

Oct. 22, 1935.

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2,018,586

METAL CASTING SYSTEM

Filed June 4, 1934

5 Sheets-Sheet 1

Fig. 1.

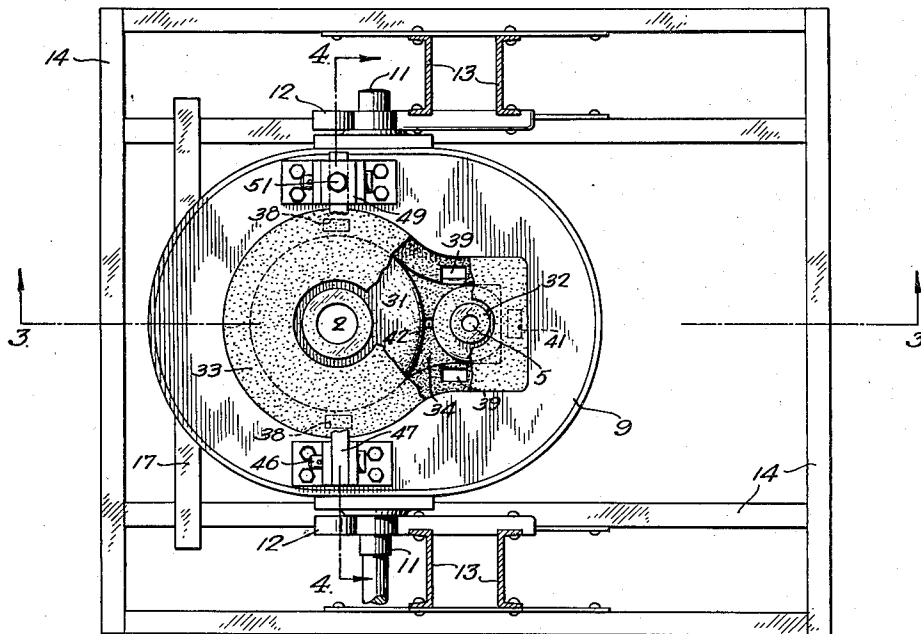


Fig. 2.

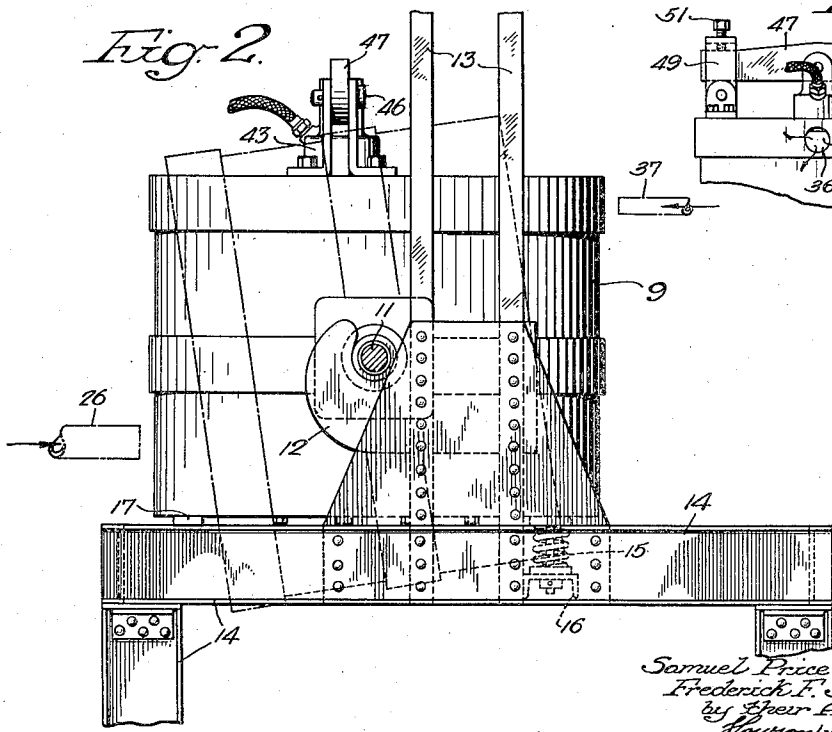
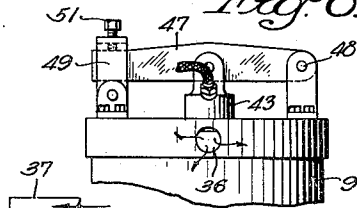


Fig. 6.



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5 Sheets-Sheet 2

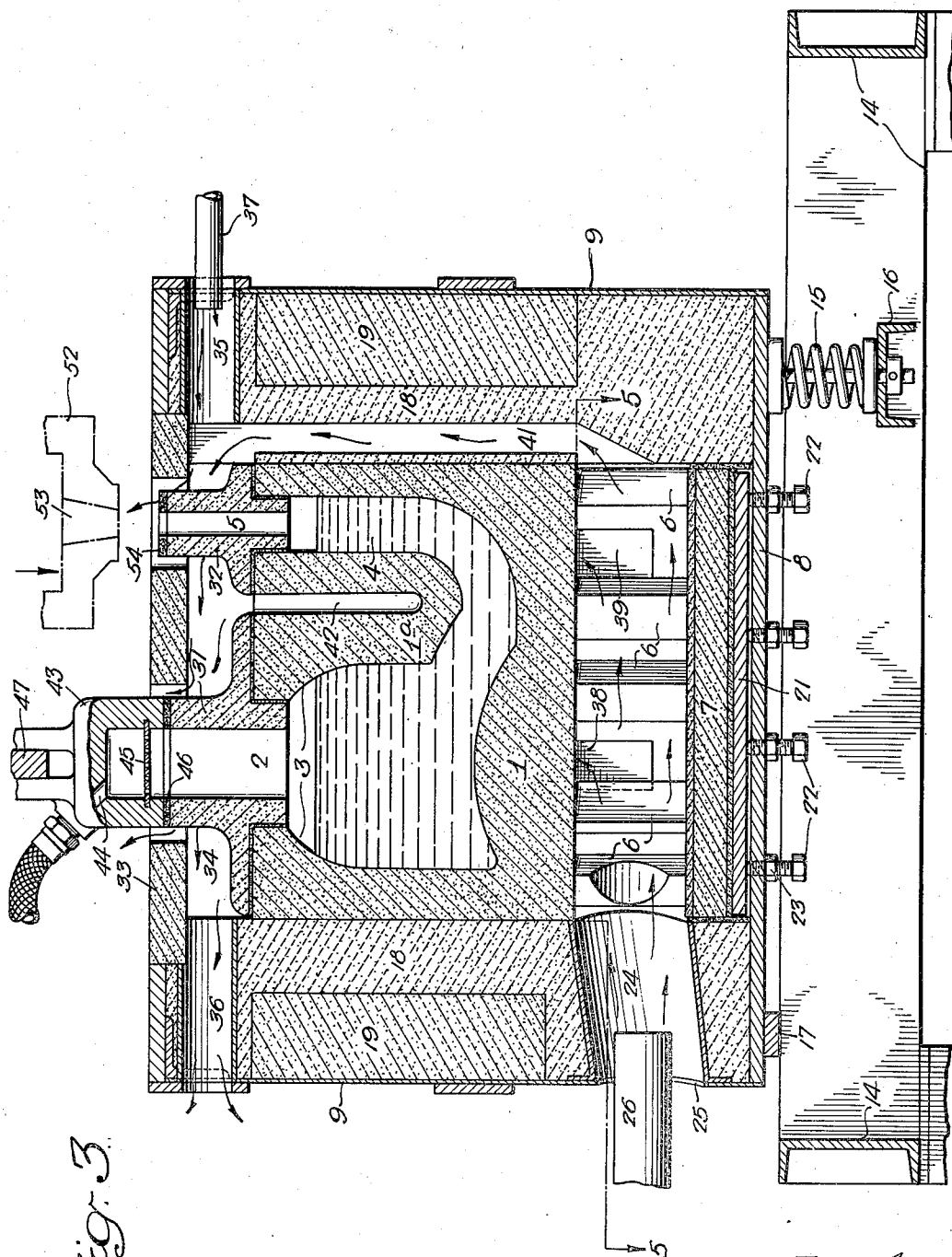


Fig. 3

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METAL CASTING SYSTEM

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5 Sheets-Sheet 3

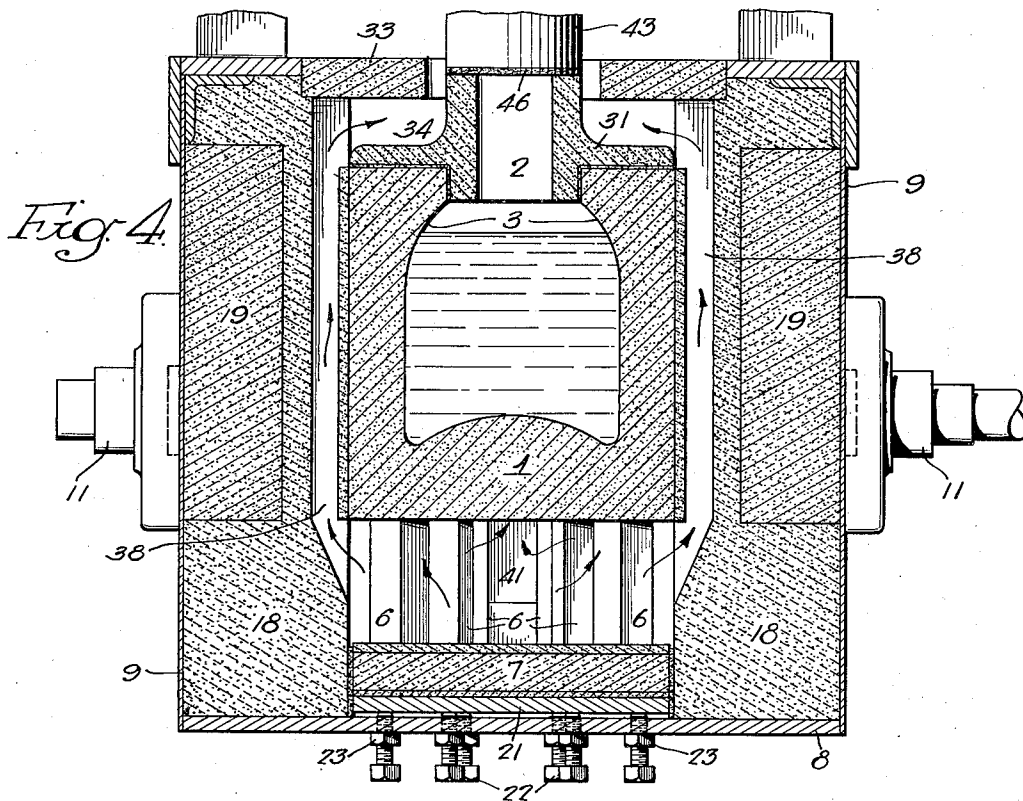
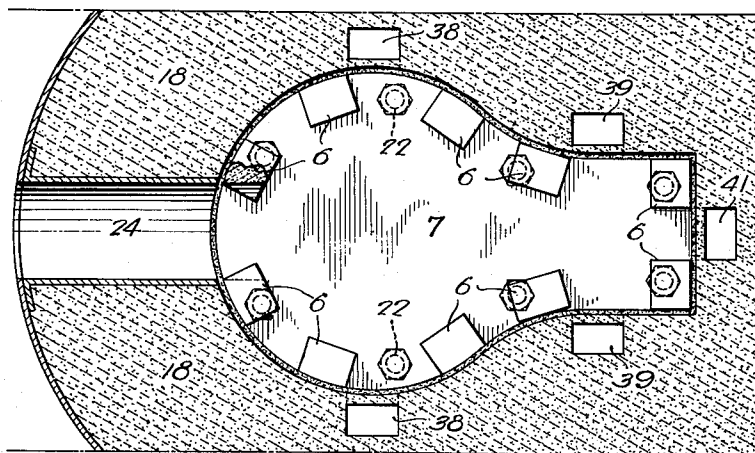


Fig. 5



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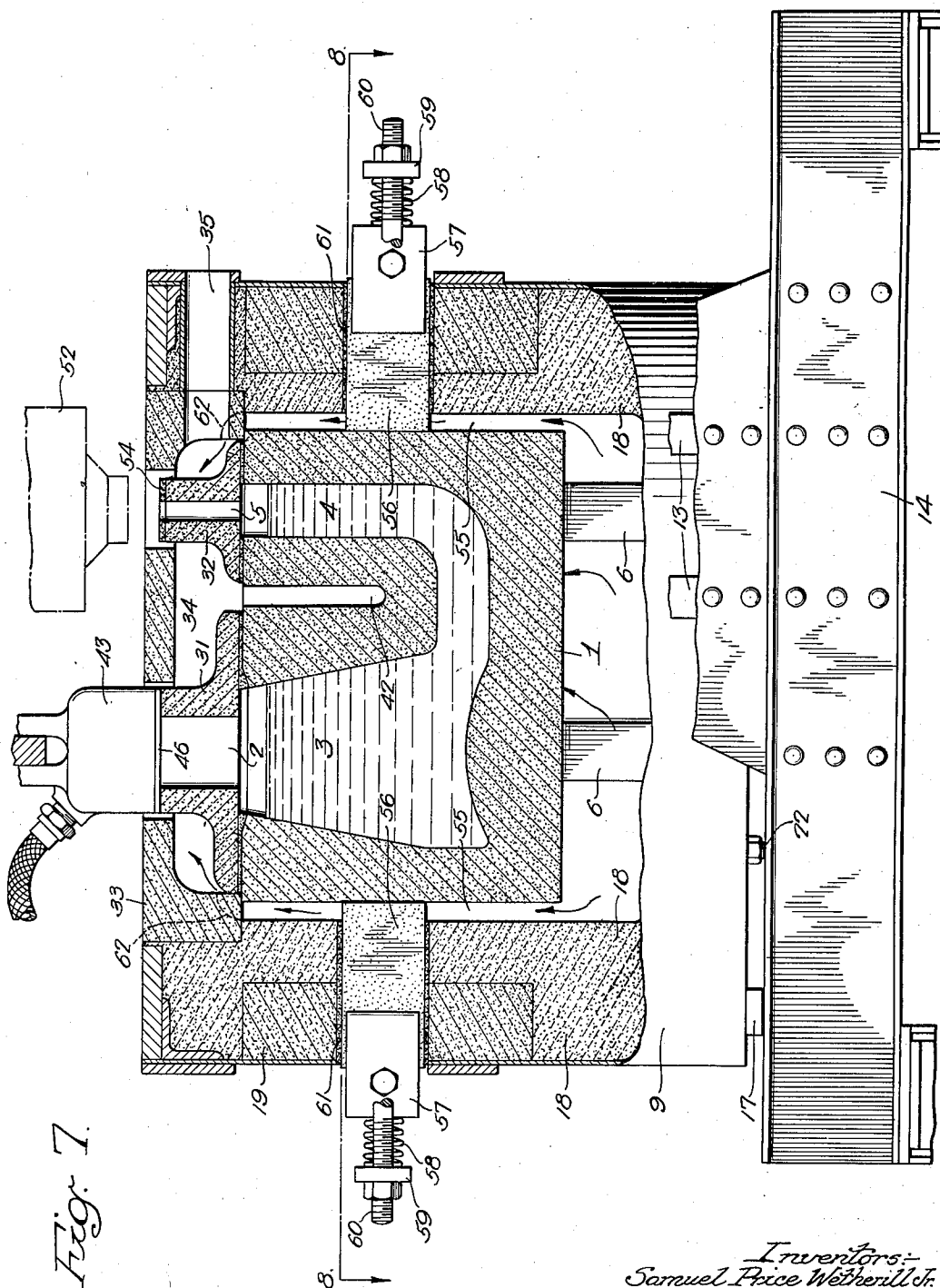
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METAL CASTING SYSTEM

Filed June 4, 1934

5 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,018,586

METAL CASTING SYSTEM

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Application June 4, 1934, Serial No. 729,002

28 Claims. (Cl. 22-69)

This invention relates to improvements in metal casing systems of the character wherein the molten metal is fed to a mold or die under pressure, and the principal object of the invention is to provide novel and improved apparatus for this type of casting that shall be both efficient and commercially practicable. The apparatus, while useful for casting other classes of metals, is adapted primarily for casting metals of the higher melting temperatures, such for example as iron and steel.

To the above general end, another object of the invention is to provide apparatus of the stated character comprising a crucible so constituted as to afford an exceptionally high efficiency of heat transmission to the interior thereof, thereby avoiding necessity for destructively high temperatures at the exterior of the crucible.

A further object of the invention is to provide apparatus of the stated character that shall be free from critical operations requiring the services of a highly skilled operator, and one that can be relied upon to provide sound castings under all but the most abnormal conditions.

A still further object of the invention is to provide in apparatus of the stated character a novel construction of discharge nozzle together with novel heating means making possible maintenance of sufficiently high nozzle temperatures to prevent chilling and consequent freezing in the nozzle of metals of the higher ranges of melting temperature, thereby for the first time permitting manufacture by this process and in an uninterrupted operation of any required number of castings of metals such as iron and steel.

The invention further resides in certain novel structural arrangements and details hereinafter set forth and illustrated in the attached drawings, in which:

Figure 1 is a plan view of apparatus made in accordance with our invention;

Fig. 2 is a side elevational view of the apparatus;

Fig. 3 is a section on the line 3-3, Fig. 1;

Fig. 4 is a section on the line 4-4, Fig. 1;

Fig. 5 is a section on the line 5-5, Fig. 3;

Fig. 6 is a fragmentary reduced elevational view illustrating the container or crucible-sealing and pressure-applying means;

Fig. 7 is a vertical sectional view on the line 7-7, Fig. 8, illustrating a modified embodiment of our invention.

Fig. 8 is a horizontal section on the line 8-8, Fig. 7, and

Fig. 9 is a view in perspective of the cover member in the embodiment illustrated in Figs. 7 and 8.

In general, the invention contemplates the use of a crucible of a refractory composition capable of withstanding both the corrosive action of the molten metal and the temperatures required for the casting of iron, steel and other high temperature metals, and which is capable also of withstanding in some degree the expansive effect of the pressure to which the metal must be subjected in the normal casting operation. In conjunction with a crucible of this character, the invention further contemplates the use of a structure remotely positioned with respect to the crucible and strong enough in itself to support the expansive pressure to which the relatively weak refractory material of the crucible is subjected, together with means for transferring to this structure the major part of said expansive pressure while leaving portions of the exterior surface of the crucible exposed for direct application of heat. In a construction of this character in which the heat can be applied to the crucible at a point remote to the supporting structure, it is only necessary to force the heat through the walls of the crucible while the expansive pressure imposed upon the crucible walls is transferred through a heated zone to the relatively cool and strong supporting structure by means, capable of resisting compression as well as withstanding the heat to which it necessarily is exposed.

With reference to the drawings, the crucible or container for the molten metal is indicated at 1. As shown in Fig. 3, this container has in its top an opening 2 affording access to the main chamber 3, and communicating with the bottom of the chamber 3, is a nozzle passage 4 which extends upwardly and terminates in a port 5 at the top of the container. Preferably this crucible is made of a carbon-bonded graphitic refractory material of the character described in pending application for United States Letters Patent Serial Number 663,259, filed March 29, 1933, and known in the trade as synthetic carbon, this material having in marked degree the required characteristics of resistance to the corrosive action of the molten metal and to the temperatures required for casting metals, such as iron and steel, of the higher melting temperatures, and a relatively high heat conductivity permitting maintenance in the interior of the crucible of the required relatively high temperatures without a destructively high temperature at the exterior of the crucible, and having also the inherent strength

and low porosity required for practice of the present invention.

The container 1 is supported in the present instance upon a plurality of piers 6, which as shown in Figs. 3 and 4 rest upon a hearth 7, and this hearth is supported upon the bottom plate 8 of a metallic casing, the walls 9 of which extend upwardly at points remote from the sides of the container 1. This casing is provided at opposite sides with trunnions 11 which are journaled in hook-shaped bearings 12 projecting from the uprights 13 of an elevated supporting framework 14. This trunnioned mounting permits the casing to be pivoted from the normal upright position to the inverted position shown in broken lines in Fig. 2. In the normal upright position, the casing rests at one end upon a spring 15 supported on a transverse member 16 of the frame 14. The opposite end of the casing may be releasably supported in any suitable manner, such for example as by a transverse removable bar 17 extending between and resting upon the horizontal side members of the frame 14. Withdrawal of the bar 17 permits the casing to be tilted, as previously set forth. Preferably the piers 6 are of a refractory composition, such as silicon carbide, having the necessary strength to adequately support the container 1, together with the ability to withstand the high temperatures to which they are subjected, as hereinafter set forth, in the operation of the apparatus.

Surrounding the sides of the container 1 and partially filling the space between the sides of the container and the side walls 9 of the casing is a body 18 of a high-temperature refractory of relatively low conductivity, and this refractory is in turn embraced, within the area of the side walls of the container 1, by a layer 19 of suitable insulating material.

The hearth 7, which is preferably formed of aluminum oxide or similar refractory material and which may be lined on the top with a thin layer of a suitable high temperature cement is supported through a sheet of asbestos upon a metallic plate 21, and this plate in turn rests upon a series of set screws 22 threaded into the bottom plate 8 of the metallic casing. Preferably each set screw is provided with a lock nut 23. By this means it is possible to adjust the hearth in accordance with the expansion and contraction of the piers 6 and of the container 1. As hereinafter described, the piers 6 are exposed to the heat applied to the exterior surface of the container 1. These piers when heated will have a tendency to expand, but due to partial vitrification of the silicon carbide material, the expansion and contraction will not remain a constant factor of the temperature. For adequate support of the container 1, it is essential that the piers remain in firm contact both with the under side of the container and with the hearth, and the adjustable mounting of the hearth provides for maintaining this necessary relation.

It will be noted that the piers 6 are so arranged that the major portion of the under surface of the container 1 is exposed. The space between the hearth and the under side of the container occupied by the piers is connected through a passage 24 in the refractory 18 with an opening 25 in the side wall 9 of the casing. This opening provides for insertion of a burner tube 26 which may be of the Bunsen type, by means of which a flame may be projected into the space immediately below the container 1 and against the under surface of the latter. In order to give the bottom wall of the container sufficient strength in that portion not

immediately supported by the piers 6, the inner bottom surface of the container 1 and of the main chamber 3 is arched, as shown in Figs. 3 and 4.

Seated in the opening 2 at the top of the container 1 is a flanged fitting 31 which projects upwardly above the top of the container 1 and provides a port through which access may be had to the chamber 3 of the container. A similar fitting 32 is seated in the top of the nozzle passage 4 and forms in effect a tip for the nozzle. The upper portions of these fittings occupy openings in a cover-plate 33, preferably of a low conductivity refractory, which is supported in the top of the casing in spaced relation to the top of the container 1. A chamber 34 is thus formed at the top of the container 1, access to which through the wall of the casing and through the refractory material 18 is afforded by passages 35 and 36. The passage 35 enters the chamber 34 at a point adjoining the nozzle tip 32 and provides for the insertion into the casing of a burner tube 37 which may be of the Bunsen type and which is adapted to project a flame against the nozzle tip 32, and around this tip into the chamber 34. Circulation through the chamber of the heating gases is afforded by the passage 36 and by the openings in the cover-plate 33 around the upper ends of the fittings 31 and 32. Flues 38, 39 and 41 extend upwardly from the space between the bottom of the container 1 and the hearth 7 and through the refractory material 18 into the chamber 34 at the top of the container, it being noted by reference to Fig. 1 that the flues 39 and 41 enter the chamber 34 closely adjacent to the nozzle tip 32, while the flue 38 enters the inner end of the passage 35, which as previously set forth also lies adjacent the nozzle tip 32. The heated gases from the burner 26 after impinging upon the bottom of the container 1 pass upwardly through the flues 38, 39 and 41 into the chamber 34 at the top of the casing, the greater portion of the heat thus circulating passing through the flues 39 and 41, which as previously set forth are contiguous to that portion of the container 1 through which the nozzle opening 4 passes, so that the greater proportion of the circulating heat is applied to this portion of the container and to the nozzle tip 32.

It will be noted that the depending portion 1a of the container 1 which lies between the main chamber 3 and the nozzle passage 4 is provided with a recess or channel 42 which extends downwardly to a point adjacent the bottom of said depending portion 1a and which terminates at the top in the chamber 34. This constitutes a trap for air tending to pass through the depending portion 1a of the container from the chamber 3 towards the nozzle passage 4 and prevents this air from passing into the body of molten metal discharging through the nozzle, as hereinafter set forth.

In a normal casting operation, the container 1 is charged with a suitable quantity of molten metal through the opening 2 and the fitting 31, the high conductivity material of the crucible insuring a highly efficient transmission of heat to the metal and maintenance within the crucible of an adequate temperature without excessively high temperatures within the space immediately below the crucible. Thereafter the charging port through the said fitting 31 is closed by applying to the top of the fitting a fixture 43 formed with a port 44 through which air pressure may be imposed upon the upper surface of the molten metal in the main chamber 3. Preferably the

fixture 43 is provided with a foraminous plate or baffle 45 which preheats and distributes the air forced into the dome and prevents this air impinging in a concentrated blast upon the upper surface of the molten metal. An asbestos or other suitable gasket 46 may be provided at the upper face of the fitting 31 in order to form an effective seal between the fixture 43 and the top of the fitting.

As shown in Fig. 6, the fixture 43 is carried by and depends from a lever 47 hinged at 48 upon a suitable supporting structure in a position overlying the casing, and means in the form of an adjustable yoke 49 may be provided for retaining the free end of the lever 47 in the horizontal position in which the fixture 43 engages the fitting 31. This bracket may be provided with a set screw 51 for exerting a downward pressure upon the free end of the lever, forcing the member 43 firmly down upon the gasket 46.

A die 52 having a charging port 53 is now brought down by suitable means upon the upper end of the nozzle tip 32, a suitable gasket 54 being provided to seal the joint between the tip and the abutting die surface. Air pressure is imposed through the port 44 of the fixture 43 upon the top of the chamber 3 and upon the surface of the molten metal therein, this pressure being sufficient to force the metal downwardly in the chamber 3 and upwardly in the discharge nozzle 4, the metal passing through the tip 32 and through the registering die opening 53 into the die. After sufficient metal has thus been discharged to completely fill the die and to provide an excess of metal sufficient to compensate for shrinkage in the die chamber, the air pressure is relieved from the chamber 3, and the die 52 is removed. This cycle of operations is repeated until the required number of castings is provided, the crucible being recharged when necessary.

It is apparent that the metal thus discharged from the casing 1 must be interrupted before the level of the metal in the casing is reduced to a point below the bottom of the depending portion 1a of the container. Air forced through the somewhat permeable material of the portion 1a of the container is bypassed through the channel 42 to the chamber 34, and is thus prevented from entering the column of metal passing through the discharge port 4 to the die. Shock upon the container 1 by impact of the die 52 on the upper end of the nozzle tip 32 and excessive pressures arising from expansion between the die and the container is relieved by the spring 15, which permits that end of the casing to move downwardly under excessive pressure. Additional charges of molten metal may be introduced into the container 1 by displacement of the fixture 43 from its normal position upon the fitting 31. A solid abutment for the bottom of the container 1 upon the hearth 7, which is essential in order to prevent damage to the container 1 by the pressure applied to the interior thereof in discharging the molten metal, is maintained through the medium of the adjusting screws 22, through which any play developing by reason of contraction of the piers 6 or in the container may be taken up.

It is essential, in order to maintain the apparatus in continuous operation, to prevent chilling and consequent freezing of the metal in the discharge nozzle. While this has been a relatively simple matter in apparatus of the general character used for casting metals, such as type metal, of low melting temperature, the requirement has never been fully met in apparatus for

manufacturing castings from metals, such as iron and steel, of the higher range of melting temperatures. Production by this method of the latter class of castings has been so slow, by reason of the necessity for frequent interruptions to clear the nozzle of accretions of metal, that the method has not heretofore been found commercially practicable on any substantial scale.

Referring to Fig. 3 of the drawings, it will be noted that the discharge end of the nozzle 4 is necessarily remote to the principal source of heat and is subject to considerable heat loss by exposure to the atmosphere and by contact with the relatively cold die, which contact is necessarily sustained during the periods in which the metal is "setting" in the die. To prevent progressive clogging, these heat losses in the nozzle must be replaced and the nozzle maintained at a temperature in excess of the melting temperature of the cast metal, which in the case of iron and steel is relatively high. This requirement is complicated by the fact that the tip of the nozzle contacted by the die must have at these high temperatures a structural strength capable of withstanding the impact and sustained pressures imposed by the die, which are considerable. By the present invention, we provide the nozzle 4 with the tip 32 of silicon carbide or similar refractory material which as we have established by exhaustive experiment possesses the characteristics meeting the multiple requirements. This material is capable of withstanding without undesirable physical change sustained temperatures in excess of the melting temperatures of the higher melting temperature metals such as iron and steel. It possesses also the required structural strength at these high temperatures, is non-porous, and has the additional desirable characteristic of relatively high heat conductivity insuring efficient transfer of heat to the interior bore from an external source. As previously described, provision is made through the medium of the flues 39 and 41 for directing heat from the burner 26 to the portions of the crucible embracing the nozzle 4 and to the area immediately surrounding the tip 32. Under normal conditions, this heat has been found sufficient to maintain the minimum allowable operating temperature, and additional heat may periodically be directly applied to the nozzle tip through the burner 31.

Apparatus constructed in accordance with the principles set forth above can be kept in continuous uninterrupted operation over extended periods of time as required for manufacture of high quality castings on a production basis.

When the casting operation is to be discontinued for any substantial period of time, the residual metal within the container 1 may be discharged therefrom by removal of the fixture 43, withdrawal of the support 17 and tilting of the entire casing to the inverted broken line position shown in Fig. 2 permitting discharge of the molten metal from the charging opening 2 through the fitting 31.

The embodiment of our invention illustrated in Figs. 7, 8 and 9 is in its essential principle of construction and operation the same as that previously described. The corresponding elements in this embodiment are, therefore, identified by the same reference numerals. It will be noted that the crucible 1 is supported in the casing and in the same manner previously described by the piers 6, at least some of which are located preferably in the vertical planes of the access opening 2 of the crucible and the discharge port 5.

In this instance, however, the body of refractory 18 embracing the crucible does not contact the sides of the latter but is spaced therefrom so as to provide an uninterrupted flue passage 55 around the crucible. The crucible is centered in the casing and the walls thereof are reinforced by blocks 56 of silicon carbide or other material of similar characteristics which project inwardly through the walls of the casing and which are held at their outer ends by clamps 57. These clamps and the blocks 56 to which they are attached are urged inwardly by compression springs 58 which are confined between the outer ends of the said clamps and bars 59, which bars are supported and retained by stud bolts 60, the inner ends of which are secured in the metallic shell 9 of the casing. The bars 59 are adjustable on the studs to regulate the tension of the springs 58 and thereby the pressures with which the blocks 56 engage the sides of the crucible. The joints between the blocks 56 and the walls of the casing are sealed by a suitable refractory cementing material 61.

The cover-plate 33 shown in Fig. 7 and in the perspective view of Fig. 9 has at the under side and in the inner surface a series of recesses 62 which in assembly and as shown in Fig. 7 register with the upper end of the flue passage 55 and establish communication between this passage and the chamber 34 in which, as in the previously described embodiment, are established the fitting 31 overlying the main chamber 3 of the crucible and the nozzle tip 32 at the upper end of the nozzle passage 4. The combustion gases thereby pass from the combustion chamber below the crucible upwardly through the flue passage 55 and into the chamber 34, as indicated by the arrows in Fig. 7, and thereby supply heat not only to the side walls of the crucible but also to the fitting 31 and the discharge nozzle 32. As in the previous embodiment, provision is made through the passage 35 for direct application of heat from a suitable burner to the nozzle tip 32, if this is found necessary in order to maintain the said tip at the required temperature.

It will be apparent that this embodiment of our invention contains the same basic principles found in the embodiment illustrated in Figs. 1 to 6, inclusive.

We claim:

1. In casting apparatus of the character set forth, the combination with a crucible of non-metallic refractory composition, of a relatively strong structure remote to the crucible, means for applying heat to the exterior of the crucible, means for applying pressure to the interior of the crucible, said pressure being in excess of the pressure in the area surrounding the crucible and thereby tending to expand and disrupt the relatively weak walls of the latter, and means for transferring to the said structure the disruptive forces thus imposed upon the said walls of the crucible.

2. In casting apparatus of the character set forth, the combination with a crucible of non-metallic refractory composition, of a relatively strong structure remote to the crucible, means for applying heat to the exterior of the crucible, means for applying pressure to the interior of the crucible, means for transferring to the said structure the expansive pressures thus imposed upon the relatively weak walls of the crucible, said pressure-transferring means including a plurality of relatively spaced piers of non-metallic refractory composition exposed to said heat

and bridging the space intervening between the crucible and said structure, and adjustable means for maintaining a solid bearing between the piers and the crucible and the said structure.

3. In casting apparatus of the character set forth, the combination with a crucible of non-metallic refractory composition, said crucible having a discharge nozzle and an opening providing for application of pressure to the interior of the crucible to forcibly discharge the molten contents through the nozzle, of a relatively strong structure remote to the crucible, and refractory means interposed and forming solid abutments between the crucible and said structure for reinforcing the walls of the crucible against the said internal pressures, said reinforcing means being constructed and arranged to leave a portion of the exterior surface of the crucible exposed for application of heat to the latter.

4. In casting apparatus of the character set forth, the combination with a crucible of non-metallic refractory composition, of a metallic housing remotely embracing said crucible, said crucible having a discharge nozzle and an opening providing for application of pressure to the interior of the crucible to forcibly discharge the molten contents through the nozzle, and the housing being constructed and arranged to afford access to the nozzle and said opening, and refractory abutments extending between the housing and the crucible and reinforcing the walls of the latter against the said internal pressures, said abutments leaving portions of the outer surface of the crucible exposed and the housing having an opening affording access to said exposed portions for application of heat to the exterior of the crucible.

5. In casting apparatus of the character set forth, the combination with a crucible of non-metallic refractory composition, of a metallic housing remotely embracing said crucible, said crucible having a discharge nozzle and an opening providing for application of pressure to the interior of the crucible to forcibly discharge the molten contents through the nozzle, and the housing being constructed and arranged to afford access to the nozzle and said opening, refractory abutments extending between the housing and the crucible and reinforcing the walls of the latter against the said internal pressures, said abutments leaving portions of the outer surface of the crucible exposed and the housing having an opening affording access to said exposed portions for application of heat to the exterior of the crucible, and adjustable means in said housing for compensating expansion and contraction in the apparatus affecting the normal relation between the housing and the refractory elements.

6. In casting apparatus of the character described, the combination with a crucible having a discharge nozzle and an opening providing for application of pressure to the interior of the crucible to forcibly discharge the molten contents through the nozzle, said crucible being of refractory composition of insufficient strength to withstand the expansive effect of said pressure, of a relatively strong structure remote to said crucible, and means extending between the said structure and crucible for reinforcing the latter, said reinforcing means engaging portions only of the outer surface of the crucible and leaving other portions exposed for direct application of heat to the crucible.

7. In casting apparatus of the character set

forth, the combination with a crucible of composition both highly refractory and of high heat conductivity, of a relatively strong reinforcing structure, a hearth member movably mounted in said structure below the crucible, support means for said crucible extending upwardly from said hearth, said support means leaving a portion of the under surface of said crucible exposed, means for applying heat to the exposed portion of the under surface of said crucible, and means for adjusting the hearth vertically to compensate for expansion and contraction of said support means.

8. In casting apparatus of the character set forth, the combination with a crucible comprising a main chamber and a nozzle passage extending from the lower portion of said chamber through a wall of the crucible and terminating in the top of the latter, a hearth positioned below and in spaced relation to the bottom of said crucible, means for projecting a flame into the space between the hearth and said crucible and against the under surface of the latter, and flue passages extending upwardly from said space in proximity to said nozzle passage.

9. In casting apparatus of the character set forth, the combination with a crucible comprising a main chamber and a nozzle passage communicating with the lower portion of said chamber and terminating in the top of the crucible, a hearth positioned below and in spaced relation to the bottom of said crucible, means for projecting a flame into the space between the hearth and said crucible and against the under surface of the latter, flue passages extending upwardly from said space in proximity to said nozzle passage, a nozzle tip projecting from the upper end of said passage, and means for circulating the heated gases from said flues around said tip.

10. In casting apparatus of the character set forth, the combination with a crucible comprising a main chamber and a nozzle passage communicating with the lower portion of said chamber and terminating in the top of the crucible, a hearth positioned below and in spaced relation to the bottom of said crucible, means for projecting a flame into the space between the hearth and said crucible and against the under surface of the latter, flue passages extending upwardly from said space in proximity to said nozzle passage, a nozzle tip projecting from the upper end of said passage, means for circulating the heated gases from said flues around said tip, and means independent of said heated gases for heating said tip.

11. In casting apparatus of the character set forth, the combination with a container having a main chamber and a discharge passage extending from the lower end of said chamber and terminating in the top of said container, a tip of refractory composition projecting upwardly from the terminal end of said passage, means forming a combustion chamber below the container, flues extending upwardly from said combustion chamber in proximity to said nozzle passage, a transverse flue communicating with the upper ends of the flues first named and embracing said tip, and means for projecting a flame into said transverse flue and against said tip.

12. In casting apparatus of the character set forth, the combination with a sealed container having a main chamber and a nozzle passage extending upwardly from the lower end of said chamber, a flue passage extending transversely over the top of said container, a combustion chamber formed at the bottom of said container,

and a plurality of flue passages extending upwardly from said combustion chamber to said transverse flue passage.

13. In casting apparatus of the character set forth, the combination with a container having a main chamber and a nozzle passage extending upwardly from the lower end of said chamber, means for applying fluid pressure to the top of said main chamber to discharge the molten contents of the container through said nozzle passage, and a recess extending inwardly from an exterior surface of said container in a position interposed between the main chamber of said container and the nozzle passage.

14. In casting apparatus of the character set forth, the combination with a container of air-pervious composition, said container having a main chamber and a nozzle passage extending from the lower end of said main passage transversely and upwardly through said composition, means forming an air trap in said container intermediate the main chamber and said nozzle passage, and means for imposing air pressure in the top of said main chamber to discharge the molten contents of the container through the nozzle passage.

15. In casting apparatus of the character set forth, the combination with a crucible of a carbon-bonded graphitic refractory composition and a discharge nozzle therefor, of a relatively strong reinforcing structure remote to said crucible, compression members extending between said structure and the crucible and engaging the latter at spaced points, means for applying pressure in the interior of said crucible to discharge the molten contents through said nozzle, and means for applying heat to the exterior surface of the crucible within the areas intermediate said compression members.

16. In casting apparatus of the character set forth, the combination with a container structure, of means for supporting said structure on a transverse pivotal axis to permit adjustment between normal upright and inverted positions, said structure comprising a main chamber and a nozzle passage extending transversely from the lower end of said chamber and upwardly to the top of the container, said passage being positioned at one side of said pivotal axis, resilient means for supporting the corresponding side of said container structure, means for releasably supporting the structure at the other side of said pivotal axis, means for establishing communication between the upper end of said nozzle passage, and a molding die, and means for applying fluid pressure in the top of said main chamber.

17. In apparatus adapted for pressure casting of metals, such as iron and steel, of the higher melting temperatures, the combination with a container for the molten metal having a nozzle through which the said metal is discharged to and maintained under pressure in a mold forcibly engaged with the end of said nozzle, of a nozzle tip at the discharge end of the nozzle, and means for heating said tip to a temperature substantially in excess of the melting temperature of said metal and for supplying heat to the tip at a rate to continuously maintain said temperature against heat losses due to radiation and to conduction whereby solidified metal is excluded from the nozzle passage, said tip being formed of a non-metallic refractory composition of high heat conductivity capable of withstanding said elevated temperatures and having at said temperatures a structural strength capable of withstanding

ing the impact and pressure imposed thereon by the said mold.

18. In apparatus adapted for pressure casting of metals, such as iron and steel, of the higher melting temperatures, the combination with a container of non-metallic refractory composition comprising a main chamber and a discharge nozzle communicating with the lower end of said chamber and through which the molten metal is discharged under fluid pressure in the main chamber to a die forcibly engaged with the end of said nozzle, of a nozzle tip of non-metallic refractory material adapted for engagement with the die, means for maintaining said nozzle and tip at a temperature in excess of the melting temperature of said metal, and means for preventing passage of air from said main chamber to the nozzle passage through the intervening wall of said container.

19. In casting apparatus of the character set forth, the combination with a crucible of non-metallic refractory material having a main chamber and a discharge passage extending from the lower end of said chamber and terminating in the top of said crucible, means forming a combustion chamber below the crucible, flue means extending upwardly from said combustion chamber and substantially embracing the sides of the crucible, a relatively strong structure remote to and embracing the crucible, insulating material interposed between the crucible and said structure and forming the outer wall of said flue, and refractory means carried by said structure and intersecting said flue passage to engage and to reinforce the walls of said crucible.

20. In casting apparatus of the character set forth, the combination with a crucible of non-metallic refractory material having a main chamber and a discharge passage extending from the lower end of said chamber and terminating in the top of said crucible, means forming a combustion chamber below the crucible, flue means extending upwardly from said combustion chamber and substantially embracing the sides of the crucible, a relatively strong structure remote to and embracing the crucible, insulating material interposed between the crucible and said structure and forming the outer wall of said flue, refractory means carried by said structure and intersecting said flue passage to engage and to reinforce the walls of said crucible, and resilient means for urging said refractory means into engagement with the crucible.

21. In apparatus for pressure casting metals of relatively high melting temperature such as brass, iron and steel, the combination with a heated non-metallic refractory container for the molten metal and a discharge nozzle for said container, of means for applying pressure in the interior of said container to discharge the molten metal through the nozzle, said pressure being in excess of the pressure in the region surrounding the container, and a non-metallic refractory closure for maintaining said container substantially air-tight at the operating temperatures and pressures, said container and closure constituting a closed pressure vessel.

22. In apparatus for pressure casting metals of relatively high melting temperature such as brass, iron and steel, the combination with a non-metallic refractory container for the molten metal from which said metal is discharged by pressure applied in the interior of said container, of means for heating the exterior of said container, and a non-metallic refractory closure for

the container for maintaining said container substantially air-tight at the operating temperatures and pressures, the pressure applied to the interior of the container being in excess of the pressure of the region surrounding the container.

23. In apparatus for pressure casting metals of relatively high melting temperature such as brass, iron and steel, the combination with a heated non-metallic refractory container for the molten metal, and a discharge nozzle for said container, of means for applying pressure in the interior of said container to discharge the molten metal through the nozzle, said pressure being in excess of the pressure in the region surrounding the container, a non-metallic refractory closure for maintaining said container substantially air-tight at the operating temperatures and pressures, said container and closure constituting a closed pressure vessel, a relatively strong structure remote to the container, and means for transferring to said structure a part of the expansive pressures imposed upon the walls of the container by said internal pressure.

24. In apparatus for pressure casting metals of relatively high melting temperature such as brass, iron and steel, the combination with a non-metallic refractory container for the molten metal from which said metal is discharged by pressure applied in the interior of said container, of means for applying fluid pressure in the interior of the container to discharge the molten contents, means for maintaining said container substantially air-tight at the operating temperatures and pressures and for thereby excluding said fluid pressure from the space surrounding the container, a relatively strong structure remote to the container, and means for transferring to said structure a part of the expansive force imposed upon the walls of the container by said internal pressure.

25. In apparatus for pressure casting metals of relatively high melting temperature such as brass, iron and steel, the combination with a non-metallic refractory container for the molten metal from which said metal is discharged by pressure applied in the interior of the container, of a relatively strong structure remote to the container, means for applying heat to the exterior of the container, means for applying pressure in the interior of the container to discharge the molten contents, means for maintaining said container substantially air-tight at the operating temperatures and pressures and for thereby excluding said pressure from the area surrounding the container, and means for transferring to said structure a part of the unbalanced expansive force thus imposed upon the walls of the container by said internal pressure.

26. In apparatus adapted for pressure casting of metals, such as iron and steel, of the higher melting temperatures, the combination with a container for the molten metal and a nozzle through which said metal is discharged under pressure to a mold forcibly engaged with the end of said nozzle, of a nozzle tip at the discharge end of the nozzle, means for exerting pressure in excess of atmospheric upon the molten metal to discharge said metal from the container to the mold and for maintaining said pressure over the period during which the setting of the metal in the mold is completed, and means for heating said tip to a temperature substantially in excess of the melting temperature of said metal and for supplying heat to the tip at a rate continuously maintaining said temperature against heat losses due to radiation and to conduction to thereby

exclude solidified metal from the nozzle passage, said tip being formed of a non-metallic refractory composition capable of withstanding said elevated temperatures, and having at said temperatures a structural strength capable of withstanding the impact and pressures imposed thereon by said mold.

27. In apparatus adapted for pressure casting of metals, such as iron and steel, of the higher melting temperatures, the combination with a container for the molten metal and a nozzle through which the said metal is discharged under pressure to a mold forcibly engaged with the end of said nozzle and arranged vertically thereabove so that all portions of the mold cavity lie above the nozzle passage, of a nozzle tip at the discharge end of said nozzle, means for heating said tip to a temperature substantially in excess of the melting temperature of said metal and for supplying heat to the tip at a rate to continuously maintain said temperature against heat losses due to radiation and to conduction whereby solidified metal is excluded from the nozzle passage, said tip being formed of a non-metallic refractory composition capable of withstanding said elevated temperatures, and having at said temperatures a structural strength capable of withstanding the impact and pressure imposed thereon by the mold, and means for exerting pressure substantially in excess of atmospheric upon the

molten metal within the container to discharge the said metal to the mold and for maintaining said pressure over the period during which the setting of the metal in the mold is completed.

28. In apparatus adapted for pressure casting of metals, such as iron and steel, of the higher melting temperatures, the combination with a container for the molten metal having a nozzle through which the said metal is discharged to and maintained under pressure in a mold forcibly engaged with the end of said nozzle, of a nozzle tip at the discharge end of the nozzle, a heat-insulating gasket at the end of said tip for retarding heat loss from said tip by conduction to the mold, and means for heating said tip to a temperature substantially in excess of the melting temperature of said metal and for supplying heat to the tip at a rate to continuously maintain said temperature against heat losses due to radiation and to conduction whereby solidified metal is excluded from the nozzle passage, said tip being formed of a non-metallic refractory composition of high heat conductivity capable of withstanding said elevated temperatures and having at said temperatures a structural strength capable of withstanding the impact and pressure imposed thereon by the said mold.

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