Dec. 9, 1941. T. A. WRY 2,265,333

METHOD AND APPARATUS FOR PRESSURE DIE CASTING

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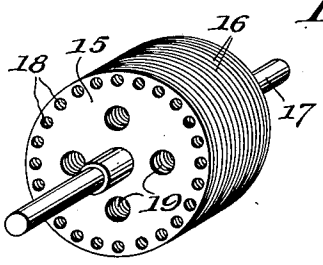


Fig. 1

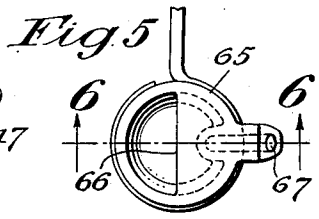


Fig. 5

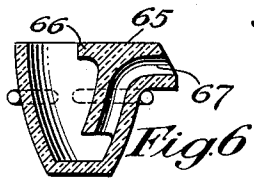


Fig. 6

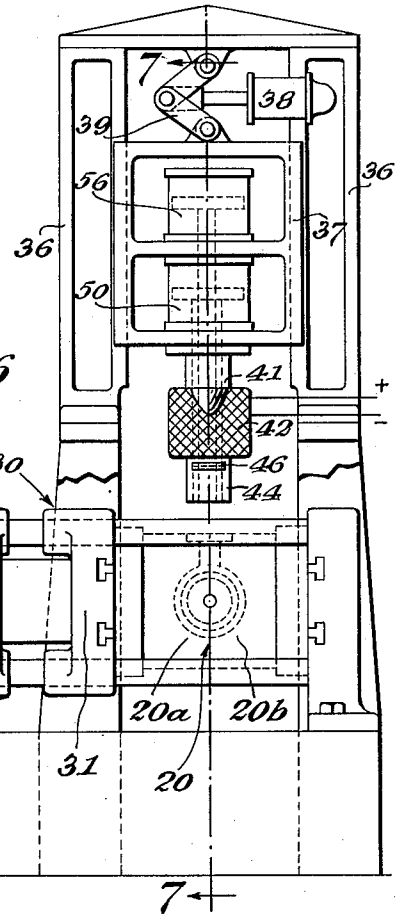


Fig. 3

Fig. 4

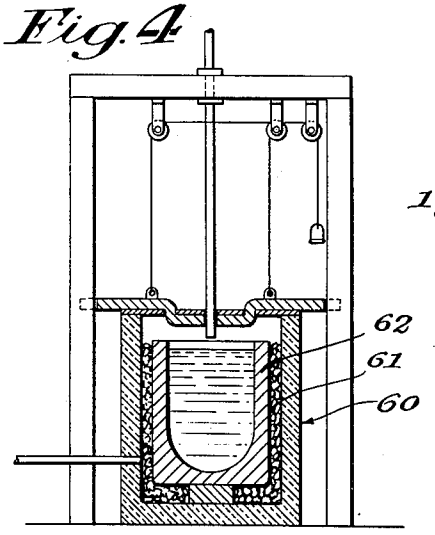
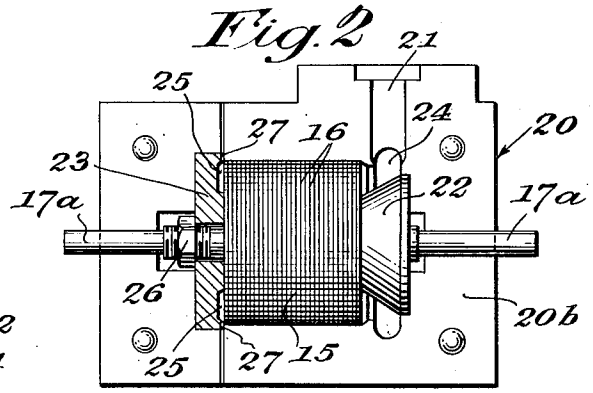


Fig. 2



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METHOD AND APPARATUS FOR PRESSURE DIE CASTING

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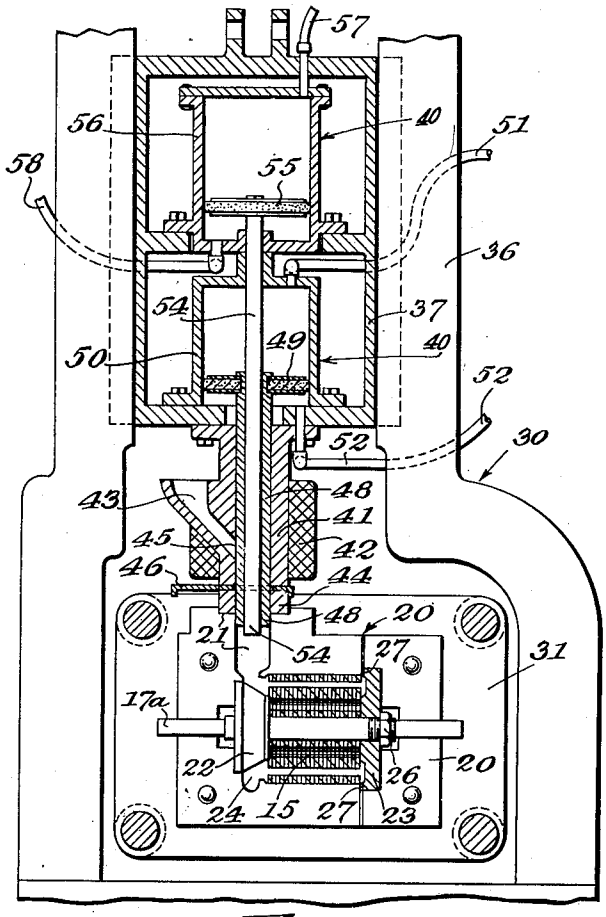


Fig. 7

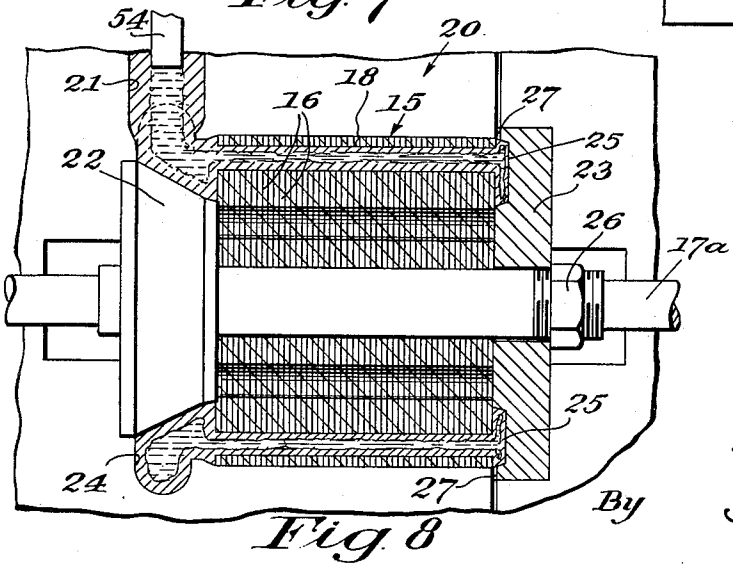
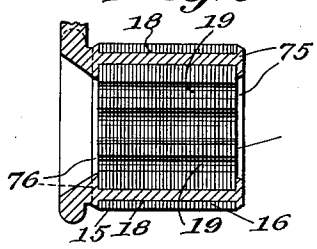


Fig. 8

Fig. 9



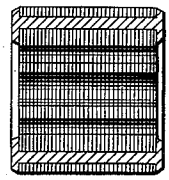


Fig. 10

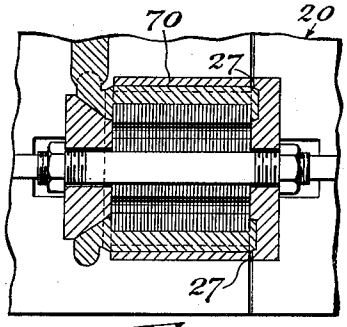


Fig. 11

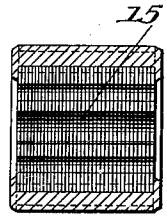


Fig. 12

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METHOD AND APPARATUS FOR PRESSURE DIE CASTING

Thomas A. Wry, Lynn, Mass.

Application May 31, 1939, Serial No. 276,569

11 Claims. (Cl. 22—68)

This invention relates to a method of pressure die casting of metals and apparatus therefor.

Heretofore, in casting metals great difficulty has been experienced in obtaining castings which are whole, free from pipes or cracks, and of uniform density throughout. The molten metal, when poured, instantly begins cooling, hardening and contracting from the outside, while the inside is still molten or soft. The interior then cools, and in so doing, shrinks and pulls against the already hardened outer shell of the casting, which does not yield, thus commonly causing the inner metal to be porous or spongy, or have small cracks or lines in it which cause structural weakness or defects in the finished article. Great care is taken and great expense incurred in the steel mills and forge shops for instance to detect these weaknesses in the billets. In steel mills the pig or billets of steel are X-rayed, or the tops are cut off, polished, and etched with acid, and examined with magnifying glasses to determine the interior structure of the billets. These tests and inspections are repeated in forge shops later. Many of these pigs and billets are found defective and have to be returned for resmelting at great cost and financial loss. In aluminum foundries similar difficulties are experienced. Cast aluminum objects are tested by reheating, and if they have porous centers the air therein causes bubbles or warts to appear on the surface. This test causes the rejection of as high as 50% of the castings, an important cause of the high cost of cast aluminum utensils. These difficulties in casting metals have been avoided to some extent by casting under great pressure ranging from 700 to 8000 lbs. per square inch but trouble is still experienced and great losses caused for these reasons.

I have discovered that these difficulties can be very largely, if not entirely, prevented by my method of pressure die casting which consists in applying pressure to the molten metal in the closed mold in two successive stages, the primary application of pressure forcing the metal into the mold until the surface hardening of the molten metal stops the further advance of the pressure-applying mechanism and the secondary application of pressure following immediately directed against the still molten interior of the casting to compress the interior separately. Thus all voids, porous places, strictures or cracks caused by the shrinkage and pull of the inner metal against the hardened outer shell of the casting are filled or prevented and a solid interior of uniform density is provided. For this purpose a suitable reservoir of surplus molten metal is preferably maintained at the entrance of the mold which, after hardening, can be trimmed off the casting. Thus tremendous savings can be made in making metal castings by means of my invention.

My invention is also of great utility and value in giving a high finish in any cast objects and so eliminating additional and expensive finishing operations.

I have also devised a suitable apparatus or machine disclosed herein for carrying out my process. For purposes of illustration, my machine is shown as used in casting copper or other metal, windings and end rings in rotors of electric motors, for which my invention has particular utility, but it is obvious, and to be understood, that my process or machine is not limited in any way to this particular use.

Heretofore rotors have generally been made with cast aluminum windings and end rings. To carry the same electric current the core is approximately twice the area of a copper winding of equal conductivity and its conductive efficiency is only 50%. A few rotors are made with copper windings—by forcing rods of copper through the rotor holes, the rods being slightly smaller than the holes, fitting copper end rings over the ends of the rods, the rings having been drilled with corresponding holes, and brazing the rods and rings together, as with silver solder. 92–93% electric conductivity is the highest efficiency ordinarily commercially obtainable in such rotors so far as I am aware.

By using my invention for casting windings of rotors I am able to obtain an efficiency of electrical conductivity in the copper windings of rotors as high as 98–100%. This means that the electrical productivity of any motor is greatly increased or the size of the motor may be considerably reduced and the same electrical production received from it. Thus the cost of building an electric motor of any required horsepower can be reduced by as much as one-half through savings in the cost of material, wiring, labor, etc. Even in rotors using aluminum windings, the efficiency of electrical conductivity of the aluminum windings is raised by means of my invention from 47% to 55%, which is the maximum efficiency possible for aluminum.

Before explaining in detail the present invention it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the

invention is capable of other embodiments and of being practiced or carried out in various ways. Also it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation, and it is not intended to limit the invention claimed herein beyond the requirements of the prior art.

In the drawings:

Fig. 1 is a perspective view of a rotor, the windings and end rings of which are to be cast;

Fig. 2 is a front elevation partly in section showing the rotor mounted in the mold;

Fig. 3 is a front elevation of my pressure die casting machine;

Fig. 4 is a vertical sectional view of my smelter furnace;

Fig. 5 is a plan view of a ladle;

Fig. 6 is a vertical cross section thereof on line 6—6, Fig. 5.

Fig. 7 is a vertical cross section of my pressure die casting machine on the line 7—7, Fig. 3;

Fig. 8 is an enlarged sectional view of the rotor in the mold as in Fig. 7, after the molten metal has begun to cool;

Fig. 9 is a cross section of a rotor immediately after being cast and removed from the mold;

Fig. 10 is a cross section of the same rotor after surplus copper has been trimmed off;

Fig. 11 is a cross section of another type of rotor in which the winding slots are open at the side, requiring a sleeve in the mold;

Fig. 12 is a cross section of the same rotor as in Fig. 11 after being removed from the mold and surplus metal trimmed off.

My method of pressure die casting comprises pouring the molten metal into a suitable mold, applying pressure to the molten metal by suitable mechanism in two successive stages, the first stage consisting in forcing the molten metal into the mold by a primary application of pressure and continuing it until the further advance of the primary pressure-applying mechanism is stopped by the resistance of the molten metal and its surface hardening, which occurs almost immediately after the primary pressure is applied, and following it immediately with a secondary application of pressure from a secondary pressure-applying mechanism directed against the still molten interior of the casting. This secondary application of pressure is designed to force the molten metal under great pressure against the hardened outer shell of the casting and fill all the voids, porous places, strictures, pipes or cracks which may be formed by the shrinkage of the interior metal pulling against the hardened outer shell of metal. Thus a solid casting of substantially uniform density is provided. For this purpose a suitable reservoir of surplus metal is preferably maintained at the entrance of the mold which, after hardening, can be trimmed off the casting.

The apparatus or machine I have devised to carry out my process is, for purposes of illustration, shown as used in casting copper or other metal windings in rotors of electric motors, but it is to be understood that similar mechanism with such modifications as may be necessary can be used for other forms of castings utilizing the process of my invention.

In Fig. 1, 15 represents a standard rotor having laminations 16, a central shaft 17, winding holes 18 to be filled with copper (or other suitable metal) and air holes 19 for cooling the rotor which are not filled.

In Fig. 2, the rotor 15 is shown mounted in the mold 20 ready for casting. The mold is preferably made of steel formed in two halves 20a and 20b (Fig. 3) and has a sprue 21 for receiving the molten metal. End plates 22 and 23 are placed in the mold and grip the rotor tightly at its ends. End plate 22 is inserted at the entrance or sprue end of the mold and is preferably cut away to form a relatively large reservoir of molten metal at the entrance end of the end ring and windings. Opposite end plate 23 provides space 25 for the formation of an end ring 15 outside the winding slots 18. A similar end ring 16 at the opposite or entrance end of the mold is later cut from the large surplus ring of metal formed in the reservoir 24, as shown in Fig. 10. Preferably the original shaft 17 of the rotor is replaced with a threaded bolt 17a, to avoid injury to the original shaft, and to provide means for holding end plates 22 and 23 tightly against the rotor laminations, as by means of nut 26 threaded onto the central bolt 17a. The two halves 20a and 20b of the mold are then held tightly clamped together under great pressure in the machine hereinafter described. If the original shaft of the rotor is used an extra end plate (not shown) can be used and wedged into the mold omitting the nut 26 as will be readily perceived. As shown in Figs. 2 and 8, a plurality of air vents 27 are provided around the edge of end plate 23, permitting the escape of air from the mold as the molten metal is forced therein. These vent holes are slots not more than .006 inch deep to allow the escape of air, but to prevent the escape of the molten metal from them at the same time. For cooling purposes, to permit the castings to be moved sooner from the molds, water is preferably circulated around the mold.

The machine 30 of which the mold 20 forms a part is in general construction a standard Lester die casting machine which has been modified for carrying out the process of my invention. Clamping mechanism 31 is provided for holding the halves 20a and 20b of the mold tightly together to withstand the great pressure applied to them in the casting operation. This mechanism may be of any suitable construction and as such mechanism is old and well known, it need not be described in detail. As shown in Fig. 3, the halves 20a and 20b of the mold are held tightly locked together by the clamping mechanism 31, in turn operated by an hydraulic pressure unit, including a moving hydraulic cylinder 32 and toggle linkages 33.

As shown in Figs. 3 and 7, the pressure-applying mechanism of my machine 30 comprises an upright frame 36 on which is mounted for vertical reciprocal movement a plunger frame 37 actuated by a moving hydraulic cylinder 38 and toggle linkages 39. Centrally mounted in the plunger frame 37 is a plunger mechanism 40 for applying pressure to the molten metal in the mold 20, which comprises a head 41 which is preferably heated by electric coils 42 and has an opening or sprue 43 for receiving the molten metal. It is understood that the smelting furnace can be made integral with machine 30, to pour directly into the mold. Also the head 41 can be mounted directly on the mold if desired. The bottom end 44 of head 41 is pressed down tightly over sprue hole 21 of the mold 20 by the operation of hydraulic cylinder 38 and toggle 39. A central vertical receiving chamber 45 is provided in head 41 into the bottom of which molten metal passes from sprue 43 and which chamber registers directly with the sprue 21 of the mold 20. The bottom end of chamber 45 is ordinarily held closed by means of a valve 46 which can

be manually or automatically operated on the descent of the main plunger mechanism **40** as desired. Mounted for reciprocal movement in chamber **45** is an outer hollow cylindrical ram **48**, connected to a piston **49** in a steam or pneumatic cylinder **50** which piston and ram are forced back and forth by steam or compressed air entering through pipes **51** and **52**. Travelling within the outer ram **48** is a central ram **54** actuated in turn by another piston **55** moving back and forth in a second steam or pneumatic cylinder **56** actuated again by steam or compressed air entering alternately at opposite sides of piston **55** by means of air pipes **57** and **58**. Central ram **54** is preferably made large enough to fill the remaining area in sprue **21** of mold **20** after the outer surface of the molten metal in the sprue **21** has hardened in the time interval before ram **54** is separately operated, as shown in Fig. 8.

Both rams **48** and **54** are designed to travel together in the primary application of pressure to the molten metal in mold **20**. Travelling as a unit rams **48** and **54**, preferably in one stroke, force the molten metal into the mold under great pressure until stopped by the resistance of the molten metal and its surface hardening, which occurs almost immediately after the descent of the rams. Immediately thereafter, and in timed relation therewith (to be controlled by a suitable regulating instrument according to the time cycle required), the secondary application of pressure to the molten metal in the mold **20** is made by means of ram **54** which preferably directs a quick succession of blows under great pressure against the still molten interior of the casting as illustrated in more detail in Fig. 8. Thus the still molten interior metal is forced under great pressure against the hardened outer shell of the casting, filling all voids and places of lighter density caused by shrinkage of the interior metal, and preventing porosity, strictures, pipes and cracks in the interior portion of the casting. The pressure to be applied is varied according to the requirements of the particular metal used and the article being cast by varying the size of the cylinders as will be readily understood in the art. A pressure of 9000 lbs. is preferably exerted upon the piston **55** in cylinder **56** for casting windings of rotors but this pressure can be varied as desired. The casting of the windings of a rotor takes about five seconds in these operations and as soon as the mold **20** is cooled enough to permit removal of the rotor, another rotor can be inserted and the operation repeated. Molds **20** can, of course, be placed in a rotating turret or other mechanism, for quantity production if desired, without departing from my invention. The pressure-applying mechanism shown is a combination of hydraulic and steam or pneumatic devices, but it is to be understood that these can be electrically or mechanically operated as well.

A specific application of my process and apparatus of great utility and value is for casting windings in rotors of electric motors as above mentioned, which windings are usually made of aluminum or copper. Because impurities, voids, small air holes and the like in the copper or aluminum windings greatly interfere with the electrical conductivity of the windings and the consequent electrical productivity of the motor, it is of the utmost importance that great care be taken to keep these impurities and voids out of the metal when finally cast in the rotors. My process and apparatus are, therefore, very useful in preventing such voids in the metal windings. Because other impurities in the metal also effect its electrical efficiency, the particular efforts desirable to keep the metal in a substantially chemically pure state are described below, but it is to be understood that in uses in which a chemically pure state of the molten metal is unnecessary, such steps may be omitted.

For the smelting any suitable crucible can be used. In Fig. 4 an ordinary small coke-fired furnace **60** is shown with coke **61** and crucible **62**. It is to be understood that a furnace heated with oil, gas or electricity can be used as well. It is important first to burn out the crucible thoroughly keeping it red hot preferably from 8 to 10 hours to burn off all impurities from the crucible. Pure copper scrap is then melted in the usual manner in the crucible. It is desirable to burn a gas flame in the top of the crucible, as is well known, to keep the copper from becoming oxidized by contact with oxygen in the air. The molten metal should be stirred carefully with a suitable rod, such as a birch rod, to get all the air out of it. In Figs. 5 and 6 is shown a ladle **65** which pours from the bottom and which preferably holds more copper than is needed for the particular casting to be made. As will be seen in Fig. 6, a partition **66** extends down the ladle **65** on one side and forms a spout **67** for pouring the molten metal. By this construction the molten metal can be poured only from the bottom of the ladle, which means that only the top surface portion can become oxidized with the air and as this is not to be poured from the ladle, the copper does not become oxidized in the pouring. The copper is then poured from the ladle **65** into the sprue **43** of the die casting machine **30**. I have found the copper is ordinarily not oxidized to any substantial degree in pouring from the ladle **65** into the sprue hole **43** if the pouring is done when the two objects are very close together, but again if needed a gas flame can be maintained over the sprue hole **43**. It is desirable also to smudge with an acetylene torch every portion of the rotor to which the copper in the windings may have a chance to adhere, to put an insulating film between the copper windings and the iron laminations of the rotor and thus prevent electrical leakage. The rotors are also preferably preheated before their windings are cast. In Fig. 9 the rotor **15** is shown in cross section as it comes from the mold after casting. The surplus metal forming at the entrance end of the mold is then trimmed off as shown in Fig. 10 leaving an end ring **76**, similar to end ring **75**, around the ends of the windings. In Fig. 11 the rotor is shown differing from that of Figs. 1, 9 and 10 only in that the winding holes **18** are open at the side forming a slot. For this reason a sleeve **70** is provided which is merely an extension of end plate **23** to prevent the molten metal from escaping through the open slots. In Fig. 12 the same rotor is shown as in Fig. 11, after the surplus molten copper has again been trimmed off at the entrance end of the casting.

It is to be understood that any suitable metal can be used for casting the windings in these rotors. As stated above, the electrical efficiency of rotors treated and cast in this manner is greatly increased, approximating the maximum possible efficiency of electrical conductivity for the metal used, thus permitting great savings in the cost of manufacturing electric motors of any required horsepower.

The tremendous savings made possible in making metal castings in general in this manner have already been stated.

It will also be seen that my invention is likewise of great utility in giving a high finish in casting metal and plastic objects, and thus eliminating the expense of additional finishing operations.

I claim:

1. The method of pressure die casting which comprises pouring molten metal into the entrance end of a mold, maintaining a substantial surplus reservoir of molten metal at said entrance end of the mold, applying pressure to the molten metal from the entrance end of the mold in the same direction in two successive stages, the first to insure that the molten metal engages all parts of the mold until surface hardening at the edges of the mold occurs, and the second to compress the still molten interior of the casting inside its hardened outer shell.

2. The method of pressure die casting which comprises pouring molten metal into the entrance end of a mold, applying pressure in the entrance end directly to the molten metal in two successive stages, the first in one continuous stroke to insure that the molten metal engages all parts of the mold and continuing until surface hardening at the edges of the mold occurs, and the second following immediately in a rapid succession of blows to compress the still molten interior of the casting inside its hardened outer shell.

3. The method of pressure die casting which comprises pouring molten metal into the entrance end of a mold, applying pressure to the molten metal in the mold by means of a ram which fills the entrance of the mold, and continuing until surface hardening of the metal occurs at the edges of the mold, and then applying pressure to the still molten interior metal by a second ram which at the time of its operation substantially fills the area remaining molten in the entrance of the mold after the hardening of the outer surfaces of the metal at the edges of the mold.

4. The method of pressure die casting which comprises pouring molten metal into the entrance end of a mold which provides a substantial reservoir of surplus molten metal, applying pressure to the molten metal at the entrance end to force it into the mold by means of a ram which fills the entrance of the mold and continuing until hardening of the outer surfaces of the metal at the edges of the mold occurs, and then applying pressure to the still molten interior metal by a second ram and so timing its operation that the second ram substantially fills the area remaining molten in the entrance of the mold after hardening of the outer surfaces of the metal at the edges of the mold.

5. The method of pressure die casting which comprises pouring molten metal into the entrance end of a mold which provides a substantial reservoir of surplus molten metal, applying pressure to the molten metal at the entrance end in one continuing stroke by means of a ram which fills the entrance of the mold which stroke continues until hardening of the outer surfaces of the metal at the edges of the mold prevents further advance of the ram, and then applying pressure in a rapid succession of blows to the still molten interior metal by a second ram which at the time of its operation substantially fills the area remaining in the entrance of the mold after the hardening of the outer surfaces of the metal at the edges of the mold.

6. The method of casting windings for rotors of electric motors which comprises melting and maintaining the molten metal in approximately a chemically pure state, supporting the rotor in the mold, forcing the molten metal by pressure at the entrance end of the mold into the winding holes in the rotor while in the mold, applying additional pressure in the same direction against the still molten interior of the casting after its surface portions at the edges of the mold have hardened slightly, and withdrawing the rotor from the mold.

7. The method of casting windings for rotors of electric motors which comprises melting and maintaining the molten metal in approximately a chemically pure state, supporting the rotor in the mold, maintaining a substantial surplus reservoir of metal at the entrance end of the mold, forcing the molten metal by pressure from the entrance end into the winding holes in the rotor while in the mold, applying additional pressure in the same direction against the still molten interior of the casting after its surface portions at the edges of the mold have hardened slightly, withdrawing the rotor from the mold and trimming off surplus cast metal from the rotor.

8. The method of casting windings for rotors of electric motors which comprises melting and maintaining the molten metal in approximately a chemically pure state, supporting the rotor in a mold providing space for casting end rings on the rotor connecting the windings, forcing the molten metal by pressure from the entrance end into the winding holes and the ring spaces of the mold, applying additional pressure in the same direction against the still molten interior of the casting after the surface portions at the edges of the mold of the casting have hardened slightly, and withdrawing the rotor from the mold.

9. In a machine for pressure die casting, a mold for casting the molten material, means for clamping the mold to withstand great pressure, vents in the mold permitting the escape of air therefrom but preventing the escape of molten material, means for applying pressure to the molten metal in the mold at the entrance end thereof comprising a pair of movable rams, one moving inside the other, means for moving both rams together initially in one continuing stroke, and subsequently moving the inner ram separately in a rapid succession of blows against the still molten interior of the casting after the surface portions at the edges of the mold of the casting have hardened slightly.

10. In a machine for pressure die casting, a mold for casting the molten material, means for clamping the mold to withstand great pressure, vents in the mold permitting the escape of air therefrom but preventing the escape of molten material, means for applying pressure to the molten material in the mold, comprising a pair of movable rams one moving inside the other and both filling the entrance of the mold, means for moving both rams together initially in one continuing stroke, and subsequently moving the inner ram separately against the still molten interior of the casting in a rapid succession of blows after the surface portions at the edges of the mold of the casting have hardened slightly, and means for timing the operation of the inner ram that at the time of its operation it substantially fills the area remaining in the entrance

of the mold after the surface portions at the edges of the casting have hardened slightly.

11. The method of die casting a molten material which comprises forcing the molten material into a mold under pressure in one continuing stroke and providing a surplus reservoir of molten material, and as successive outer portions of the molten material solidify subjecting the remaining interior molten material to pressure from the same direction and in a rapid succession of blows to force additional molten material from the surplus reservoir against the solidified portions and fill spaces within the casting produced by shrinkage due to solidification and without fracturing the previously solidified portions.

THOMAS A. WRY.