Jan. 5, 1937. J. R. WYATT 2,067,110

SUPERHEATING INDUCTION FURNACE

Filed March 29, 1934 2 Sheets-Sheet 1

Fig. 1.

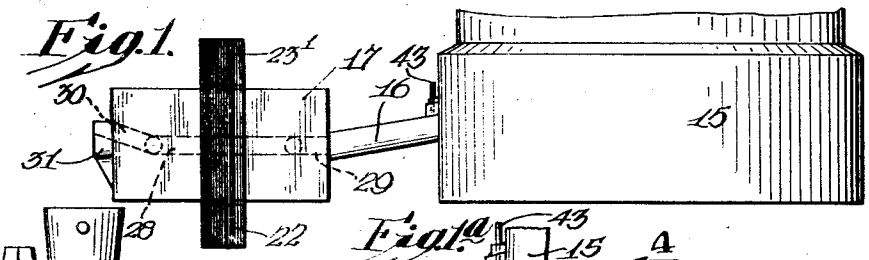


Fig. 1a.

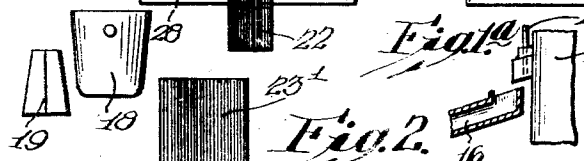


Fig. 2.

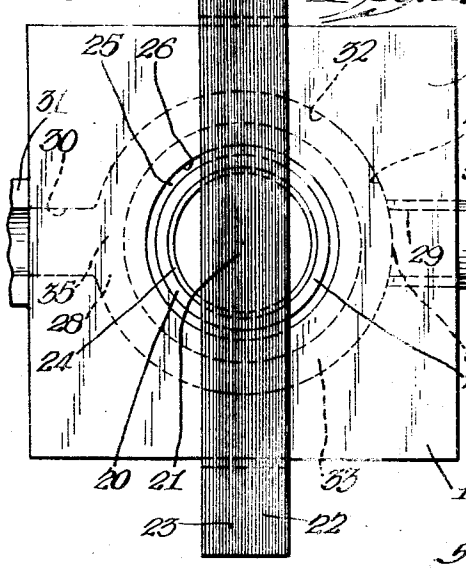


Fig. 3.

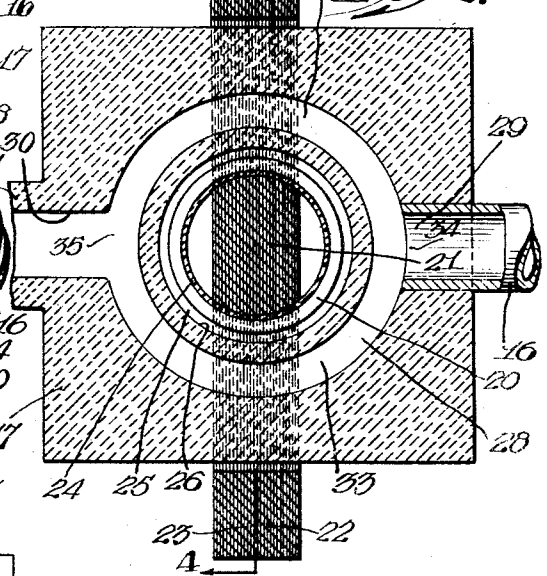
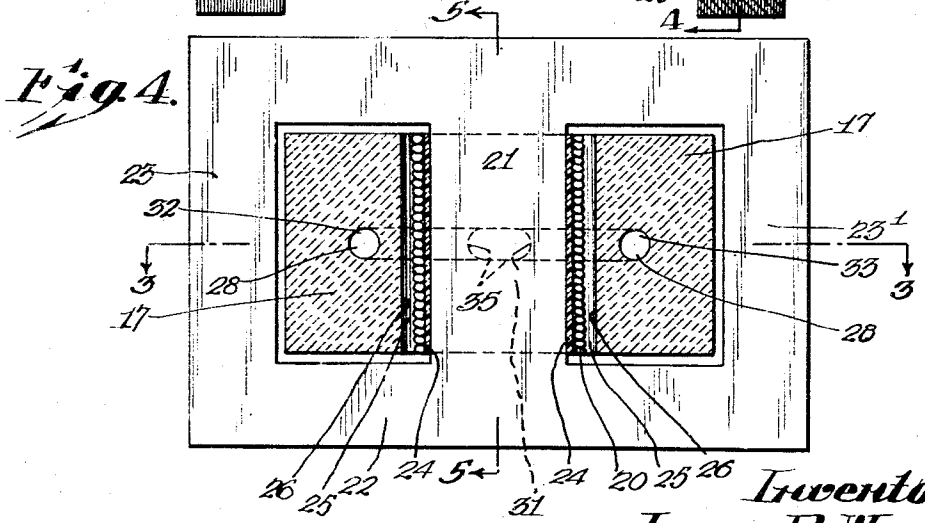


Fig. 4.



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Filed March 29, 1934 2 Sheets-Sheet 2

Fig. 5.

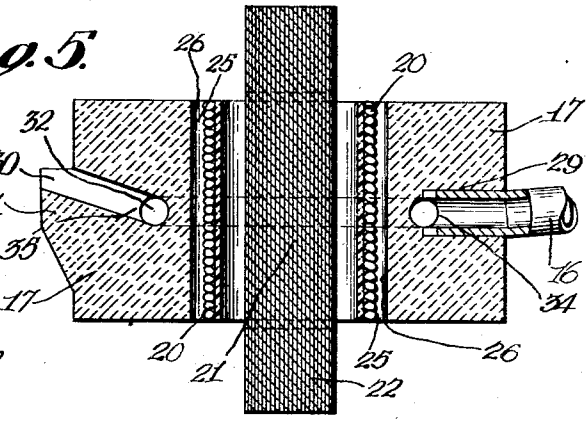


Fig. 5a.

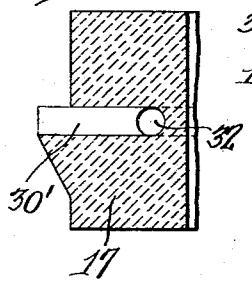


Fig. 6.

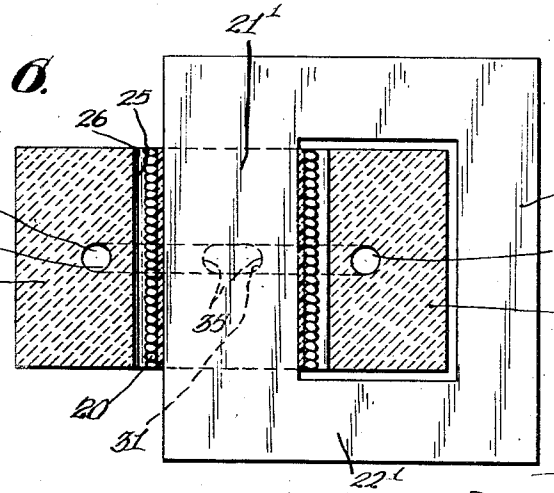


Fig. 2a.

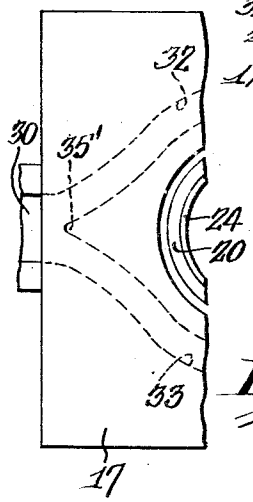


Fig. 2b.

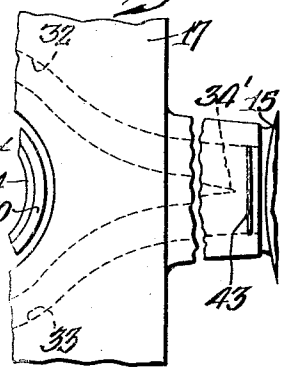
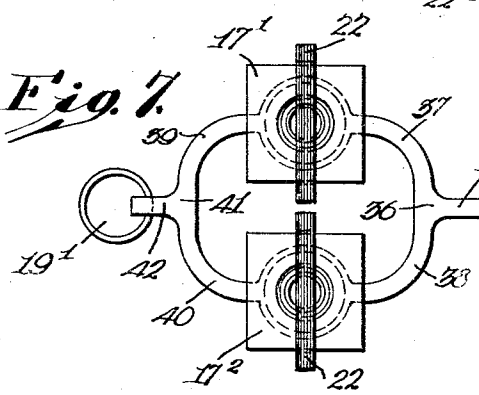


Fig. 7.



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UNITED STATES PATENT OFFICE

2,067,110

SUPERHEATING INDUCTION FURNACE

James R. Wyatt, Camden, N. J., assignor to Ajax Electric Furnace Corporation, Philadelphia, Pa., a corporation of Pennsylvania

Application March 29, 1934, Serial No. 717,994

13 Claims. (Cl. 13—2)

My invention relates to the superheating of molten metal preferably during pouring, either into a mold or into a ladle from which it is to be poured into a mold.

The main purpose of my invention is to pour the molten metal from a blast furnace, a cupola, or other container in which it has been melted, through passages subjected to high electromagnetic flux, either directly into the mold or ladle, or with so little storage between as to merely assist in unifying the flow. This permits melting within a blast furnace or a cupola by fuel combustion in which the expense of melting is the least, but where the expense of superheating is high, and electromagnetically superheating the metal from a temperature below that desirable for final pouring to its final pouring temperature or above, holding it after superheating where temperatures above final casting temperatures are attained.

A further purpose is to electromagnetically superheat molten metal while it is flowing from the place at which it has been little more than melted to the ladle or mold from which, or in which, it is to be cast.

A further purpose is to pass molten metal in parallel through curved lines of flow about the two sides of a transformer leg and preferably about a primary transformer winding to hug the transformer coil closely and at the same time be heated through secondary action while the metal is flowing through the passages.

A further purpose is to divide the flow of molten metal passing at relatively low temperature from a cupola or other initial point of melting and lead it continuously—that is, preferably without appreciable stoppage of its flow—about a transformer primary core, to a point of intended use, whereby the molten metal need not be raised to pouring temperature in the cupola, but can be given the necessary pouring fluidity and heating on its way through the divided channels where it is subject to close regulation both by speed of travel and rate of input to the transformer primary.

Further purposes will appear in the specification and in the claims.

My invention is directed not only to the methods or processes involved, but to structure showing one or more ways in which the methods or processes claimed can be carried out. Because of the conditions present in cast iron my invention finds its higher usefulness at the present time in the treatment of cast iron, but is not restricted to use upon this metal as it is of benefit also for any metal in which exact control of the temperature at pouring is desirable, or in which superheat for pouring or other purposes is better applied outside of the furnace of initial melting than inside it.

It is well to distinguish at this point between superheating and pouring temperature. There are a number of situations in which metal is superheated and subsequently allowed to cool before pouring, so that the temperature of superheating may be considerably above the pouring temperature.

From the metallurgical standpoint the principal advantages of superheating cast iron lie in the saving in time and in cost necessary to secure the proper condition for pouring and in the improved quality and greater uniformity of the product. By superheating, the same quality of iron is secured in less time. Stirring assists in this, but, independently of the stirring, superheating results in better quality of iron in less time than would be secured without superheating.

Superheating sometimes leaves a very desirable effect which persists after the superheated metal has solidified. As examples, a few instances may be cited in which superheating, as distinguished from mere pouring temperature, is of importance.

It has been observed that increase of the extent of superheating (without changing the pouring temperature) produces small graphite particles, better distribution of graphite particles, and improved physical properties in gray cast iron. Tanimura, Influences of cooling velocity and melting temperature on the graphitization of cast iron, 6 Memoirs, College of Engineering, Kyushu Imperial University, Japan (No. 2, 1931); Marbaker, High-test gray cast iron—European developments, 37 Transactions of the American Foundrymen's Association (1929) 405.

The difficulty in duplicating results in a gray iron foundry has been due largely to not heating the iron sufficiently to bring about complete solution of the carbon and the desired degree of homogeneity.

Superheating cast iron increases its homogeneity and therefore produces a more uniform product. Bromer, Electric-melted iron for cylinder castings, 39 Transactions of the American Foundrymen's Association (1931) 585, 593, 594.

The extent of formation of iron carbide in iron increases and then decreases with the tem-

perature of superheating to which the metal is subjected, the critical point being about 2730° F. for 0.06 per cent silicon. The material is likely to be carbidic if cooled from below this temperature and graphitic if cooled from above this temperature. Increase in silicon lowers the transition point; Marbaker, High-test gray cast iron—European developments, 37 Transactions of the American Foundrymen's Association (1929) 409, 410.

After superheating above the critical point, graphite separates in the cooling iron from an infinite number of tiny nuclei and the resultant graphite crystals are smaller, more numerous and more uniformly distributed than would be true for a lower superheating temperature. Superheating assists in obtaining uniformity in hardness as it causes the graphite to divide more finely and also distributes it more uniformly. The control of carbon and silicon contents is easier where superheating is used.

Increase of the superheating temperature shortens the malleableizing time, favors the formation of smaller graphite particles and improves the physical properties of white cast iron. White and Schneidewind, Effect of superheat on annealing of malleable iron, paper delivered before American Foundrymen's Association, at Chicago, June 21, 1933.

My invention is intended to facilitate superheating and the control of the extent of superheating and to provide a maximum of flexibility coincidental with a maximum of temperature for the iron. I provide also for complete superheating during the flow of the molten metal through the electromagnetic superheater which may be an element of an electric furnace.

In the drawings I have preferred to illustrate a few forms only among the many in which my invention may appear, selecting forms which are practical, efficient and quite reliable, but which have been chosen chiefly for their suitability in explaining the invention.

Figure 1 is a fragmentary side elevation of my invention.

Figure 1*a* is a fragmentary side elevation partly in section showing a modification of the structure of Figure 1.

Figure 2 is an enlarged top plan view of a part of Figure 1.

Figures 2*a* and 2*b* are fragmentary top plan views showing modifications of the structure of Figure 2.

Figure 3 is a section of Figure 2 parallel to the plane of the paper, corresponding to a section upon the line 3—3 of Figure 4.

Figure 4 is a section upon the line 4—4 of Figure 3.

Figure 5 is a section taken upon the line 5—5 of Figure 4.

Figure 5*a* is a fragmentary section showing a modification of the structure of Figure 5.

Figure 6 is a form corresponding generally with Figure 4, but modified to show a different transformer.

Figure 7 is a top plan view of a form corresponding generally with those seen in Figures 1 to 5 and in Figure 6, respectively, but having duplicate paths and multiphase operation.

In the drawings similar numerals indicate like parts.

Taking up first the form of Figures 1 to 5, inclusive, 15 indicates any melting furnace adapted to melt metal in bulk and preferably a blast furnace or a cupola, or other fuel fired furnace, from which molten metal is discharged through a launder 16 at a temperature lower than the superheating temperature desired for the molten metal.

In my preferred form this molten metal is run continuously from the furnace 15 by the launder 16 through a superheater 17 and into a ladle 18 which pours into a mold 19. During the flow of the metal it is continuously and considerably superheated by electric current developed within the molten metal as a secondary by an alternating current primary. The current may be of commercial frequency, passed through a primary winding 20 wound upon the interior leg 21 of a suitably laminated transformer core 22. The winding 20 may desirably be insulated with heat resisting enamel. The transformer is shown in Figures 1 to 5, inclusive, to be of shell type, provided with return legs 23 and 23'. The primary winding 20 is preferably formed as a single layer of turns upon insulation 24 which surrounds the interior transformer leg 21, and the primary winding may be spaced as at 25 from the inside 26 of the refractory 27 within which the branched channels for the molten metal are formed. The space 25 may carry a blast of air for cooling purposes.

My preferred form of superheating channel surrounds the primary winding as closely as may be, with proper cooling space and a reasonable thickness of refractory wall. The channel 28 connects with the launder 16 by an inlet opening 29, and discharges through an outlet opening 30, having a spout 31. The branches 32 and 33 which separate at 34 join again at 35.

The preferred flattened character of the inlet and outlet openings 29 and 30 will appear from comparison of the cross-sections seen in Figures 3 and 4.

Though the mere flow of the metal from an elevated launder may afford sufficient head to pass the molten metal through the superheating channel, it is desirable to use a closed launder so that the hydrostatic head of the metal in the furnace 15 will maintain pressure upon the molten metal flowing through the superheating channel.

The hydrostatic head of the furnace 15 transmitted through the closed launder not only assists in giving a quick even flow of molten metal through the superheating channel, but performs a very important additional function. It is to be noted that the superheating channel is closed or submerged, so that pressure can be maintained upon it. With the high energy input necessary to superheat a rapidly moving stream of molten metal, pinch effect will "pinch off" or interrupt the stream of molten metal and break the secondary circuit in many instances unless the molten metal is under pressure. The hydrostatic pressure from the furnace 15 prevents breaking of the secondary circuit due to pinch effect as long as the pinch pressure is less than the hydrostatic pressure, and accordingly the hydrostatic pressure should be determined by the intended energy input, which controls the pinch pressure for the particular superheater.

For much the same reason that the hydrostatic head at the furnace (inlet) end of my superheater is desirable to make it possible to use a higher rate of heating in the superheater without trouble from pinch effect, it is desirable also to prevent blowing out of the metal at the pouring spout from this cause since the pinch effect operates in both directions.

Where the lower rate of heating intended or larger cross section make such a head at the pouring spout unnecessary the outlet may be at the same level as the superheater and such a construction is shown in Figure 5*a*. The pouring spout **31** is here horizontal.

In Figures 1 and 5 I have attempted to differentiate between the inlet head and the head at the pouring spout, making the head at the pouring spout lower than that shown within the launder **16** for the purpose of pointing out diagrammatically that at the inlet end a head is required to cause movement through the superheater which head is additional to that required to prevent interruption of the circuit by pinch effect. For this reason the diagrammatic illustration of the pouring spout head is shown as equivalent to a part only of the head given in the launder **16**.

Where the metal is to be passed through the superheater continuously, i. e., is continuously to be in motion, the point **35** at which the divided paths of the superheater meet may be at some distance from the outlet of the pouring spout (as in Figure 2) without danger of trouble from chilling.

If the molten metal is to be held molten in the superheater, the secondary current must pass through substantially all of it and a pouring spout or launder carrying metal located at any considerable distance from the superheater divided channels would be likely to give trouble by chilling. For this reason I have shown in Figures 2*a* and 2*b* fragmentary diagrammatic illustrations in which the divided paths separate substantially at **35'** at the furnace gate and recombine at **34'** substantially at the outlet of the pouring spout.

By extending the division to cover the entire or nearly the entire distance from the furnace to the outlet of the pouring spout the secondary current is passed through substantially the entire path of the molten metal and chilling is prevented.

If current is not to be maintained in the superheater it should be capable of being emptied.

It will be obvious that any mechanism by which the head may be maintained and the superheater may be tilted will serve the purpose. In the instant case the upper end of the launder **16** may constitute a trough as in Figure 1*a* receiving the molten metal from the cupola outlet leaving the superheater free for such movement and replacement as may be desired. In this event the entire head relied upon must be within the launder.

Where the pouring outlet is horizontal the metal will flow out freely.

Where it is the intention to keep the current on during intervals between use of the superheater the launder may be connected fixedly with the furnace to allow use of head within the furnace but in this case—and in any case—some means of stoppage of flow within the launder must be provided. I have shown this diagrammatically by gate **43**.

In order that the power factor of the superheater may be high, the cross-section of the channel must be reasonably small so that the resistance of the secondary circuit will be relatively high.

The path of the branched channel is as close as reasonably possible to the primary winding **20** and to the interior leg **21** of the transformer core **22**, in order to obtain close coupling. In the form of Figures 1 to 5, inclusive, there is a complete magnetic circuit through the core and between the branches **32** and **33** of the channel.

In operation, the molten metal, which will ordinarily be melted in the furnace **15**, is carried by the closed launder **16** into the inlet opening **29** of the electromagnetic superheater. The molten metal divides at the point **34** and flows in parallel through the branches **32** and **33** to the point **35** where the branches join. At the point **35** the molten metal enters the outlet opening **30** and flows from the spout **31** into the ladle **18**, which pours into the mold **19**.

While the continuously flowing molten metal is passing through the channel branches **32** and **33**, secondary current is induced in the metal by the primary winding **20**, which sets up flux in the transformer core **22**. The secondary current flows around the circular channel, superheating the molten metal in the channel. The superheating progresses continuously notwithstanding that metal enters the inlet opening **29** and leaves the outlet opening **30** of the channel during the operation of the superheater. Thus the superheater acts upon flowing metal or metal in transit to the point of casting.

The ladle **18** is not essential, and in fact I show in Figure 7 pouring directly from the superheater into the mold **19'**. The ladle **18** performs several desirable functions, however. It receives the superheated molten metal while molds are being changed, and, for a time, takes up the additional flow in case the rate of flow of the molten metal from the melting furnace is faster than the rate of pouring into the final mold. It also receives the molten metal from the launder and channel during interruption of the operation, after the flow of metal from the furnace **15** has been cut off in any well known manner, and makes it possible to recharge from the ladle into the furnace **15** the metal drained from the superheater and not required to fill the last mold.

The ladle **18** (or a holding furnace to perform its function) also offers a distinct metallurgical advantage in some instances, by cooling the molten metal from the superheating temperature down to the pouring temperature, where it is not desirable to pour at the temperature of superheat. In certain cases, the molten metal is superheated for any suitable purpose, such as one of the purposes referred to above, but the superheating temperature is too high for proper pouring. The superheated metal may then be held in the ladle until it cools to a satisfactory pouring temperature, at which time it may be poured.

While I prefer to use a shell type transformer core, as shown in Figures 1 to 5 inclusive, a core type transformer core may be used as shown in Figure 6. In this figure a core type transformer core **22'** has an interior leg **21'** and a return leg **23'**. The winding and channel construction are the same as that employed in the form of Figures 1 to 5, inclusive.

The operation of the form of Figure 6 is the same as the operation of the form of Figures 1 to 5, inclusive, except that there is a higher magnetic field effective to induce secondary current in branch **33** of the superheating channel than that effective to induce secondary current in branch **32**. The current originated in one branch must flow through the other also to complete the secondary circuit.

In Figure 7 a superheating furnace, of the

type which may be used for polyphase operation, is shown. The launder 16' separates at 36 into two branches 37 and 38, one of which supplies molten metal to a superheater 17', which may be identical with the superheater shown in Figures 1 to 5, inclusive, and connects to one phase of a two phase source, and the other of which supplies molten metal to a similar superheater 17^2, which connects to the other phase of the two phase source. The molten metal from the superheaters 17' and 17^2 enters conduits 39 and 40 which join at 41 near the outlet opening 42.

The operation of the form of Figure 7 is similar to the operation of the other forms. Molten metal from a blast furnace, cupola or other suitable furnace, preferably under considerable pressure due to the head of molten metal, enters the launder 16', divides at 36 into the branches 37 and 38, flows continuously through the parallel branches of the superheaters 17' and 17^2, where it is superheated as it flows along, leaves by the conduits 39 and 40, joining at 41, and discharges from the outlet opening 42 into the mold 19'.

The electromagnetic superheating obtained in the present invention is particularly desirable because it produces superheating quickly, as the molten metal flows to the point of casting, and therefore avoids heat losses and metal losses and the destructive action on the furnace which would be present in case the superheating were attempted in the blast furnace, the cupola or in some other furnace which might be employed for the purpose.

While my invention may be best suited to superheating cast iron it is also applicable to steel, as for example to secure uniformity of temperature among Bessemer converter heats, or to nonferrous metals, for instance to reduce metal losses while superheating to obtain the proper pouring temperature.

The superheater of my invention produces thorough mixing of the metal due to the agitation accompanying flow through the superheater channel. This is desirable to homogenize the metal.

An important advantage of my invention is the economy with which superheating is obtained, since the initial heating efficiency is very high, as the heat is actually developed in the molten metal itself, and since the molten metal is available for casting or other use immediately after superheating, so that it is not necessary to make up for heat losses while holding the molten metal at the temperature of superheat.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. The method of superheating molten metal, after it has left a furnace in which the molten metal is contained, which consists in progressing the metal wholly outside the furnace, while fully molten, subsequent to any smelting and subsequent to any refining action, as a continuously flowing unidirectional stream of a cross section having substantial resistance through an inductive heating magnetic field effective for the desired superheating while the molten metal is in motion from the furnace in which the metal was melted to the point of use, thus inducing a secondary current within the stream, and in maintaining a substantial hydrostatic head of molten metal on the stream to avoid interruption of operation due to pinch effect.

2. The method of superheating molten metal, after it has left a furnace in which the molten metal is contained, which consists in progressing the metal wholly outside the furnace, while fully molten, subsequent to any smelting and subsequent to any refining action, in a stream of cross section having substantial resistance through an inductive heating magnetic field effective for the desired superheating while the molten metal is in motion from the furnace in which the metal was melted to the point of use, in electrically connecting points on the stream respectively behind and forward of the magnetic field through molten metal, inducing a secondary current within the stream, and in maintaining a substantial hydrostatic head of molten metal throughout the portion of the stream under induction heating to avoid interruption of operation due to pinch effect.

3. The method of superheating molten metal after it has left a fuel furnace while pouring it fully molten from the fuel furnace to a ladle or mold within which or from which it is to be cast, which consists in utilizing the fully molten metal in the fuel furnace to give a head and maintaining the pressure from the head while dividing the paths of the molten metal wholly outside of the fuel furnace and maintaining the head also throughout the divided paths, re-combining the divided paths for the pouring, in passing the molten metal hydraulically in parallel through the paths from the point of dividing to the point of re-combining, and, while the paths are divided, electromagnetically heating the molten metal by inducing secondary current throughout the divided paths from division point to meeting point in series as the metal is flowing, producing superheating of the molten metal by the intensity of the induced current while the molten metal is in flow in the paths.

4. The method of superheating molten metal after it has left a furnace in which the molten metal is contained, using the secondary effect of an electric current passing about a transformer core, which consists in flowing the metal wholly outside the furnace and while fully molten, into close proximity to the core, while maintaining about the core an alternating current effective to superheat the molten metal while it is in flow, in dividing the metal into unidirectional streams passing in parallel about the core at substantially the same distance therefrom, in uniting the streams and in pouring the molten metal continuously as it is superheated.

5. The method of progressively superheating molten metal, after it has left a furnace in which the molten metal is contained, which consists in maintaining a head of molten metal, flowing a submerged stream of molten metal wholly outside of the furnace and while fully molten, to and in parallel about the core of an electromagnetic transformer, while maintaining about the core an alternating current effective to superheat the molten metal while it is in flow and uniting the divided parts of the stream of molten metal, in maintaining the flow about the core substantially the same distance from the core and in pouring the molten metal as it is superheated.

6. The method of making castings of superior quality, which consists in producing fully molten metal in one furnace under fuel-fired conditions, in tapping off the molten metal from said furnace, in dividing the tapped molten metal wholly outside said furnace into submerged branching unidirectional streams, in subsequently uniting

a plurality of unidirectional streams, in maintaining a substantial hydrostatic head of molten metal throughout the branched streams to avoid interruption of operation due to pinch effect, in inducing alternating current in the molten metal circuit formed by the subsequently uniting branched unidirectional streams continuously as the molten metal flows toward the point of casting and effective to superheat the molten metal while it is in flow, in cooling the united stream of molten metal to a pouring temperature substantially below the superheating temperature and in later casting the united stream of molten metal which has undergone superheating and cooling.

7. The method of making metal castings of superior quality, which consists in producing fully molten metal in one furnace under fuel-fired conditions, in tapping off the molten metal from said furnace, in continuously flowing the molten metal in submerged unidirectional streams of cross section having substantial resistance, toward the point of pouring, in maintaining a substantial hydrostatic head of molten metal throughout the branched streams to avoid interruption of operation due to pinch effect, in inductively superheating the molten metal wholly outside said furnace while it is flowing to the point of pouring and at the intended rate of pouring, in cooling the united stream of molten metal to a pouring temperature substantially below the superheating temperature and in pouring the molten metal after it has undergone superheating and cooling.

8. A fuel melting furnace, a closed launder connected therewith at the point of tapping the fully molten metal therefrom, walls forming a divided closed channel which is entirely filled with molten metal during the operation, connected with the launder at the point of division of the channel and re-connected to feed into an outlet opening, the metal in the channel forming a complete metallic circuit, and a transformer leg and primary thereabout enclosed by the channel, the level of molten metal in the fuel-fired furnace being at all times during the operation of the launder substantially above the outlet opening, whereby the molten metal within the fuel-fired furnace provides a head for the metal in the channel and is superheated inductively wholly outside the fuel-fired furnace.

9. In a metallurgical apparatus, a furnace adapted to produce molten metal, an electric induction superheater wholly outside said furnace and substantially free from smelting and from refining action, comprising walls forming a charging opening, walls forming a discharge opening, walls forming a plurality of submerged channels communicating with the charging opening at the inlet side and communicating with the discharge opening at the outlet side, the channels being entirely filled with molten metal during operation, and the metal in the channels forming a complete metallic circuit, a launder connecting the tap opening of said furnace with the charging opening of the superheater, the level of molten metal in the furnace being above the level of the superheater, a core surrounding one of the submerged channels and a winding around the core, whereby molten metal is superheated outside of said furnace after it has left said furnace and while it is in flow.

10. In a metallurgical apparatus, a fuel-fired furnace adapted to produce molten metal, an electric induction superheater wholly outside said furnace and substantially free from smelting and from refining action, comprising walls forming a charging opening, walls forming a discharge opening, walls forming a plurality of submerged channels communicating with the charging opening at the inlet side and communicating with the discharge opening at the outlet side, the channels being entirely filled with molten metal during operation, and the metal of the channels forming a complete metallic circuit, a launder connecting the fuel-fired furnace with the charging opening of the superheater, the launder being not lower than the bottoms of the superheater channels, a core surrounding one of the submerged channels and a winding around the core, whereby molten metal is superheated outside of said furnace after it has left said furnace and while it is in flow.

11. In a metallurgical apparatus, a fuel-fired furnace adapted to produce molten metal, an electric induction superheater wholly outside said furnace comprising walls forming a charging opening, walls forming a discharge opening, walls forming a plurality of submerged channels communicating with the charging opening at the inlet side and communicating with the discharge opening at the outlet side, the channels being entirely filled with molten metal during operation, a closed launder connecting the fuel-fired furnace with the superheater, there being gravity flow through the launder and superheater from the fuel-fired furnace and the level of molten metal in the fuel-fired furnace being substantially higher than the level of molten metal in the superheater, a core surrounding one of the submerged channels, and a coil around the core, whereby a hydrostatic head of molten metal from the fuel-fired furnace is maintained on the superheater to prevent interruption of the circuit due to pinch effect and molten metal is superheated outside of said furnace after it has left said furnace and while it is in flow.

12. An induction electric furnace comprising a launder forming both a passage and a hydraulic head, a submerged divided channel for which the launder forms the head, the channel being entirely filled with molten metal during operation, a pouring spout into which the flow from the divided channel is guided and which also affords hydraulic head to the divided channel, a transformer having a leg enclosed by the divided channel and primary alternating current supply for the transformer leg.

13. An induction electric furnace comprising a launder forming both a passage and a hydraulic head, a submerged divided channel for which the launder forms the head, the channel being entirely filled with molten metal during operation, a pouring spout into which the flow from the divided channel is guided and which also affords hydraulic head to the divided channel, a transformer having a leg enclosed by the divided channel and primary alternating current supply for the transformer leg, part of the hydraulic head at the launder and pouring spout ends being formed by the ends of the divided channel.

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