casting cavity of a permanent mold which comprises, supporting the mold with a longitudinal edge of the casting cavity lowermost, filling the mold cavity by feeding metal upwardly into the cavity along substantially the full length of said lowermost edge, reversing the mold to bring said edge through which metal is fed to an uppermost position, supplying metal through said edge in uppermost position to compensate for shrinkage in the casting, and chilling thick portions of the casting remote from said edge through which metal is supplied to freeze the same before the freezing of portions of the casting adjacent said edge.

6. The method of casting an aluminum alloy head for a multicylinder engine, which is hollow and of elongated form having transversely and longitudinally spaced portions intermediate the sides and ends thereof which integrally join the base and top walls, in a permanent mold having meeting faces recessed to provide a cavity conforming to the exterior of said head, which comprises assembling the mold with a sand core in the casting cavity which has openings to form the integral joining portions of the casting, positioning the mold with a longitudinal edge of the casting cavity lowermost and substantially horizontal, filling said cavity with the mold so positioned by causing molten metal to flow upwardly into the cavity along said longitudinal edge, reversing the mold to bring said longitudinal edge from lowermost to uppermost position, chilling the integral joining portions of the casting which are remote from the longitudinal edge into which the molten metal is fed more rapidly than the integral joining portions which are adjacent such edge are chilled, and supplying metal to the casting cavity along the upper edge thereof during freezing to compensate for shrinkage in the casting.

7. The method of casting an aluminum alloy head for a multicylinder engine, which is hollow and of elongated form having a base wall thicker than the side and top walls thereof and transversely and longitudinally spaced portions intermediate the sides and ends thereof which integrally join the base and top walls, in a permanent mold having meeting faces recessed to provide a cavity conforming to the exterior of said head, which comprises assembling the mold with a sand core in the casting cavity which is positioned in the casting cavity to provide a base wall

thicker than the other walls of the casting and which has openings to form the integral joining portions of the casting, positioning the mold with a longitudinal edge of the base forming wall of the casting cavity lowermost and substantially horizontal, filling said cavity with the mold so positioned by causing molten metal to flow upwardly into the cavity along said longitudinal edge, reversing the mold to bring said longitudinal edge from lowermost to uppermost position, chilling the integral joining portions of the casting which are remote from the longitudinal edge into which the molten metal is fed more rapidly than the integral joining portions which are adjacent such edge are chilled, and supplying metal to the casting cavity along the upper edge thereof during freezing to compensate for shrinkage in the casting.

8. A permanent mold for making aluminum alloy castings, comprising separable mold sections abutting face to face with continuous contact between marginal portions of abutting faces, said faces being recessed to provide a casting cavity, a feeding cavity and a pouring passage, said feeding cavity extending along one side of the casting cavity and communicating along its inner side with the casting cavity, said pouring passage having a portion which substantially parallels the feeding cavity and communicates with longitudinally spaced portions of the feeding cavity only at the outer side thereof, said passage extending to the exterior of the mold in the direction of the openings therefrom to the feeding cavity, and means for supporting said mold to turn from a pouring position, in which said feeding cavity is lower than the casting cavity and the pouring passage feeds upwardly into the feeding cavity, to a reverse freezing position in which molten metal is trapped in said feeding cavity and can flow only into the casting cavity and molten metal in the pouring passage is discharged from the mold by gravity.

9. A permanent mold for making aluminum alloy castings, comprising separable mold sections abutting face to face with continuous contact between marginal portions of abutting faces, said faces being recessed to provide a casting cavity, a feeding cavity and a pouring passage, said feeding cavity extending along one side of the casting cavity and communicating along its inner side with the casting cavity, said pouring passage having a portion which substantially parallels the feeding cavity and communicates with longitudinally spaced portions of the feeding cavity only at the outer side thereof, said passage extending to the exterior of the mold in the direction of the openings therefrom to the feeding cavity, means carried by the mold sections for supporting and positioning a sand core within said casting cavity, and means for supporting said mold to turn from a pouring position, in which said feeding cavity is below the casting cavity and the pouring passage feeds upwardly into the feeding cavity, to a reverse freezing position in which molten metal is trapped in said feeding cavity and can flow only into the casting cavity and molten metal in the pouring passage is discharged from the mold by gravity.

10. A permanent mold for making aluminum alloy castings, comprising separable mold sections abutting face to face with continuous contact between marginal portions of abutting faces, said faces being recessed to provide a casting cavity, a feeding cavity and a pouring passage, said feeding cavity extending along one side of

the casting cavity and communicating along its inner side with the casting cavity, said pouring passage having a portion which substantially parallels the feeding cavity and communicates with longitudinally spaced portions of the feeding cavity only at the outer side thereof, said passage extending to the exterior of the mold in the direction of the openings therefrom to the feeding cavity, means carried by the mold sections for supporting and positioning an apertured sand core within said casting cavity, a metal core carried by one of said sections adapted to be positioned within an aperture of the sand core, and means for supporting said mold to turn from a pouring position, in which said feeding cavity is below the casting cavity and the pouring passage feeds upwardly into the feeding cavity, to a reverse freezing position in which molten metal is trapped in said feeding cavity and can flow only into the casting cavity and molten metal in the pouring passage is discharged from the mold by gravity.

11. A permanent mold comprising separable mold sections and having an elongated casting cavity, a feeding cavity extending substantially the full length of said casting cavity, a gate extending substantially the full length of the feeding cavity between the inner side thereof and the casting cavity, a pouring passage extending from the exterior of the mold laterally of the feeding cavity on the same side thereof as the casting cavity, said passage having a portion which extends in the same direction as the feeding cavity and communicates with longitudinally spaced portions of the feeding cavity, and means for supporting said mold to turn from a pouring position, in which the feeding cavity is below the casting cavity, to a position in which the feeding cavity is above the casting cavity.

12. A permanent mold comprising separable mold sections and having an elongated casting cavity of irregular contour with parts of thick section and parts of thin section, a feeding cavity extending substantially the full length of said casting cavity, a gate extending substantially the full length of the feeding cavity between the inner side thereof and the casting cavity, said gate having enlarged portions adjacent the thick sectioned parts of the casting cavity which require a greater volume of metal, a pouring passage extending from the exterior of the mold laterally of the feeding cavity on the same side thereof as the casting cavity and communicating with the feeding cavity only at the outer side of the feeding cavity, and means for supporting said mold to turn from a pouring position in which the feeding cavity is below the casting cavity to a position in which the feeding cavity is above the casting cavity.

13. A permanent mold for making aluminum alloy castings, comprising a pair of mold sections which have inner faces with marginal portions formed for continuous contact and with recesses which provide a casting cavity, a feeding cavity and a pouring passage, said casting cavity being of elongated form, said feeding cavity being alongside the casting cavity, extending substantially the full length of the casting cavity and communicating along its inner side with the casting cavity, said pouring passage having a portion which extends in the same direction as the feeding cavity and communicates with longitudinally spaced portions of the feeding cavity at the outer side thereof only, said passage extending to the exterior of the mold in the direction of

the openings therefrom to the feeding cavity, and means for supporting said mold to turn from a pouring position in which molten metal flows downwardly through the pouring passage upwardly into the feeding cavity and upwardly from the feeding cavity into the casting cavity to a reverse freezing position in which the feeding cavity feeds downwardly into the casting cavity.

14. A permanent mold for making aluminum alloy castings, comprising a pair of mold sections which have inner faces with marginal portions formed for continuous contact and with recesses which provide a casting cavity, a feeding cavity and a pouring passage, said casting cavity being of elongated form, said feeding cavity being alongside the casting cavity, extending substantially the full length of the casting cavity and communicating along its inner side with the casting cavity, said pouring passage having a portion which extends in the same direction as the feeding cavity and communicates with longitudinally spaced portions of the feeding cavity at the outer side thereof only, said passage extending to the exterior of the mold in the direction of the openings therefrom to the feeding cavity, means carried by the mold for supporting and positioning an apertured sand core within said casting cavity, a metal core carried by one of said sections adapted to be positioned within an aperture of the sand core, and means for supporting said mold to turn from a pouring position in which molten metal flows downwardly through the pouring passage, upwardly into the feeding cavity and upwardly from the feeding cavity into the casting cavity to a reverse freezing position in which the feeding cavity feeds downwardly into the casting cavity.

15. A permanent mold for casting hollow cylinder heads and the like of aluminum alloys and the like, which comprises in combination metal mold sections recessed to provide an elongated casting cavity, a frangible sand core shaped to conform to the desired interior water chamber of the head to be cast, said core having apertures extending therethrough and pin receiving recesses, means for supporting and positioning the core in the cavity comprising positioning pins mounted in one of the mold sections and engaged in the core recesses and supporting pins mounted in one of the mold sections and engaged with the surface of the core, retractable core pins smaller than the core apertures and arranged to extend across the casting cavity through said apertures, a feeding cavity along one edge of the casting cavity and substantially co-extensive in length therewith, a gate between the inner side of the feeding cavity and the casting cavity extending substantially throughout the length of one of the cavities, a pouring passage extending from the exterior of the mold adjacent the side of the casting cavity opposite the feeding cavity, said passage having a portion which communicates with the feeding cavity along the length of the latter whereby metal flowing into the feeding cavity from the pouring passage fills the feeding cavity substantially without longitudinal flow of metal in the feeding cavity, and means for supporting the mold to turn from a pouring position in which the feeding cavity is below the casting cavity to a freezing position in which the feeding cavity is above the casting cavity.

16. A permanent mold for casting aluminum alloy cylinder heads and the like comprising separable mold sections having confronting faces

recessed to provide an elongated casting cavity, a feeding cavity extending along one edge of the casting cavity substantially the full length thereof, and a pouring passage along the outer side of the feeding cavity substantially the full length thereof, gates through which said feeding cavity communicates along its length with the casting cavity and with the pouring passage, the cross sectional area per unit of length of the gate from the pouring passage to the feeding cavity progressively increasing in the direction of normal flow of metal in the pouring passage during filling of the casting cavity to provide substantially uniform flow of metal into the feeding cavity along the length thereof.

17. Apparatus for making thin sectioned aluminum alloy castings and the like having relatively large surface areas, comprising a supporting frame, metal mold sections mounted on the frame for pivotal movement about a substantially horizontal axis and formed to cooperatively provide an elongated relatively thin sectioned casting cavity, a pouring passage in the mold sections having an opening above the level of the cavity and through which molten metal may be introduced into the mold, said passage extending downwardly from said opening to a region below the bottom edge of the casting cavity and horizontally beneath the said cavity, an elongated feeding chamber in the mold sections above said region and between the bottom horizontal portion of the passage and the bottom edge of the cavity, said chamber having a length several times its width and being approximately co-extensive in length with the bottom edge of the cavity, gate passages between the pouring passage and the feeding chamber along the length of the latter and between the feeding chamber and the casting cavity whereby molten metal introduced into the mold through said opening flows downwardly through the pouring passage, thence upwardly into the said chamber substantially uniformly along the length thereof and through the feeding chamber and into the casting cavity, and means for moving the mold sections about said axis to a position in which the feeding chamber is above the level of the cavity and the gate passage from the pouring passage is above the level of the feeding chamber whereby metal introduced into the mold during the latter part of the pouring operation is trapped in the feeding chamber and flows downwardly by gravity into the casting cavity during freezing of the metal in the mold to compensate for shrinkage of metal in the cavity.

18. A permanent mold for casting aluminum alloys and the like about a frangible core of sand or the like to produce hollow thin walled castings, comprising, in combination, separable metal mold sections mounted for rotation about a substantially horizontal axis and formed to cooperatively provide an elongated casting cavity having metal walls, a frangible core supported in the cavity and spaced from the walls thereof to define the shape of the article to be cast, means for holding the mold in a pouring position in which one edge of the cavity is lowermost, a pouring passage in the mold having an opening above the cavity through which metal may be introduced into the mold, said passage extending downwardly from the opening to a region below said lowermost edge and having a portion which extends under the casting cavity for the major part of the length of the latter, a feeding chamber in the mold in said region and between the casting cavity and the lower portion of the pas-

sage, said chamber having a length several times its width and being approximately co-extensive in length with the bottom edge of the cavity, gate passages between said portion of the pouring passage and the feeding chamber along the length of the latter and between the feeding chamber and the cavity, whereby molten metal introduced into the mold through said opening flows downwardly through the pouring passage, thence upwardly into the chamber along the length thereof and through the chamber and upwardly into the casting cavity, the metal entering the casting cavity dividing adjacent the lowermost edge to flow upwardly on opposite sides of the core, and means for moving the mold sections to a position in which the feeding chamber is above the cavity and metal from the feeding chamber flows by gravity into the casting cavity to compensate for shrinkage therein during freezing.

19. A permanent mold for casting aluminum alloys and the like about a frangible core of sand or the like to produce hollow thin walled castings, comprising, in combination, separable metal mold sections formed to cooperatively provide a casting cavity having metal walls, a frangible core supported in the cavity and spaced from the walls thereof, said cavity being disposed so that a narrow edge thereof is lowermost and substantially horizontal, a pouring passage in the mold having an opening above the cavity through which metal may be introduced into the mold, said passage extending downwardly from the opening to a region below said lowermost edge and having a horizontal portion under the casting cavity, a feeding chamber in the mold between the cavity and the horizontal passage portion, said chamber being substantially horizontal and approximately co-extensive in length with said lowermost edge of the cavity, and means connecting the chamber with the passage and cavity so that molten metal poured into the passage opening flows downwardly below the cavity and chamber, then horizontally and upwardly into the chamber and from the chamber upwardly in a substantially vertical direction into the casting cavity where the metal divides to flow simultaneously up both sides of the core while maintaining a substantially uniform level of the metal in the cavity from end to end thereof during the casting operation, substantially without horizontal flow of metal in the casting cavity.

20. In the method of casting an elongated hollow cylinder head, or the like, of a metal such as an aluminum alloy by the use of a frangible core of sand or the like in a permanent mold having a casting cavity with metal walls, the improvement which comprises, in combination, supporting the core in the cavity in generally spaced relation to the walls thereof, positioning the mold so that the longitudinal edges of the cavity are substantially horizontal and one edge is above the other, continuously conducting molten metal from above the cavity to a region below the cavity, accumulating a relatively large quantity of the conducted metal in a feeding pool of flow quieting volume below and approximately parallel to the lowermost edge of the cavity, and continuously introducing molten metal from said pool into the cavity along said lowermost edge of the latter at substantially the same rate as molten metal is conducted into the pool and substantially without longitudinal flow of the metal in the cavity, whereby the relatively large mass

of metal in the pool diminishes the turbulence of the conducted metal and the metal introduced into the cavity flows quietly in a generally ascending direction over opposite sides of the core while the rising surface of the metal in the cavity is maintained substantially level from end to end of the cavity.

21. In the method of casting an elongated hollow cylinder head, or the like, of a metal such as an aluminum alloy by the use of a frangible core of sand or the like in a permanent mold having a casting cavity with metal walls, the improvement which comprises, in combination, supporting the core in the cavity in generally spaced relation to the walls thereof, positioning the mold so that the longitudinal edges of the cavity are substantially horizontal and one edge is above the other, continuously conducting molten metal from above the cavity to a region below the cavity, accumulating a relatively large quantity of the conducted metal in a feeding pool of flow quieting volume below and approximately parallel to the lowermost edge of the cavity, continuously introducing molten metal from said pool into the cavity along said lowermost edge of the latter at substantially the same rate as molten metal is conducted into the pool and substantially without longitudinal flow of the metal in the cavity, whereby the relatively large mass of metal in the pool diminishes the turbulence of the conducted metal and the metal introduced into the cavity flows quietly in a generally ascending direction over opposite sides of the core while the rising surface of the metal in the cavity is maintained substantially level from end to end of the cavity, and feeding molten metal from said pool into the cavity during freezing of the introduced metal to compensate for shrinkage.

22. The method of casting a hollow cylinder head, or the like, of a metal such as aluminum alloy, in a permanent mold having a casting cavity with metal walls, which comprises positioning a frangible core of sand or the like in the mold cavity in generally spaced relation to said walls, introducing molten metal substantially vertically into the cavity along one edge thereof and at such rates along the edge that the metal flows evenly up both sides of the core substantially without horizontal flow in the cavity in the direction of the length of said edge, whereby air in the cavity and gas liberated from the surface of the core upon initial contact with the hot metal is forced upwardly and out the top of the mold by incoming metal, inverting the mold to position said edge uppermost, feeding additional metal into the cavity along said edge during the freezing of the casting to provide for shrinkage, and venting the core to the atmosphere while the metal is freezing to permit the escape of gas generated within the core by the heat of the metal and thereby prevent liberation of the gas into the freezing metal in the cavity.

23. A permanent mold for casting elongated objects of aluminum alloys comprising separable mold sections formed to provide an elongated casting cavity, a feeding cavity of relatively large cross sectional area extending along one edge of the casting cavity, a pouring passage along the side of the feeding cavity opposite the casting cavity, and gate means through which the feeding cavity communicates along its length with both the casting cavity and the pouring passage, the gate means between the pouring passage and the feeding cavity having an increasing effective cross sectional area from one end of the feeding cavity

toward the center thereof to provide greater frictional resistance to the flow of metal into the feeding cavity at said end than at the central part thereof whereby molten metal entering the pouring passage adjacent said end tends to flow through the gate means in substantially equal quantities along the length of the feeding cavity.

24. A permanent mold for casting elongated objects of aluminum alloys comprising separable mold sections formed to provide an elongated casting cavity, a feeding cavity of relatively large cross sectional area extending along one edge of the casting cavity, a pouring passage along the side of the feeding cavity opposite the casting cavity, gate means through which the feeding cavity communicates along its length with both the casting cavity and the pouring passage, the effective cross sectional area per unit of length of the gate from the pouring passage to the feeding cavity progressively increasing in the direction of normal flow of metal in the pouring passage during filling of the casting cavity to provide substantially uniform flow of metal into the feeding cavity along the length thereof, and means mounting the mold sections for facile shifting movement from a pouring position in which the feeding cavity is below the casting cavity to a freezing position in which the feeding cavity is above the casting cavity.

25. A permanent mold for casting elongated objects of aluminum alloys comprising separable mold sections formed to provide an elongated casting cavity, a feeding cavity of relatively large cross sectional area extending along one edge of the casting cavity and along at least one end thereof, a pouring passage having a portion which

substantially parallels the part of the feeding cavity disposed along the edge of the casting cavity, gate means connecting one side of the feeding cavity with longitudinally spaced portions of the casting cavity and another side of the feeding cavity with longitudinally spaced portions of the pouring passage, said passage extending in the direction of the gate means past the feeding cavity and the casting cavity to the exterior of the mold, and means for supporting the mold sections for facile shifting movement from a pouring position in which the casting cavity is generally above the feeding cavity to a freezing position in which the casting cavity is generally below the feeding cavity.

26. A permanent mold for casting elongated objects of aluminum alloys comprising separable mold sections formed to provide a horizontally elongated casting cavity, a feeding cavity of relatively large cross sectional area extending along the bottom edge of the casting cavity, a pouring passage extending from the exterior of the mold above the casting cavity to below the feeding cavity, gate means connecting the feeding cavity with the casting cavity above along its length and with the pouring passage below, and means supporting the mold sections for facile shifting movement to a freezing position in which the feeding cavity is generally higher than the casting cavity and molten metal previously introduced into the feeding cavity is trapped therein to provide a relatively large body of liquid metal positioned to feed downwardly into the casting cavity during solidification of the casting to replace shrinkage loss in the metal casting.

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