

May 3, 1955

M. TAMA

2,707,718

INDUCTION PUMP FOR CASTING MOLTEN METALS

Filed May 26, 1948

7 Sheets-Sheet 2

Fig-5-

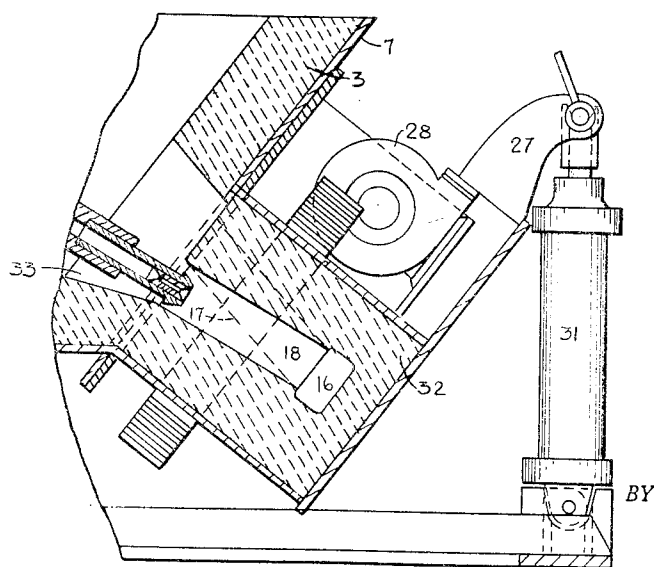
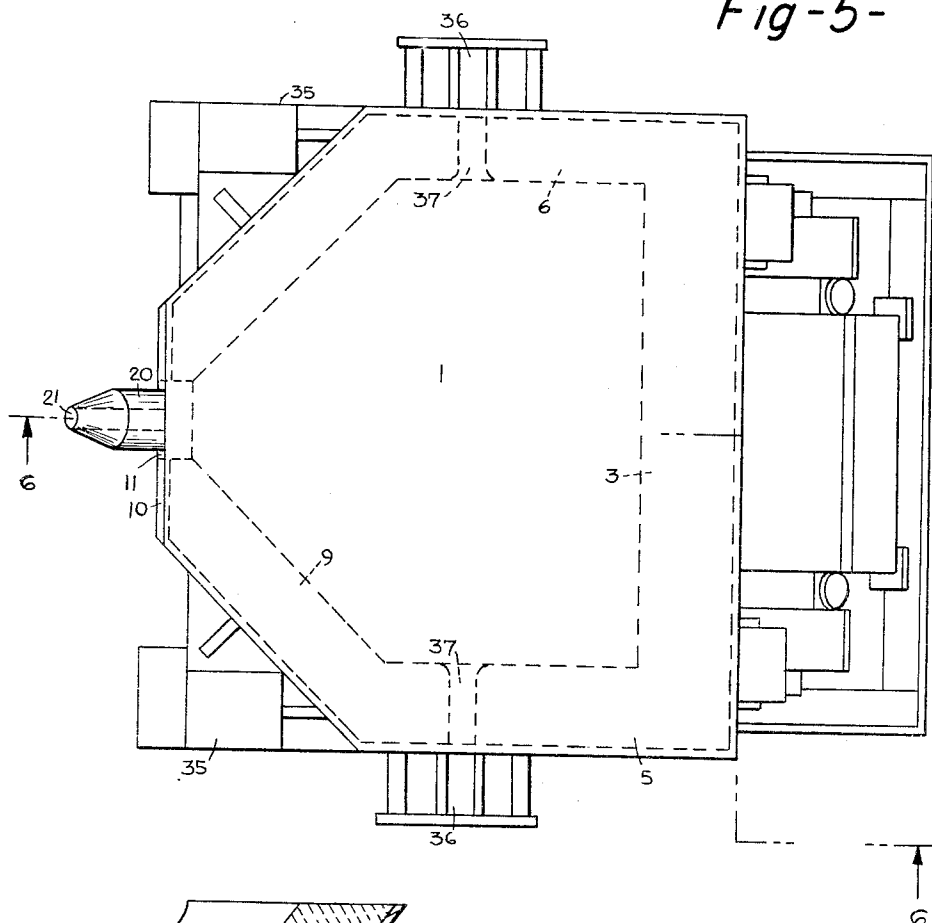


Fig-3-

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INDUCTION PUMP FOR CASTING MOLTEN METALS

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7 Sheets-Sheet 3

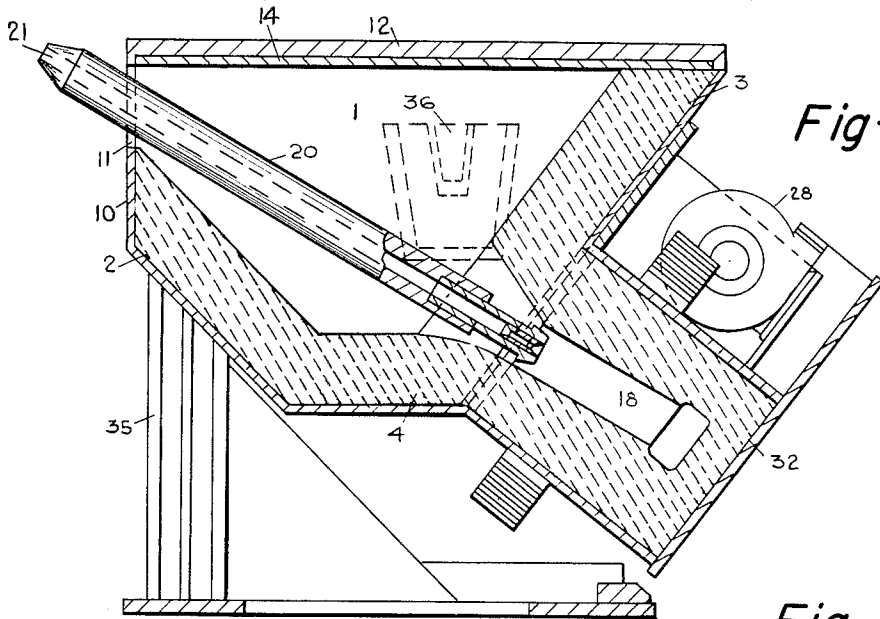


Fig-6-

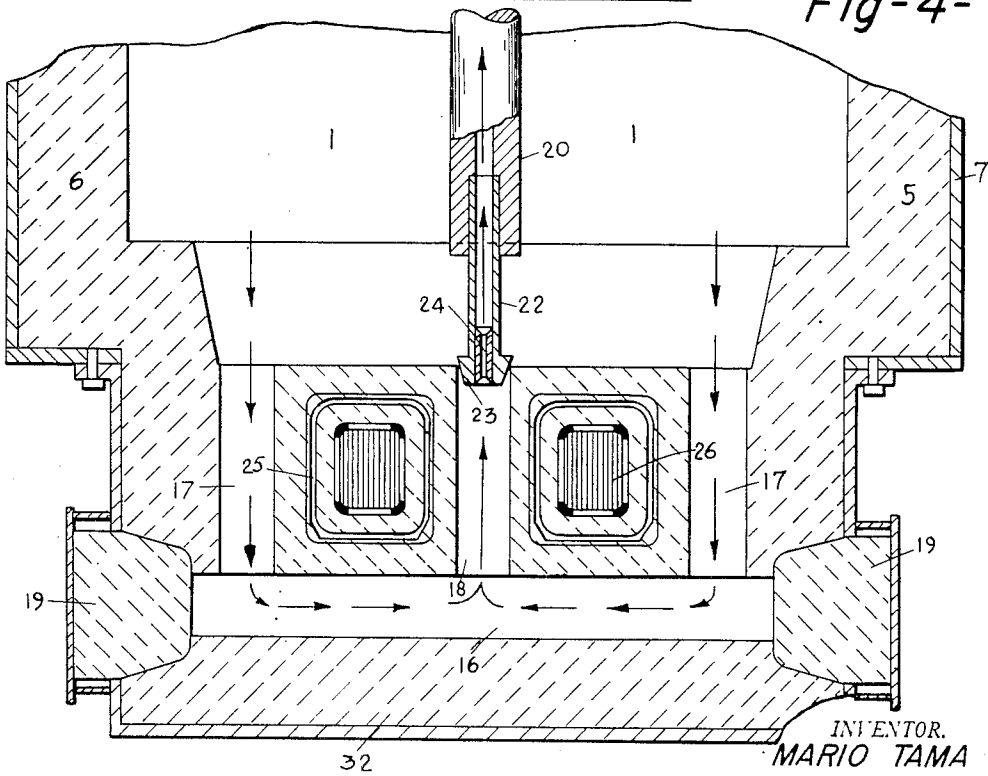


Fig-4-

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INDUCTION PUMP FOR CASTING MOLTEN METALS

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7 Sheets-Sheet 4

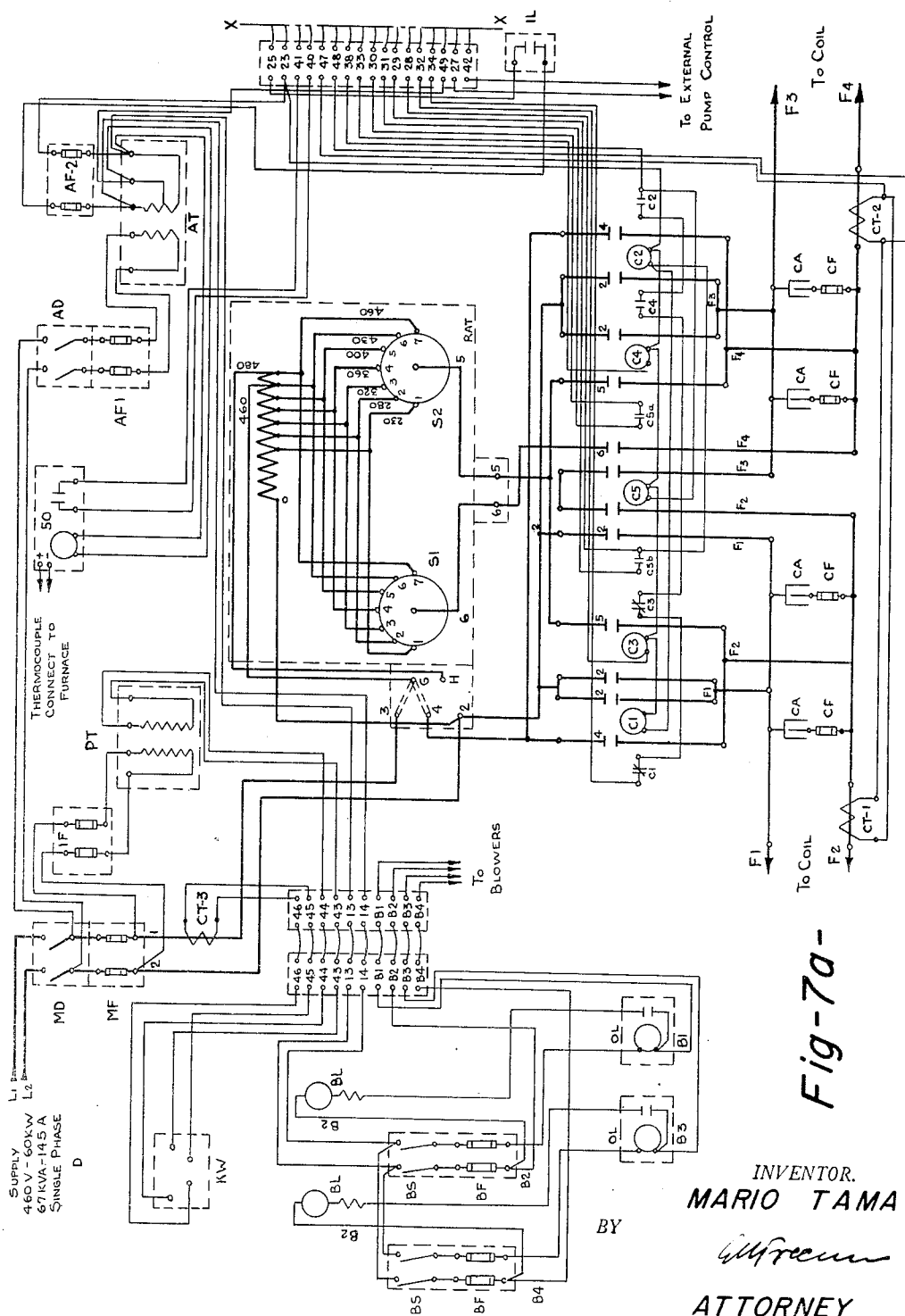


Fig-7a-

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INDUCTION PUMP FOR CASTING MOLTEN METALS

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7 Sheets-Sheet 5

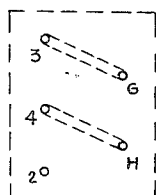
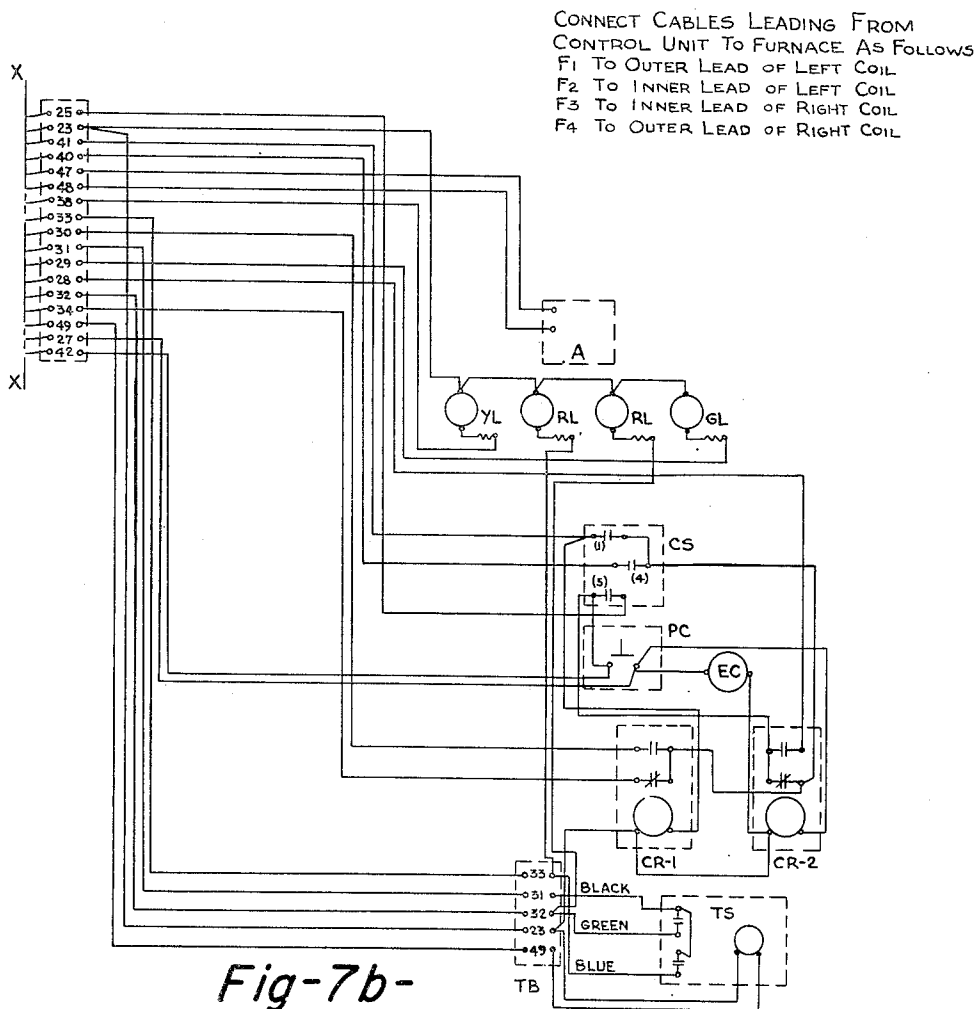


Fig-8

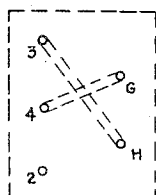


Fig-9-

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INDUCTION PUMP FOR CASTING MOLTEN METALS

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7 Sheets-Sheet 6

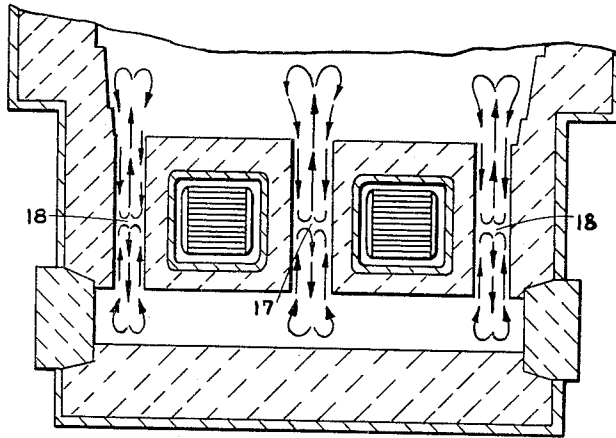


Fig-10-

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INDUCTION PUMP FOR CASTING MOLTEN METALS

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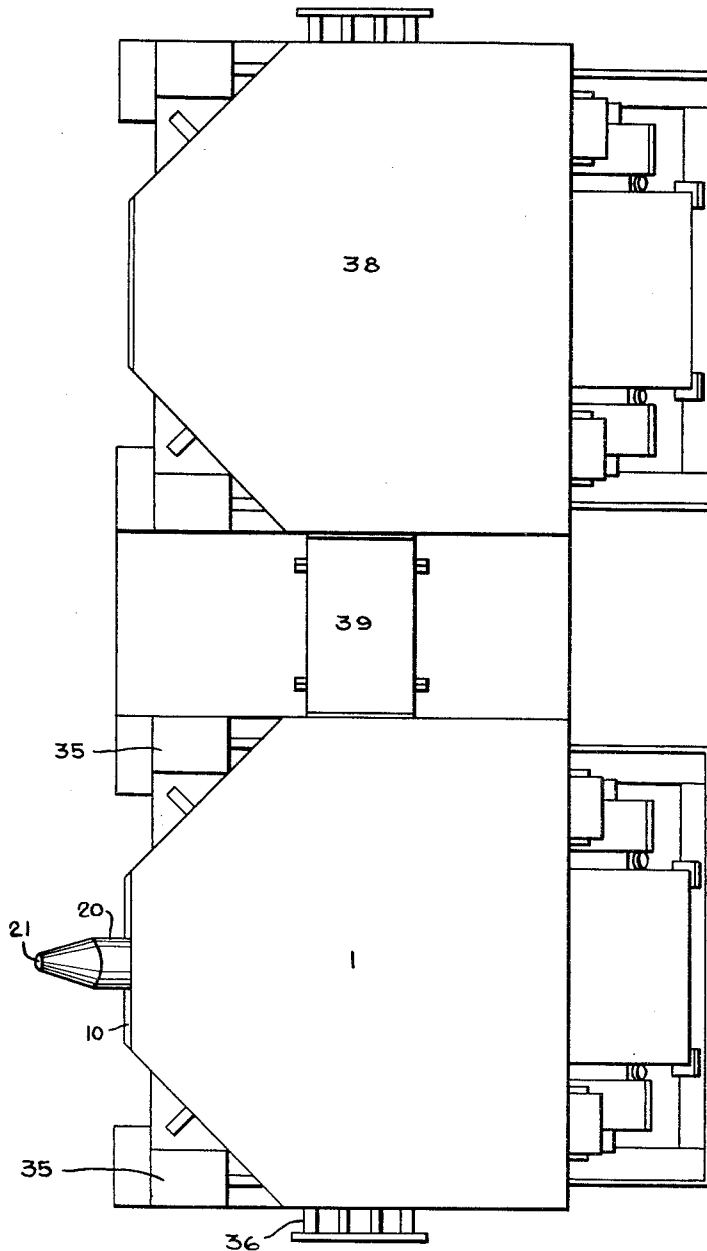


Fig-11-

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INDUCTION PUMP FOR CASTING MOLTEN METALS

Mario Tama, Morrisville, Pa., assignor to Ajax Engineering Corporation, Trenton, N. J., a corporation of New Jersey

Application May 26, 1948, Serial No. 29,263

10 Claims. (Cl. 13—29)

This invention relates to an inductively operated pump of the submerged resistor type for pouring and mold-casting metals and particularly for dispensing accurate quantities of molten metal; this is a continuation-in-part of my copending applications: Ser. No. 647,831, filed February 15, 1946, now Patent No. 2,536,325, dated January 2, 1951; Ser. No. 671,818, filed May 23, 1946, now Patent No. 2,536,859, dated January 2, 1951; Ser. No. 735,851, filed March 20, 1947, now Patent No. 2,539,800, dated January 30, 1951; and Ser. No. 755,886 filed June 20, 1947, now Patent No. 2,541,841, dated February 13, 1951.

Inductively operated metal pumps of the submerged resistor type, here shortly called "induction pumps" have been disclosed for the first time in the above referred to applications.

While these former inventions covered the theory and the broad principles of the electromagnetic pumping of molten metals the present invention relates to the practical construction of pumping devices which have been carefully tested in foundry practice.

Numerous attempts have been made to transport and to pump liquid conductors and to circulate molten metals by means of the repulsion effect between the primary and the secondary of an inductively operated system of which the primary generally consists of current carrying metal coils and iron cores and the secondary of one or several channels, tubes or passages for the transport of the liquid conductor. Accordingly, a large number of publications, such as for instance U. S. Patents 1,660,209, issued February 21, 1928; No. 1,660,407, issued February 28, 1928; No. 1,736,643, issued November 19, 1929; No. 1,792,449, issued February 10, 1931; No. 2,083,022, issued June 8, 1937; No. 2,386,369, issued October 9, 1945; No. 2,224,982, issued December 17, 1940; British Pat. 126,947, granted April 10, 1919; a paper entitled "A New Induction Furnace," presented September 22, 1922, by J. Murray Weed in the 42nd General Meeting of the American Electrochemical Society, illustrate the importance, the diversified ramifications and the difficulties of this problem.

In these prior art devices the electromagnetic moving impetus is directly applied to the liquid by magnets or metallic electrodes or conductors and the horizontally extending passage way for the liquid conductor is being recessed from a metal plate. Based on the same principle of direct current connection tubes have been designed to transport liquid conductors in a horizontal direction the tube walls being provided with slots and the current being passed by metal electrodes through the slots to the fluid conductor. The path of the current is perpendicular to the flow direction of the liquid conductor and specially shaped magnets are provided to serve this end.

Large scale attempts have also been made to utilize the repulsion effect between the primary and the secondary circuits for the creation of a unidirectional flow of molten metals in submerged resistor type induction

furnaces. For this purpose an axial displacement of the primary relative to the secondary has been suggested. The realization of this displacement of the primary, however, involves difficulties which are practically unsurmountable. Similar drawbacks arise in forcing and discharging molten metal by electromotive forces from a container surrounded by a heating chamber in one direction and then move it away from the discharge end in the opposite direction. None of the above referred to devices has attained a practical usefulness.

This invention as well as the inventions disclosed in my copending patent applications signify a decided departure from the art. This departure is based on the discovery that an entirely different and more effective utilization of the electromagnetic field had to be found which renders it possible to operate with high pressure differences within the molten metal and not with the natural forces created by the magnetic field in combination with the use of electrodes or magnets.

The invention utilizes the internal pressures produced within a molten metallic conductor by current induction for the purpose to create a flow of the molten metal in the same direction as the current flows which is, as described in my prior applications, an essential deviation from the prior art, where the pumping of the liquid conductor results from field lines cutting the same transversally to its flow direction.

According to the theory disclosed in my before mentioned prior patent applications the internal pressures increase with the square of the current density; hence, with large current densities appreciable pressures may be obtained and forces created which are of particular importance for the discharge of molten metals by pumping.

As commonly known, the molten metal charge is in a submerged resistor type induction furnace in a state of constant violent motion caused by the induced internal electromagnetic pressures.

The influence of these pressures in the melting section of a submerged resistor type induction furnace is illustrated in Fig. 10 of the attached drawings which represents the current influenced loop section and the lower portion of the metal holding hearth of the furnace.

The electromagnetic field of highest intensity is located in the center portion of the straight channels 17, 18 and about half their length. The metal is forced from this center section through the channels in a direction which is indicated by the arrows. The molten metal stream emerging from the center portion of a channel draws the metal from adjacent portions of the bath into the same channel whereby two lateral flow branches result which are again upwardly forced as they approach the center portion of the channel. In this manner and under the direct influence of the electromagnetic field an intensive up-and-down flow of the melt through the same channel results.

The thus created circulation systems each composed of two adjacent up-and-down streams of the molten metal continuously interfere with each other and collide. As a result jerks and eddies are formed which are transferred into the higher strata of the molten metal and create the before-mentioned violent motion and volcano-like eruption rendering a uniform uninterrupted discharge of the metal into molds an utter impossibility.

These phenomena which will oppose the use of a submerged resistor type induction furnace for the successive pouring and mold-casting of metal are essentially changed if, as disclosed in my above referred to copending patent applications, a refractory tube is inserted with its one end into a channel of the secondary duct system and led with the other end to a location which is free from the influence of the electromagnetic field. The obnoxious re-

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turn flow of the metal into the channel is thus eliminated and a unidirectional flow results from the hearth through a secondary channel to that channel into which the tube has been inserted and through this tube from the furnace, as indicated by arrows in Fig. 4.

It therefore, is the important object of my invention to utilize this unidirectional metal flow for pouring and mold-casting purposes and particularly also for the mold-casting of metal shots.

It is another object of this invention to keep the molten metal to be successively cast into molds at a substantially equal level.

It is also an object of this invention to automatically maintain the level constancy of the molten metal bath.

It is another object of the invention to avoid level differences between the molten metal in the pump and the discharge end of the tube or spout through which the metal is poured.

It is another object of the invention to obtain full uniformity of the cast metal portions or shots with regard to casting temperature and composition.

It is also an object of the invention to reduce the inertia of the molten metal mass in the pump and accordingly the pumping costs. It is an important object of the invention to regulate and to constrict the metal flow, which is discharged from the pump.

Since an uninterrupted mold-casting operation and the production of uniform castings greatly depends upon the conditions in the melting channels of the induction pump, it is also an object of this invention to facilitate the accessibility to these channels.

With the above recited and additional objects in view which will be apparent as this specification proceeds, several modifications of my invention will now be described in detail and with reference to the attached drawings.

In the drawings,

Fig. 1 is a plan view of a first embodiment of my induction pump for pouring and mold-casting metals,

Fig. 2 is a vertical sectional view on line 2—2 of Fig. 1, Fig. 3 is a vertical part sectional view similar to Fig. 2 of a further embodiment,

Fig. 4 is an enlarged sectional view on line 4—4 of Fig. 2,

Fig. 5 is a plan view of a third embodiment of the pump,

Fig. 6 is a vertical sectional view on line 6—6 of Fig. 5,

Figs. 7a and 7b illustrate a wiring diagram control unit of the induction pump,

Figs. 8 and 9 are diagrammatic views of links for connecting the inductor coils of the transformer units,

Fig. 10 is a vertical sectional view of the part of a submerged resistor type induction furnace showing the hitherto usual metal flow from the secondary duct system into the metal holding hearth; and

Fig. 11 is a plan view of the pump in combination with a metal melting and holding furnace.

The induction pump shown in Figs. 1 and 2 for mold-casting equal successive comparatively small quantities of molten metals or shots is of the tiltable compensating type. The pump will be charged from time to time with metal in amounts of 200 to 300 pounds. The pump is provided with a metal holding hearth or chamber 1.

The tilting of the pump is accomplished for the only purpose to keep the level of the molten metal or the distance between the same and the point of discharge substantially constant, whereas the pumping and the casting of the mold is solely effected by electromagnetic forces. The maintenance of level constancy is essential in order to assure uniformity of the shots with regard to quantity and casting temperature.

The metal holding chamber of hearth 1 of the pump has substantially the shape of a triangle. The chamber is housed by two opposite refractory side walls 2, 3 which

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are downwardly inclined towards each other and two opposite refractory end walls 5, 6. Walls 2 and 3 are cut short at their converging center line to form a small horizontal bottom portion 4. A steel casing 7 covers the outer face of the walls.

The front portions 8, 9 of the side walls 5, 6 converge towards the vertical center plane of the pump; the end portion thereof as well as the corner portion of wall 2 are cut-off to form a small frontal face 10. An opening 11 is provided in front face 10 for a purpose which will be explained in a later part of this description.

The metal holding hearth 1 is partly closed by a cover 12 leaving an opening 13 for the supply of fresh charges. Cover 12 has a heating strip 14 which reaches into the proximity of that part of the tube 20 which extends from the metal holding chamber and is located above the molten metal.

The inductor unit which is more in detail shown in Fig. 4 is attached to the inclined wall 3. The unit consists of a refractory block 32 which is surrounded by a steel casing 15. The inductor unit contains the primary consisting of copper coils 25 and iron core 26, see Fig. 4. The primary threads the secondary duct which, as disclosed in my Reissue Patent No. 22,602, dated February 13, 1945, is of the twin coil type and composed of two lateral channels 17, a center channel 18 and a horizontal channel 16 connected with hearth 1 by the channels 17, 18. Channel 16 is closed by refractory plugs 19.

A tubular spout or a metal discharge tube 20 is provided for the discharge of the metal from the pump. This spout projects with its lip end 21 from hearth 1 and is led with its lower end into groove 33 provided in the refractory of wall 3. A nozzle 22 is inserted into the lower end of spout 20; this nozzle is provided with a conical extension 23, see Fig. 4. The spout 20 reaches with this extension into center channel 18 and a small clearance is provided between the nozzle extension 23 and the channel. A short tube 24 is inserted into the end of nozzle 22. This nozzle arrangement serves the purpose of regulating or restricting the stream of metal discharged from the pump.

The installation of spout 20 entirely changes the above described two-stream metal movement from the ducts into the hearth and from the hearth into the ducts. The metal is not any more redrawn into channel 18 but flows unidirectionally from the hearth 1 through channels 17, channel 16 into channel 18 and is discharged through spout 20 into the molds, as shown by the arrows in Fig. 4.

As previously stated, a foremost requirement of the operation of this pump is the maintenance of level constancy in hearth 1. This level constancy is in accordance with the embodiment of my invention shown in Figs. 1 to 4 obtained by tilting the pump about the lip end of spout 20 through a small angle. The tilting axis is indicated in Fig. 2 by a dotted circle 30; the furnace is for this purpose tiltable supported in frame structure 29.

A hydraulic cylinder 31 is provided for the tilting of the pump; the piston of the cylinder is connected by arms 27 with inductor unit 32. A blower 28 is in the usual manner attached to the inductor unit and forms a part thereof. The hydraulic cylinder 31 is at its lower end rotatably supported on frame 29.

Fig. 4 shows on an enlarged scale the lower portion of the pump and the entry of spout 20 into center channel 18. The primary transformer unit consists in the usual manner of copper coils 25 and iron core 26; this primary unit threads channels 17, 18.

Fig. 2 shows the pump in its initial position. As soon as current is supplied to the coils 25 the metal will be forced through the lip end 21 of spout 20 into molds, which are not shown in the drawing; at the same time the pump is tilted by cylinder 31 about its lip end.

The operation of the hydraulic cylinder is automatically controlled in conformity with the metal discharge. The

pump is charged intermittently with a certain amount of metal. Before charging the pump it is tilted into the starting position, shown in Fig. 2. Immediately after charging metal and after the commencement of its discharge by supply of current to the coils 25 the cylinder gradually raises the rear portion of the pump. The supply of the operating fluid to the tilting cylinder 31 may for this purpose be controlled by a known metering device, which will allow a uniform and slow raise over a certain period of time; the idea is that the operator of the pump should not need to pay attention to the lifting apparatus, which will work automatically after a certain speed of tilting has been set; the tilting mechanism may for this purpose be provided with a customary stop and return valve.

As soon as the pump has reached its highest position it will upon operation of a customary stop valve fall back to the starting position. Hereupon fresh metal is charged; in this manner it is possible to keep a practically constant metal level in conformity with the discharge of the same.

The metal is pumped from the bottom of the molten bath and is therefore free from slags and impurities. Due to the triangular shape of hearth 1 that part of the metal holding space from which the metal is pumped has been greatly restricted. An accurate control of the casting temperature and great uniformity of the cast metal is accordingly obtained. Due to the inclined location of the inductor block 32 and of the melting channels 17, 18 and of tube 20 the inertia of the molten mass can be easily overcome during the pumping action; the current requirements are accordingly reduced and the economy of the induction pump is greatly improved; moreover, and due to the inclined location of tube 20 the last traces of non-uniformity of the metal flow are eliminated.

The control unit for use with this induction pump is shown in Figs. 7a, 7b; the unit may be encased in a door provided housing.

The furnace is provided with a two coil 25 primary capable of being connected either in series, parallel, or singly and a molten metal secondary, which consists of the two channels 17 permitting circulation of the molten metal and a center channel 18 fitted with a pipe 20, as described above. Hydrostatic pressure produced by the current flowing through the molten metal secondary causes the same to rise in the pipe and when the power is sufficiently high to be discharged from spout 20 which constitutes the pumping action. The hydrostatic pressure is proportional to the square of the current flowing in the center channel 18. The control unit may be provided with an ammeter to read the sum of the currents in the primary coils. This current is proportional to the current in the center channel, and hence is proportional to the square root of the hydrostatic pressure.

The furnace coils 25 may be connected in series for low power, used singly for medium power and may be connected in parallel for high power.

The metal level in the pipe which is located in the center channel is kept constant in low and medium power. This is effected by selection of the proper voltages with tap switches S1 and S2. If the metal level is kept constant then the metering of exact amounts of molten metal is secured when pumping.

An electric pyrometer 50 connected to a thermocouple is provided. Its purpose is to record temperature and, when the pumping unit is in automatic operation, to maintain close control over the temperature.

The normal power factor at which a furnace operates may be about 60%.

The wiring diagram of the unit for the control of the furnace operation will now be described.

The main line enters through the main disconnect switch MD. This switch may be manually operated by a handle attached to the control unit. Lines F1, F2 are

connected to the one coil 25, lines F3, F4 to the other coil.

The line then goes to the regulating autotransformer RAT. The transformer has two seven-position tap switches with taps at 230, 280, 320, 360, 400, 430 and 460 volts. These voltages give equal increments of power to the furnace coils.

The autotransformer may be connected by means of links shown in Figs. 8, 9 to correct for small variations in line voltage.

There are four two-pole 100 amp. contactors, C1, C2, C3 and C4 and one four pole 50 amp. contactor, C5.

C1 and C3 as well as C2 and C4 are mechanically interlocked in such a manner that when one of either pair is closed the other cannot close. The holding coils of C1 and C2 are connected in parallel and hence operate together. All five of the contactors are electrically interlocked by means of auxiliary contacts c1 to c5, as shown in the wiring diagram.

C1 and C2, which connect the coils in parallel for high power are connected to the 460 volt tap of the autotransformer. Contactor C5 connects the coils in series for low power, and is connected to tap switch S1 of the autotransformer. Contactors C3 and C4 enable to put either coil across the line, giving medium power, and are connected to tap switch S2.

The auxiliary control circuit is connected to the main line through the auxiliary disconnect switch AD. The voltage is then stepped down to 230 volts by the transformer AT.

With the main switch MD and the auxiliary switch AD closed and the autotransformer tap switches in the desired positions, power may then be controlled by means of the control switch CS. In its off-position all five contactors are open. In the low position contactor C5 will close, placing the furnace coils in series at the voltage determined by S1. With the control switch in medium power, contactors C3 and C4 will close alternately every two and a half minutes, controlled by the time switch TS1 which has a five minute cycle. When C3 is closed one furnace coil will be across the line and when C4 is closed the other coil will be placed across the line. The purpose of alternately energizing each coil is to prevent the metal from freezing in the furnace. In the automatic position medium power will be obtained when the temperature of the metal is too low and low power when the temperature becomes too high.

High power for pumping is obtained by means of the normally open push button switch PC located just below the control switch on the door of the unit. When the button is pressed the holding coils of contactors C1 and C2 are energized, closing the respective contactors and placing the furnace coils in parallel across the line. At the same time the holding coils of contactors C3, C4 and C5 are de-energized by the control relay CR2. In the event that any contactor sticks neither C1 nor C2 will be allowed to close due to a combination of mechanical and electrical interlocking.

The control unit is adequately fused for proper protection. There are two 200 amp. fuses MF in the main circuit. In the auxiliary circuit there are two 6 amp. 600 volt fuses AF1 before the transformer AT, and two 6 amp. 250 volt fuses AF2 on the 230 volt side of AT. The fuses AF2 are situated in such a manner that in the event of blowing the blower circuits will not be affected. The blower circuits are protected by special fuses having a long time lag, called fusetrans.

The only parts of the control circuit that will not be de-energized are the two blower circuits, the pyrometer motor and the time switch motor.

In parallel with the holding coil of the control relay CR2 is placed an electric counter EC. Every time the push button switch PC is pressed the counter will record giving the number of ingots made.

A further modification of my induction pump is shown in Fig. 3.

Here channel 17 and channel 18 have a different inclination. Whereas the center channel 18 is inclined, as shown in Figs. 1 and 2, the two lateral channels 17 have a greater angle of inclination relative to a horizontal plane or, in other words, the channel 18 is less inclined than the lateral channels 17.

Due to this different inclination the melting channels are much better accessible and the cleaning of the channels is accordingly facilitated.

Since the successful operation of this pump greatly depends upon the absence of slag particles and other impurities in the metal which is pumped through spout 20 the thus improved accessibility of the channels is of great importance for the performance of this invention.

The third modification of this electromagnetic pump, which is shown in Figs. 5 and 6, is of the stationary type. This pump is in most respects similarly built to the previously described embodiments and the same numerals are used to denote identical parts. A flow regulating and restricting tubular insert identical to insert 22 of Figure 2 also forms with this modification an important element of the invention.

In order to obtain the required substantial level constancy of the molten bath, this pump may be coupled with a metal melting and holding furnace; this combination is illustrated in Fig. 11 the melting and the holding furnace being connected with the pump by a launder 39. The head of metal is kept in this large melting furnace at a level which is most suitable for the operation of the pump. Fresh metal is charged into the large supply furnace at the ratio as it is pumped; by gradually charging the large capacity supply furnace a substantially equal level of the molten metal bath is obtained in the pump.

This pump may therefore be entirely closed by cover 12 which is also provided with a strip-shaped heating element 14. The triangular shape of the metal holding chamber 1 is unaltered and the chamber is housed by walls 2, 3, 5, 6 which are shaped to form a small bottom 4 and a small front face 19, where the opening 11 is provided for the emergence of spout 29 and its lip end 21 respectively. Inductor block 32 containing this primary transformer assembly and the secondary duct system of the twin coil type is attached to inclined wall 3; blower 28 is attached to the inductor block.

The pump is stationary and mounted for this purpose on a frame structure 35.

The pouring or discharging spout 20 reaches, as in the previous embodiments of this invention into channel 18 of the secondary duct system and protrudes with lip end 21 through opening 11 from the pump.

The successive pumping of the shots into molds may be effected by customary switches as also previously mentioned which are automatically operated in the usual manner. The metal is supplied through heated troughs from the large supply furnace; the troughs are connected with the inlets 36 and the metal flows from these inlets 36 through apertures 37 provided in walls 5, 6 into the metal holding chamber 1 of the pump.

By using a large capacity metal supply furnace, shown in Fig. 11, which is gradually charged and by also gradually supplying the metal to the holding furnace a satisfactory level constancy is secured in chamber 1 of the pump.

The above explained advantages derived from the triangular shape of chamber 1, from the inclined position of the secondary ducts and of spout 20 are also apparent in this stationary induction pump.

I claim:

1. An installation for the series production of mold castings comprising a frame structure, a molten metal holding chamber approximately triangular in vertical cross-section supported by said frame structure, two opposite lateral walls downwardly inclined towards each other and two opposite end walls enclosing said metal

holding chamber, an inductor unit attached to the outside of an inclined lateral wall, a secondary melting loop and a primary transformer assembly in said inductor unit and threading said secondary melting loop, a refractory tubular pouring spout inclined relative to a horizontal plane, located in said metal holding chamber and extending with its inner end into said melting loop and with its outer discharge end from said chamber.

2. In an installation according to claim 1, the secondary melting loop consisting of one duct spaced from said metal holding chamber and of three ducts communicating therewith, the center duct having a different angle of inclination than the lateral ducts.

3. In an installation according to claim 1 means to tilt the metal holding chamber about a horizontal axis extending through the end portion of said inclined tube for the purpose to maintain the molten metal in said chamber at a constant horizontal level.

4. In an installation according to claim 1 means to tilt the metal holding chamber about a horizontal axis extending through the end portion of said inclined tube for the purpose to keep the molten metal in said chamber at a constant level, said tilting means including a hydraulic cylinder rotatably mounted on said frame structure, a piston in said cylinder and arms fastened to said inductor unit and rotatably connected with the free end of said piston.

5. In an installation according to claim 1 said tubular pouring spout freely extending its outer discharge lip from said chamber to effect a free flow of the metal from said pouring spout.

6. In an installation according to claim 1, a cover for the metal holding chamber and an opening in said cover for the feed of the metal into said chamber.

7. In an installation according to claim 1, a tubular nozzle inserted into the inner end of said tubular spout and a conical extension at the end of said nozzle and entering the melting loop.

8. In an installation according to claim 1, a tubular nozzle inserted into the inner end of said tubular spout, a conical extension at the end of said nozzle and an inner tubular section entered into the end of said nozzle.

9. An installation for the series production of mold castings comprising a frame structure, a molten metal holding chamber supported by said frame structure, an inductor unit attached to the outside of said chamber, a secondary melting loop and a primary transformer assembly in said inductor unit, a refractory tubular pouring spout located in said metal holding chamber, being inclined relative to a horizontal plane and extending with its inner end into said melting loop and with its outer discharge tip from said chamber and tilting means operatively connected with said chamber to maintain an even horizontal level of the metal surface in the same end of the tip of said pouring spout.

10. An installation for the series production of castings comprising a frame structure, a molten metal holding chamber supported by said frame structure, an inductor unit attached to the outside of said chamber, a secondary melting loop and a primary transformer assembly in said inductor unit, a refractory tubular pouring spout located in said metal holding chamber, inclined relative to a horizontal plane, extending with its inner end into said melting loop and freely extending with its outer discharge lip from said chamber to effect a free flow of the metal from said pouring spout.

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