June 1, 1943. J. R. WYATT 2,320,692

INDUCTION FURNACE

Filed Sept. 19, 1941 2 Sheets-Sheet 1

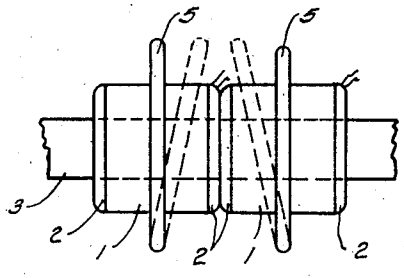


FIG. 2

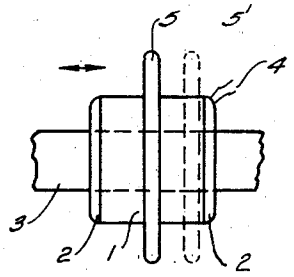


FIG. 1

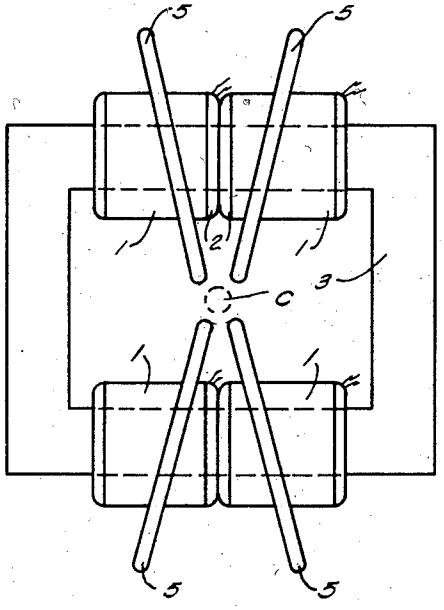


FIG. 5

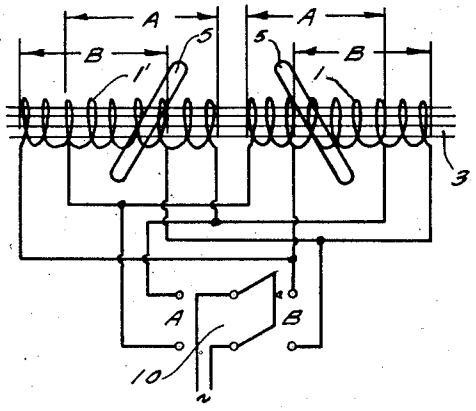


FIG. 6

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INDUCTION FURNACE

Filed Sept. 19, 1941 2 Sheets-Sheet 2

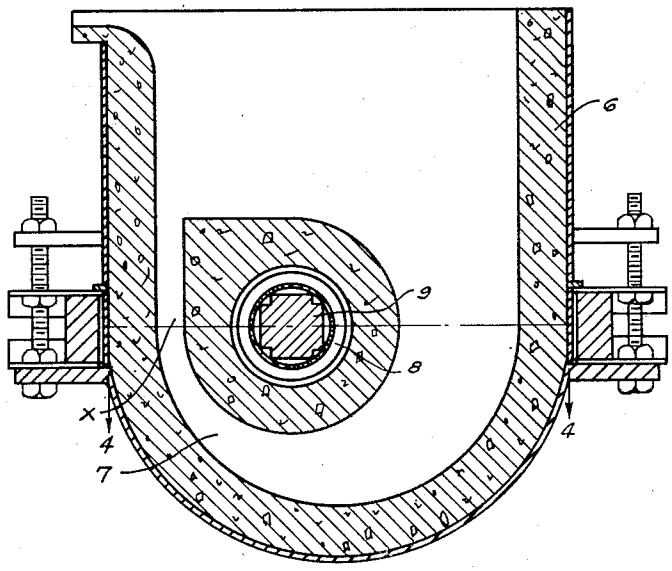


FIG. 3

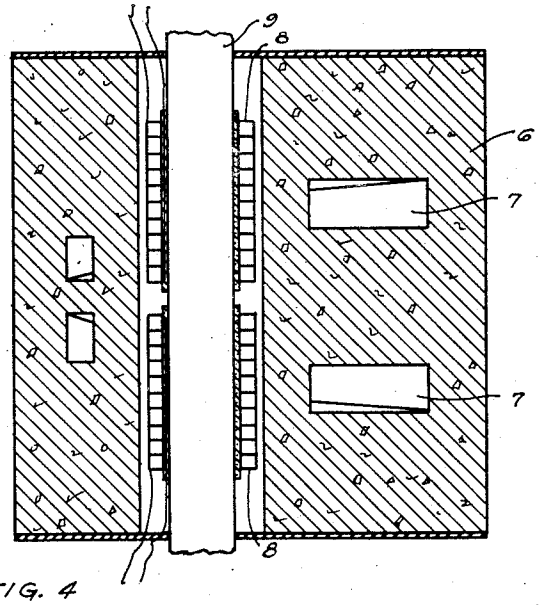


FIG. 4

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Patented June 1, 1943

2,320,692

UNITED STATES PATENT OFFICE

2,320,692

INDUCTION FURNACE

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Application September 19, 1941, Serial No. 411,461

7 Claims. (Cl. 13—29)

This invention deals with electric furnaces of the submerged resistor type and has for its purpose the improvement in circulation of molten metal in the melting channels of such furnaces.

A purpose of the invention is to provide a furnace of the class described having plural primary coils and plural melting channels or secondary loops so arranged on a common iron core assembly that the repulsion force due to end effect on the melting channels by their respective primary coils and the attraction forces due to interaction of adjacent melting channels on each other can be superimposed to create an enhanced and controllable pressure differential on molten metal in the respective melting channels for circulating same.

A further purpose is to provide a furnace of the class described having a strong unidirectional circulation in the melting channels.

A further purpose is to provide a furnace of the class described in which the degree of stirring may be controlled as a function of the way in which the lining is formed or by variation in the electrical connections to the primary coils or by variation of the location of the primary coils with respect to the melting channels.

Further purposes will appear in or be evident from the specification and the claims.

Figs. 1, 2 and 5 are diagrammatic representations of the principal elements involved in a furnace of the type described, and are used in conjunction with the description to illustrate the effect on the circulation forces of the relative location of secondary loops with respect to the primary coils.

Figs. 3 and 4 are cross section elevation and plan views of a furnace built in accordance with the present invention.

Fig. 6 is a wiring diagram showing secondary loops in diagrammatic form and is used in conjunction with the description to show how circulation control may be obtained electrically by varying end effect reactions between primary and secondary loops.

The type of furnace to which the present invention is applied is well known to the industry and has been amply described in previous patent files. Applicant's patents U. S. 1,201,671 and Re. 16,967 are referred to. The present invention is an improvement over the types heretofore described.

The submerged resistor furnace comprises a hearth for holding molten metal, a depending melting channel or secondary loop opening into said hearth and adapted to surround an iron core and primary inducing winding. In operation, when the primary winding is excited current is induced into metal in the melting channel which heats same and which because of the electrical repulsion and pinch effect forces ejects the metal from the melting channel into the hearth proper and around colder metal in that portion of the furnace.

As hot metal is expelled from the melting channel a circulation is set up and colder metal is supplied to the channel.

The circulation of metal from and to the melting channel is a function of many variables and most of the patents which have been issued for this type of furnace have dealt with methods for changing and varying the type or degree of circulation. If circulation is sluggish the amount of power which can be taken care of by the melting channel is limited. If the metal is heated more rapidly than the heat can be distributed to the metal in the hearth proper a hot spot will result in the melting channel and the furnace will fail.

The most successful design which has heretofore been developed is one in which a two way circulation takes place. The legs of the melting channel meet at a point low in the furnace and the design is such that a strong circulation takes place upward on the outside portion of each leg and downward on the inside portion. Circulation in the two legs is vigorous and extends almost to the low point.

It has been the goal of designers of furnaces of the submerged resistor type to design a furnace wherein the metal in the melting channel can be made to flow in a unidirectional manner. U. S. Patent Re. 16,967, above referred to, probably describes the best attempt made thus far to achieve this, but although a unidirectional circulation has been achieved it has not yet been made sufficiently vigorous for practical fast melting operations.

In the present specification applicant describes an improvement over the older methods whereby he is enabled to obtain a much better control over the two way stirring and whereby, if desired, he can obtain a very vigorous unidirectional circulation; an improvement which he believes will contribute materially toward the development of larger and faster melting furnaces. As the coil spacing and forces for unidirectional stirring are more complex than for the ordinary two way stirring most of the description will be directed to the unidirectional stirring effect.

A discussion of the forces involved which applicant utilizes to produce a strong unidirectional circulation or flow in the melting loop of a submerged resistor furnace follows:

Referring to Fig. 1, a primary coil 1, having an insulating sleeve and end pieces 2, surrounds an iron core member 3. Leads 4 connect the primary coil to a source of alternating current power, not shown. A secondary loop 5 is adapted to surround the primary coil and core and represents what would be the melting channel in an actual furnace. In tests made by applicant this loop comprised a single turn of heavy copper tubing adapted with water cooling means so that the mechanical forces involved could be studied without overheating of the parts. When the secondary loop is placed in the position shown about the middle of the primary coil no mechanical forces are evident. There is of course a mechanical force in a direction radially out from the axis of the primary coil but this is equal in all directions. As the secondary loop is moved toward the end portion of the coil as at 5' there is a very strong mechanical force tending to push it entirely off of the end and out of the electromagnetic field of the coil. This force is exerted at either end of the primary coil even though the secondary loop is still linked electromagnetically by the iron core.

If the secondary loop 5 is moved so that one part of it is near the end of the primary coil and another part is near the center of the coil the mechanical force set up in it will tend to be great in the direction of the axis of the coil where it is near the end of the coil and will be low where it is near the center of the coil.

If two secondary loops are put close together around a single primary coil a mechanical force is exerted which tends to pull them together. This is due to the proximity effect or reaction of the secondary electromagnetic fields around conductors carrying current in the same direction.

In Fig. 2 two secondary loops 5 are adapted to be placed around two electrically identical primary coils 1, having respective end parts 2 and a common iron core 3. When the loops are placed near the centers of their respective primary coils no mechanical force due to end effect is noticeable. There is some end effect on each loop due to the adjacent primary coil but this force is very little beyond the end of the coil and can be disregarded. Similarly, when the secondary loops are near the mid points of their respective coils the effect of one loop on the other is negligible because of the distance between them. This force also can be disregarded.

In the instance described with reference to Fig. 2, it should be noted that even though the respective primary coils are electrically identical and even though they are placed very close together the leakage fields about each are so great that the combined effect as regards mechanical forces set up in the secondary loops is about the same as for two widely separated single coil assemblies. It is the utilization of this characteristic which forms the basis of applicant's present invention, as by combining the end effect repulsion and the proximity effect attraction of the two secondary loops he has been able to obtain a considerably greater mechanical force and a better method of controlling that force than has heretofore been described, whether the desired stirring is unidirectional or two way.

In Fig. 2, when the secondary loops 5 are in the positions shown by the solid lines, each absorbs power from its primary coil much as in the standard single coil furnace. The only forces exerted are in a radial direction from the axis of the core. The reactions on the secondary loops from the adjacent primary coils and the reactions between the secondary loops themselves are practically negligible. The total results are quite similar to what would be expected if the two coils were made into one continuous coil threading the two secondary loops.

If the two secondary loops are brought together near the point where the two primary coils meet and as they approach each other over the ends of their respective coils, end effect on each secondary loop, by its primary coil, begins to become evident and the loops are vigorously pushed toward each other. As they approach each other the proximity effect due to the reaction of each loop on the other becomes effective and the loops are also pulled together by this force. By this construction the repulsion and attraction forces are superimposed and a very strong total force is exerted tending to hold the secondaries together. Both forces are of a major nature and even with the simple apparatus used in test the force exerted was so strong that one could not move the loops apart or hold them apart without mechanical aids.

Where two such secondary loops are energized by a single primary coil, no end effect forces are evident and the attraction of each loop by the other, while as great as in the two coil instance, is not nearly so great as the combined forces obtainable, and cannot be controlled as can the two coil effect.

If the two loops of Fig. 2 are placed in the positions shown by the dotted lines the end and proximity effects are great where they are close near the ends of their respective primary coils but are low or negligible where they are spaced near the centers of their respective primary coils.

The mechanical forces which have been described with reference to Figs. 1 and 2 can be measured but their effect on the circulation of metal in the melting channels of a submerged resistor furnace does not become evident until the loops are opened and arranged as in an actual furnace.

In Figs. 3 and 4 a melting furnace is shown in which the mechanical forces heretofore described are incorporated. In these figures applicant has provided a hearth having refractory walls 6, secondary loops or melting channels 7, in the lower part of the furnace and primary coils 8 surrounding an iron core assembly 9. As in the dotted lines in Fig. 2 the melting channels or secondary loops 7 are placed close together and near the ends of their respective primary coils at one side of the furnace and far apart or near the mid portions of the same coils at the other side of the furnace. They are here shown as rectangular tubes having a smaller cross sectional area where they are closer together than elsewhere, although this is not a primary consideration. Another feature of the construction as shown, which is desirable but not required, is that the melting channels or secondary loops are spaced further from their respective primary coils at the point where they are close together and join the furnace hearth.

The usual appurtenances which are customary for a furnace of this type such as power supply, switches, casings, support members, trunnions for tilting the furnace, etc., have been omitted

from the drawings to avoid confusion. It is assumed that such features are well known to those skilled in the art and need not be considered in this specification.

With the construction shown in Figs. 3 and 4, the primary coils when energized will induce current which will flow through the metal in the secondary loops and the hearth. Because of the shapes of the loops this current will be crowded in the restricted portions, and be less dense elsewhere in the loops and hearth. The electromagnetic fields set up about the primary coils and secondary loops will be greatest and the reactions will be greatest where these restricted portions are close together.

A maximum pressure will be produced at the point where the loops are placed close to each other which is due to the superimposing of the following forces—the end effect of each primary coil on its secondary loop tending to push the metal in the two loops toward each other; the proximity or attraction force due to the reaction of each secondary loop on the other tending to pull the metal in each loop toward the other and adding directly to the aforementioned end effect; the repulsion effect due to reaction between each secondary loop and its primary coil, tending to force the metal radially away from the transformer axis; the pinch effect force due to the current induced into each secondary loop by the primary coils and tending to force the metal in both directions along the loop from the point of greatest current concentration, and the funnel effect due to unequal distribution of current in a cone shaped inductor tending to cause the metal in the loop to flow along the center of the loop section from the restricted point toward the less restricted points. Other forces such as motor effect due to reaction on the secondary loops by the primary coils and by other parts of the secondary loop itself may be utilized. That these forces are of a definite and useful nature is due primarily to the superposition on the other forces of the forces due to end effect, which heretofore have not been considered in the construction of submerged resistor melting furnaces.

In the furnace described the forces combine to move the liquid metal from the hearth through the melting or secondary loops and back into the hearth. The direction of circulation is counterclockwise from the section of greater to sections of lesser pressure. In the instance cited, there will be some tendency for and possibly some eddy flow of molten metal in a clockwise direction, or upward from the point in the channel or loop marked X, due to the pinch effect force, but substantially all of the other forces, including an equal component of the pinch effect force, will tend to make the metal flow in the counterclockwise direction.

Since the forces utilized in applicant's present invention usually become greater as the melting channel or loop sections are placed closer together applicant believes that in some instances they can be actually joined without detriment, and that even greater current concentrations and circulation may be effected by so joining them.

In Fig. 5 applicant has shown four secondary loops or melting channels and four primary coils so arranged that each of the four loops is affected by end effect forces at one point in its path and so that the four secondary loop sections so affected are spaced close to each other whereby each tends to exert an influence on the other three. In this figure the individual loops could be joined to form a single loop section as at the dotted circle C.

While the feature of unidirectional circulation has been described very fully in this specification it is but one beneficial feature of applicant's invention as by the judicious spacing of the primary coils and melting loops a substantial control of the circulation may be obtained whether unidirectional or two way stirring is desired. Many arrangements suggest themselves where a plurality of primary coils and secondary melting channels or loops may be arranged to accomplish the purpose of absorbing energy and utilizing end and proximity effects for controlling metal circulation. Some such arrangements are for coils of unequal mechanical or electrical design; for single or polyphase or other multi-coil constructions; for separate magnetic core assemblies; for variations in secondary loop shape or section, and the like. These are deemed but variations of applicant's invention and it is not believed a full list of such possibilities is here necessary.

The characteristics of a furnace of this type depend largely on the location and shape of the melting loops with respect to the primary inducing coils and can be widely controlled for different types of metal melting or for different melting speeds by varying the secondary loop or melting channel arrangements while the linings are being installed. Thus for fast or for high temperature melts the circulation must be higher than for slow or low temperature melts. Then too there is some advantage from the efficiency standpoint in not having more circulation than is required for a given melt.

Some control may be built into the furnace proper to allow for making electrical or mechanical changes during the operation of the furnace. The most common is by control of voltage on the primary coil and is accomplished by external voltage control or taps on the primary coils. In some instances the relative location of coils and melting loops may be changed mechanically by shifting the location of the primary coils with respect to the secondary loops as illustrated in Fig. 1. In other instances the relative locations of primary coils and secondary loops may be shifted electrically as by some such circuit as shown in Fig. 6.

In Fig. 6 are shown two primary coils 1' and two secondary loops 5, surrounding an iron core piece 3. The secondary loops are arranged to be sufficiently close in one section of their path to react with each other, but are spaced sufficiently inside the ends of their respective coils so that when these parts of the primary coils are energized no end effect results. The primary coils are so arranged that lengths A can be energized in which case the end effect force is not great, or so that lengths B can be energized bringing the end effect force into play. The parts of the coil to be used can be controlled by the switch 10 effecting a circulation control without materially affecting the power input to the melt.

Applicant believes that in designing a furnace to utilize end effect in conjunction with the other forces available for causing circulation in a submerged resistor furnace he has greatly advanced the possibilities for extending the use of such furnaces into fields of larger and faster melting. He believes that his invention herein described is new and patentable and requests that U. S. Letters Patent be granted to him for all that is claimed, as follows:

1. An electric furnace of the submerged re-

sistor type comprising refractory walls, a hearth, a plurality of melting channels opening in and depending from said hearth, a separate but electrically generally similar primary coil associated with each melting channel, each said melting channel having a portion positioned substantially at and other portions spaced from an end of its respective primary coil, said portions near the coil ends being positioned close to each other.

2. An electric furnace of the submerged resistor type comprising refractory walls, a hearth, a plurality of melting channels opening into and depending from said hearth, a primary coil associated with each melting channel, a common iron core threading the primary coils and melting channels, each of said melting channels having a portion of restricted section as compared with other sections said portions being positioned close to each other and each said portion being positioned closer to an end of its respective primary coil than other portions of the same melting channel.

3. An electric furnace of the submerged resistor type comprising refractory walls, a hearth, a pair of melting channels opening into and depending from said hearth, a pair of substantially identical primary coils placed adjacent to each other around a common iron core, each associated with one of said melting channels, each of said melting channels having a portion of restricted section as compared with other sections, said portions only being positioned close to each other and close to the adjoining ends of their respective primary coils.

4. In an electric furnace of the submerged resistor type comprising refractory walls, a hearth, a pair of melting channels opening into and depending from said hearth, a pair of substantially identical primary coils placed around opposite legs of a common iron core each associated with one of said melting channels, each of said melting channels having a portion of restricted section as compared with other sections, said portions only being positioned close to each other and close to an end of their respective primary coils.

5. An electric furnace of the submerged resistor type comprising refractory walls, a hearth, a pair of melting channels opening into and depending from said hearth, said channels being closely spaced at one side of the furnace and widely spaced at the other side of the furnace, a pair of substantially abutting primary coils surrounding a common iron core and threading said channels, the lengths of said coils being such that they extend well beyond the secondary channels on their extreme ends and beyond said channels on their abutting ends and electrical switching means for optionally energizing the coils except for portions at the abutting ends or except for portions at the extreme ends.

6. An electric furnace of the submerged resistor type comprising refractory walls, a hearth, a pair of melting channels opening into and depending from said hearth, a pair of primary coils, similarly connected to a single phase source of alternating current, placed end to end and close to each other around a common iron core, each associated with one of said melting channels, said melting channels being positioned at least in part close to each other and close to the adjoining ends of their respective primary assemblies.

7. An electric furnace of the submerged resistor type comprising refractory walls, a hearth, a pair of melting channels opening into and depending from said hearth, a pair of primary coils, similarly connected to a single phase source of alternating current, placed end to end and close to each other around a common iron core, each associated with one of said melting channels, said melting channels being positioned close to each other and close to the adjoining ends of their respective primary assemblies.

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