

Jan. 31, 1939.

W. ADAM, JR

2,145,677

ELECTRIC FURNACE

Filed July 21, 1937

2 Sheets-Sheet 1

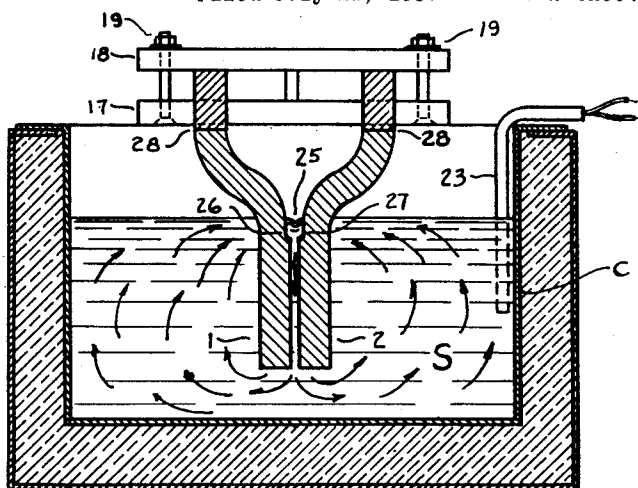


FIG. 1

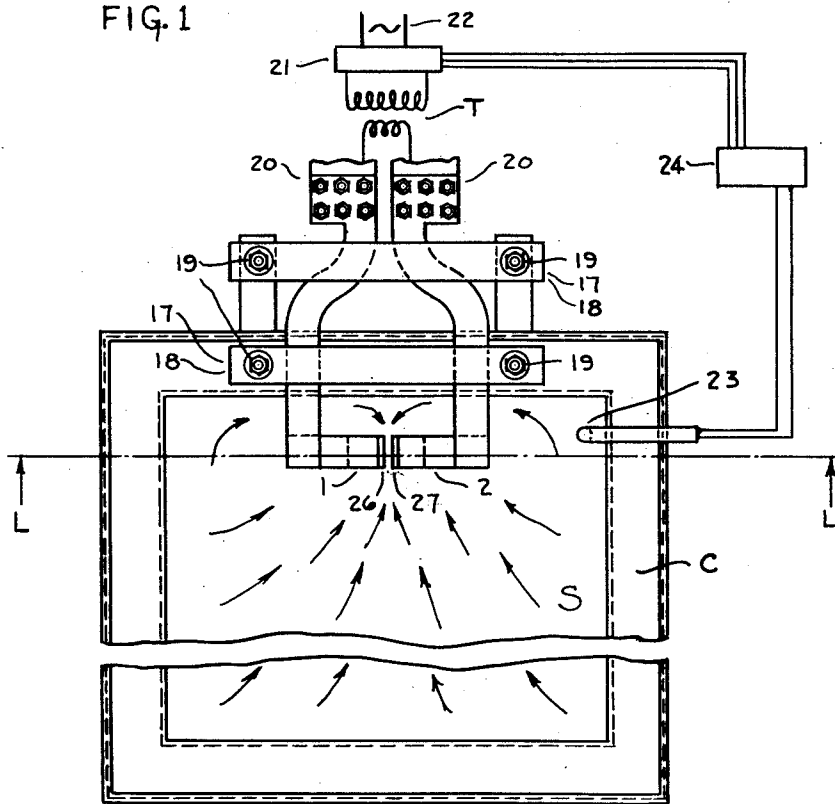


FIG. 2

INVENTOR.

William Adam, Jr.

BY

Frank T. Chesnut

ATTORNEY.

Jan. 31, 1939.

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2 Sheets-Sheet 2

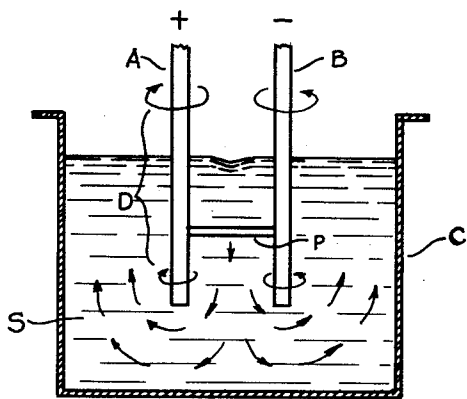


FIG. 3

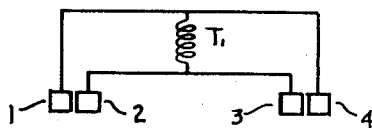


FIG. 4

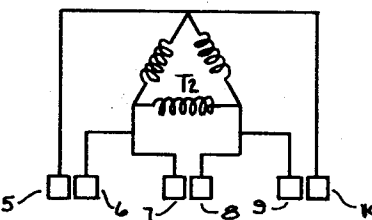


FIG. 5

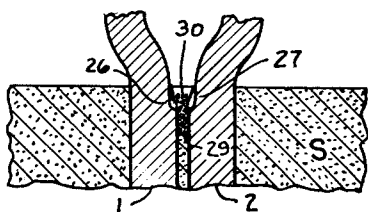


FIG. 7

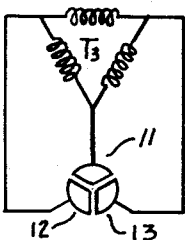


FIG. 6a

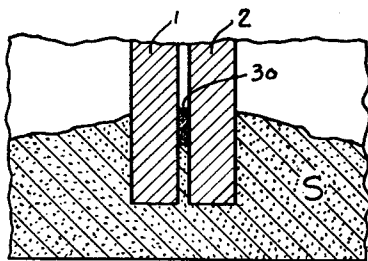


FIG. 8

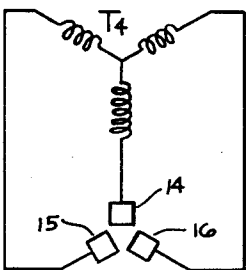


FIG. 6b

INVENTOR.
William Adam, Jr.
BY *Frank T. Chesnut*
ATTORNEY.

UNITED STATES PATENT OFFICE

2,145,677

ELECTRIC FURNACE

William Adam, Jr., Jenkintown, Pa., assignor to
Ajax Electric Company, Incorporated, Phila-
delphia, Pa., a corporation of Pennsylvania

Application July 21, 1937, Serial No. 154,729

5 Claims. (Cl. 13—23)

This invention deals with the construction and operation of an electric furnace of the submerged electrode or salt bath type.

An object of the invention is to provide in a furnace of the type described, a strong electro-magnetic stirring action whereby different parts of the bath can be maintained at a uniform temperature.

A further purpose is to provide a furnace of the type described wherein the electrodes are spaced close together and preferably parallel to impart to the bath by electromagnetic action a maximum degree of circulation.

A further purpose is to provide, in a salt bath furnace, where there is to be a high degree of circulation, an electrode system wherein the normal wear and corrosion of the electrodes is a minimum.

A further purpose is to so shape a pair of electrodes in a salt bath furnace that an excessive wear at the bath surface or sides of the electrodes facing each other may be eliminated or compensated for.

A further purpose is to construct an electric furnace of the submerged electrode type, with electrodes closely spaced below the bath surface but widely spaced near and above the bath surface.

A further purpose is to lead current into and from a salt bath at widely separated points and to bring the paths of current close together beneath the bath surface for circulation purposes.

A further purpose is to construct an electric furnace of the type described with an unusually deep bath, and with electrodes closely spaced and substantially parallel near the lowermost portion of the bath but widely spaced in the upper parts and over the bath.

A further purpose is to provide an improved electrode for a salt bath furnace.

A further purpose is to provide, in a furnace of the type described, an electrode system in which the closely spaced submerged portions are made of a magnetic material whereby the current crowding by the so called "proximity" or "surface conduction" effects may be enhanced, with a corresponding increase in the circulation of the bath.

A further purpose is to provide a novel way of starting the melt in a salt bath furnace.

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

Salt bath furnaces have been built where the heating is effected between an electrode and a conducting pot; between an electrode, a conducting pot, and a second electrode; and between two electrodes, all effecting a heating of the salt bath by resistance currents passed through the salt, and so arranged that a metallic charge piece placed in the bath proper will not fall in the path of the heating current. Patents have been grant-

ed for these constructions over previous electrode type salt bath furnaces where the voltage between electrodes was high, and where all, or a considerable portion, of the actual heating current passed directly or partially across the area reserved for the charge to be heated.

With the current traversing the charge area there was a tendency for more uniform bath temperatures but this method was open to the objection that the current crowded to and passed through the metallic pieces being treated, causing local overheating and damaging especially of the thinner sections of the pieces being treated.

When the electrodes were placed at the sides of a metallic pot or were spaced toward one side in either a metallic or a non-metallic pot, the current lines had no access to the charge pieces and all heating was accomplished between the pot and electrodes or between the electrodes proper. The bath temperature at parts removed from the electric current path was heated to a moderate degree of uniformity by natural convection due to the rising of the heated portion of the salt and ultimate replacement by the cooler portions. On small units and particularly those where the temperature was high, or on those where the temperature range was allowably great, the approach to uniformity was sufficiently satisfactory at points in the bath removed from the heating area to be tolerated. The spacing and location of electrodes was generally not considered other than to avoid current paths through the work. Natural convection currents, and duplication of the number of electrodes at different points in the bath where relied upon to insure such an approach to uniformity of temperature as was required. In much of the prior art close spacing was condemned, and electrodes were spaced far enough apart to prevent hot spots due to overheating a portion of the salt faster than the heat could be distributed by natural convection.

Natural or simple convection as used in this specification is defined as being that circulation which is due to thermal and density variations caused by the simple heating of a medium, as by a fuel burner or a hot wire resistance unit placed under or in a portion of the medium to be heated. This circulation is invariably upward from the heated area, outward over this area at the top, and downward at the sides of the heated area. Good circulation is required to secure uniformity of temperature, and the better the circulation the closer the approach to complete uniformity of temperature. Applicant has found that by proper positioning of the electrodes with respect to each other, so as to produce electromagnetic circulation, he can substitute, such electromagnetic circulation for the thermal convection circulation, and may tremendously improve the total circulation obtainable. For the purpose of this case it

will be sufficient to define electromagnetic circulation, as distinguished from thermal circulation, as that stirring due to the "motor" or "pinch" effect of an electric current and this can be controlled or directed in almost any desired manner.

In a Northrup type electric induction furnace such for example as that described in U. S. Patent 1,286,395, the effective stirring is upward in the center upper portion of a molten metallic bath, and downward at the sides; inward at the center circumferential areas of the bath; downward at the center lower portion of the bath, and upward at the sides. In the Wyatt type submerged resistor furnace, such for example as that described in U. S. Patent 1,201,671, the electromagnetic stirring effect is upward in the outside vertical sections of the resistor loop and downward in the inside vertical sections. In a motor the equivalent electromagnetic field causes a rotor to rotate about its axis, and in a developed motor field it causes a following armature to move lineally or in accordance with the shape of the field as developed. Such an electromagnetic force as applied to a liquid or salt bath furnace has not heretofore been known, and will be described in this specification.

In designing a salt bath furnace applicant tried to devise a means whereby the currents which heated the salt in a salt bath furnace might also be used to stir the salt, much as the metal is stirred in the induction furnace.

As a result of such experimentation and study he developed a salt bath furnace which not only gave uniform temperatures in a small, high temperature bath, but which permitted the application of an electrode type furnace to liquid heat treating operations requiring the use of temperature sensitive salts such as sodium cyanide. He found as others had before him, that as he moved his electrodes closer together the power drawn from the mains increased greatly and hot spots developed in the bath. But when he disregarded the logical interpretation from this fact, and moved these electrodes still closer together, a new phenomenon resulted. The hot spots, instead of increasing, began to decrease and the circulation of the bath changed from that of simple convection, upwardly and outwardly, to an electromagnetic circulation, downwardly and laterally outwardly with respect to each electrode pair or group. The improvement of circulation by reason of applicant's invention is very noticeable.

Nine figures have been used to illustrate the invention. Figure 1 is a sectional elevation view of a salt bath furnace embodying this invention. The view is taken from Figure 2 on the section L—L.

Figure 2 is a plan view of the furnace of Figure 1, showing in addition, in diagrammatic form the electric and control circuits used.

Figure 3 is a diagrammatic view of a salt bath furnace used to demonstrate how the stirring takes place.

Figures 4, 5, 6a and 6b show a few of the different ways in which the electrodes of Figures 1 and 2 may be connected for multiple or polyphase operation.

Figure 7 is a fragmentary view of the upper portion of the electrodes of Figure 1, showing applicant's method of starting the melt from a frozen state in a salt bath furnace.

Figure 8 is a fragmentary view of the lower portion of the electrodes of Figure 1, showing applicant's method of starting the melt with cold granular salt.

Assuming that in a salt bath as shown in Figure 1 the electrodes are not closely spaced but are connected to a source of electric power, then a current will flow from one to the other through the conducting salt, the heating effect depending upon the voltage impressed on the electrodes and the resistance of the bath proper. If a given voltage is impressed, and if the salt has a definite or fixed resistance, then the power applied to the bath will vary generally with the spacing of the electrodes. If the electrodes are far apart, there will be little heating. If the electrodes are brought closer together, more current will flow, and more heating will result. As the portion of the salt between the electrodes becomes heated it tends to become lighter and to rise to the surface. It is this effect which has heretofore been depended upon to circulate the bath, and to secure more or less uniform temperatures. The higher the temperature of the medium between the electrodes, up to a certain limit, over that of the rest of the bath, the more rapid will be the circulation. However, there is a limit to the heat which can be carried away by simple convection, and unless the spacing is made close enough to secure effective electromagnetic circulation, the temperature differences in the bath will become still further aggravated, causing excessive decomposition of the salt, and impractical working conditions in the bath. For this reason there has been in the past an attempt to keep the electrodes spaced sufficiently far apart to prevent excessive heating, but close enough together to get a maximum of power which can be handled by simple convection circulation.

Applicant found that the same power might be applied to a bath using a high current, low voltage, and closely spaced electrodes, as could be applied by a low current, high voltage, and more widely spaced electrodes, and that the closer spacing of the electrodes resulted in effective electromagnetic circulation. He purposely spaced his electrodes close, to a point where overheating resulted, and then instead of backing them off, spaced his electrodes still closer. As expected, the current density was sufficient to set up a strong motor action. The hot spot disappeared, and the bath took on a new type of circulation. While the furnace could be proportioned to get electromagnetic stirring at various spacings, depending upon the resistivity and viscosity of the bath, and upon the voltage and current applied, he found that in a bath of sodium cyanide operating at a temperature of 1500° F., and powered at 25 kw., with approximately 10 volts, and 2500 amperes, he had sufficient stirring to prevent hot spots with electrodes spaced apart 1½ inches, whereas he could not notice any appreciable stirring at a 2½ inch spacing.

Salts containing a decomposing compound such as sodium cyanide should not be overheated because of the rapid loss of the material at temperatures slightly over the critical, and it has not been practicable heretofore to heat such salts in electrode type furnaces. In applicant's furnace the circulation is so great that these salts may be used very effectively. Sodium cyanide salts melt at around 1000° F. and are used at around 1500° F. Rapid decomposition sets in at about 1700° F.

Any conductor which carries current, when placed in a magnetic field, tends to move at right angles to the direction of the magnetic field and at right angles to the direction of flow of the current. Applying this rule to the salt bath in this invention, by way of explanation, electrodes

A and B, Figure 3, are immersed vertically and close together in molten salt S, in a salt bath furnace C, and a current of several thousand amperes is passed between them. Each electrode is surrounded by approximately circular lines of force D. Current of approximately uniform density flows between the electrodes at all points from the surface of the liquid to their ends. If a current element P is taken midway between the two electrodes and some distance down from the surface, and the current is traveling at any instant from A to B, then with the resultant electromagnetic field between the two electrodes extending upward from the plane of the paper at the point P, the conductor, or element of the liquid salt which is carrying the current, will be forced downward between the electrodes in the direction shown by the arrow.

As the force is downward regardless of the polarity of the electrodes either alternating or direct current is effective for stirring. If in Figure 3 the direction of the current is reversed, the direction of the magnetic field automatically reverses, and the direction of movement is still downward.

The force of the circulation is greatest where the electrodes emerge at the surface of the bath, and falls off gradually as the depth increases and as the end of the electrode system is approached. This follows from the fact that all the current is flowing in the electrodes at the upper end, but less and less flows in them at lower points, due to conduction across the space between the electrodes. Hence the field of force D, as shown, is many times stronger at the top than at the bottom. The current between the two electrodes is almost constant because the drop of voltage in the electrodes proper is almost negligible.

In addition to the main force, above described, there is an additional force at the electrode ends which works in a coordinating manner, due to the current lines spreading outwardly at the electrode tips. This is the phenomenon known in induction furnace work as the "pinch" effect. It was proved by Dr. Edwin F. Northrup many years ago that if a liquid was enclosed in a cone with a small electrode at the apex and a large electrode at the base, there would be a distinct stirring action along the axis of the cone from the smaller to the larger electrode. The explanation is that, due to the repulsion effect of currents of like sign, there is an accompanying mechanical pressure on the inside of the conductor. In the case of a conical conductor this pressure is greater where the conductor is of the smallest section. Since the pressure decreases at points away from the apex, the liquid electrically conducting medium is forced in that direction. To maintain an equilibrium, a corresponding flow takes place in the reverse direction toward the outer surface of the cone.

The forces above described, together with other minor forces due to repulsion, crowding, or induction effects of the current, combined to produce a vigorous bath circulation. The flow is downward between the electrodes and outward between the electrodes at the sides and at the ends. To maintain equilibrium in the bath there is an upward flow at the sides to replace the liquid forced down from the top. The natural convection is opposed and overbalanced by the electromagnetic circulation, and becomes effective again as soon as the heated liquid leaves the area around the electrode tips. The result is that the baths may be made larger, or that charge

pieces may be inserted and removed at a faster rate, without impairing the inherent temperature regulating characteristic of a furnace embodying this stirring principle.

In previously designed salt bath furnaces the effective range of circulation by convection due to a single set of electrodes was much restricted, which limited the bath size greatly; and to increase this size additional electrodes had to be placed in the bath. So here, while the bath for a single set of electrodes is very much larger than those where simple convection is used, the bath may be increased in size if other sets of electrodes are added. By putting the electrode groups in parallel as in Figure 4 and placing them at different points in the bath it is possible to greatly increase the bath width over previous designs, and to extend the bath length greatly.

For a large bath polyphase currents are preferably used, and these can be placed as shown in Figure 5, or Figure 6a or 6b. Figures 6a and 6b are identical with Figure 5 in effect, the stirring still being due to the current between any two adjoining electrodes. The addition of the polyphase field offers no particular advantage. Figures 6a and 6b can be considered as special cases of the arrangement shown in Figure 5, each electrode in Figure 6a or 6b being the combination of the two corresponding electrodes in Figure 5, so far as the effect on the circulation is concerned. For instance electrode 11 in Figure 6a, corresponds to electrodes 5 and 10 in Figure 5; electrode 13 to electrodes 8 and 9, and electrode 12 to electrodes 6 and 7 respectively. In Figure 6a the three electrodes act as but three pairs of single electrodes the stirring being due to current flowing down in 11 and up in 13, for instance, or down in 13 and up in 11 and 12 as a divided electrode at certain other periods. Figure 4 shows how groups of electrodes are arranged for parallel operation on a single phase. In Figures 4 to 6b the transformer secondaries are denoted by T₁, T₂, T₃ and T₄ respectively, and the electrodes by the numerals 1 to 16.

While applicant prefers to use electrodes having flat faces adjacent and parallel to each other he does not wish to be so limited. It has appeared that there is less surface erosion, and that there is a better directional stirring effect when they are placed in this manner. However, the stirring effect is still pronounced when the electrode faces are not parallel, or when odd shapes are used. The arrangement shown in Figure 6b for instance, has been found to be effective.

There is no definite spacing which applies to all furnaces as the spacing must be proportioned in conformity with the type of salt, temperature of bath, the power required, and the physical dimensions of the pot. For most salt bath furnaces used for hardening small tools, gear parts, and the like, where furnace dimensions rarely exceed 3 feet wide by 2 feet deep by 6 feet long, and where the power requirement does not exceed 150 kw., applied to three pairs of electrodes, applicant prefers an electrode spacing of from ½ to 1½ inches, and current densities of about 125 amperes per square inch on the sides of the electrodes facing each other. Applicant has found that an electrode length of about 12 inches is quite successful for a bath as above described, and has tested electrodes as short as about 6 inches with some success. He has also successfully tested longer electrodes. The electrodes tested have been of a section about 2 inches

square. A current density of 125 amperes per square inch has been found sufficient for adequate stirring in most baths, but applicant has found current densities as low as 50 amperes per square inch suitable in some instances. Of the total power required for the bath, the power required for the circulation is only a negligible quantity.

Bath temperatures successfully tested range from 300° F. for the nitrate tempering salts to 2300° F. for the barium chloride and borate salts, used for high speed steel hardening. For the lower temperature baths the limits for electrode spacing are much wider than for the higher temperature baths. The higher the current density the greater spacing may be used. With existing current densities applicant has tested spacings up to 4 inches but considers the upper range of spacing not so desirable as the lower range.

The present invention alters considerably the requirements for electrode construction and shaping, and offers unique and advantageous methods for starting a melt in the furnace, either from cold granular salt, or a frozen bath.

Due to the close spacing of the electrodes and large currents flowing between them, the wear appears almost wholly on the inner surfaces. This is a distinct advantage over constructions where the current passes to or through the container wall, as the electrodes are relatively cheap by contrast with the cost of the pots, and may be changed easily, without shutting the furnace down for repair. In addition to this, the electrodes may be moved closer together from time to time as wear progresses. In furnaces where the current flows from one electrode to a conducting pot, effective electromagnetic stirring is not obtained, although there usually is some local eddy current effect.

In Figures 1 and 2 applicant has illustrated the major points of his invention. Electrodes 1, 2, are immersed in a liquid S, which is held in either a metallic or a refractory pot C. The electrodes are adjustably and rigidly clamped between insulating supports 17, 18 by bolts 19, and terminate in connecting lugs or plates 20. These studs are connected to the terminals of the secondary winding of a transformer T, the primary of which is connected through switches 21 to a power source 22. A thermocouple 23, operates a controller system 24, which can be set to open and close the energizing switches 21, to maintain a desired bath temperature.

The electrodes are shown in these figures to have closely spaced and parallel faces. The separation between the electrode faces is preferably between 1/2 and 2 inches, but can be any spacing where the current density and power applied is sufficient to give an effective electromagnetic stirring to the bath proper.

The circulation as obtained in the bath with closely spaced electrodes and a high current flow is shown by the arrows. It is downward between the electrodes, outward at the lower ends of the electrodes and upward at the sides of the bath. In many instances the stirring is so vigorous that a small depression appears in the top surface of the liquid as at 25.

The electrodes are preferably spaced more widely apart above, at, and slightly below the bath surface as at 26, 27 in Figures 1 and 2, on the sides facing each other. If there are three electrodes in the group as in Figures 6a or 6b this still applies. This is for the double purpose of supplying additional metal on the wearing surfaces and to prevent accumulation of dross, slag,

condensed vapors from the bath, and the like bridging across that portion of the electrodes above the bath. By spreading the electrodes above the bath as shown in Figure 1, damage to the electrodes is avoided which might otherwise occur due to "short circuiting" by a conductive bridging of slag, dross, or the like, across the electrodes above the bath surface. Also the total power drawn by the bath is little affected should the bath level rise above the active or closely spaced portion of the electrodes. In practice, when a charge is placed in the bath the liquid level will rise in direct proportion to volumes of the charge and bath, but the shaping of the electrodes, as shown, prevents any appreciable change in power input due to a varying liquid level.

The electrodes, as shown, are adjustably clamped between the insulating supports 17 and 18, and may be spaced to obtain a desired power or stirring effect or to bring the faces of the electrodes closer together as wear affects their usefulness.

The electrodes proper may be of any well known material, but because of their close spacing and large current carrying requirements, should be chosen with as much care as possible. Applicant has in general tried to avoid electrodes which are magnetic above the bath surface, or which react with the liquid of the bath. He has used electrodes of the austenitic alloys or stainless steel, and also composite electrodes, with great success. He has also recommended graphite and other non-metallic electrodes in special cases.

The reason that non-magnetic alloys are preferable above the bath surface is that these parts carry heavy currents, usually alternating, and the surface conduction effect is tremendously enhanced by magnetic material. By using non-magnetic material the current is more widely distributed in the pieces, and even though the specific resistance of the parts may be higher, the actual resistance is lower than for electrodes of magnetic material. Any heat I^2R loss developed in the upper part of the electrode is waste heat and reduces the efficiency of the bath.

While magnetic parts above the surface of a bath are objectionable, there are reasons why the parts below the bath may be magnetic to advantage. As any heat created by I^2R in the lower part of the electrodes is effectively used to heat the bath, the question of surface conduction in that portion of the electrode is immaterial, from the heating standpoint, and the electrode may be selected for its wearing quality alone. In fact the surface conduction can be deemed an advantage, for in addition to concentrating the current in the outer portions of the electrodes the close proximity of one electrode to the other causes the currents to crowd even more closely to the adjacent sides of the electrodes. This in effect augments the forces tending to stir the bath. While the surface conduction and edge crowding or proximity effect are noticeable with non-magnetic electrodes both are greatly enhanced with magnetic materials with a correspondingly increased stirring action.

Usually the magnetic ferrous alloys are cheaper than the non-magnetic alloys and hence the composite electrode has found favor. In a composite electrode a lower portion of magnetic or cheap material may be welded or brazed to an upper portion of austenitic or higher priced metal, and the lower part may be replaced from time to time as it wears. There is another distinct advantage

in such a composite electrode in that the replaceable part may be made in the form of a relatively simple and cheap casting, while the whole electrode usually is an expensive and complex casting.

As one example of a composite electrode, in the case of a salt bath operated at a temperature around 2000° F., the immersed portion can be made of ordinary chrome-iron, and the upper portion of a nickel-chromium-iron, non-magnetic alloy. These two materials are readily welded together, and new pieces of chrome-iron can be attached to the upper nickel-chromium-iron parts when necessary. The electrodes shown in Figure 1 are joined at 28 but they may be joined at any point above the surface of the liquid.

It must be understood that while magnetic alloys may have an advantage in stirring a bath, this feature is non-existent in most of the higher temperature baths where the temperature is in excess of the recalescent point of the ferrous alloys used.

The close spacing of the electrodes in a furnace according to this invention lends a novel means for starting a melt. As is well known, when the salt is cold it is a poor conductor of electricity, and will not pass sufficient current to start the melt. To accomplish an initial melt, applicant chips out or depresses the solid or granular salt between the electrodes, as at 29 in Figure 7, and in the depression thus formed he packs a granulated carbon or other somewhat similar material 30 which bridges the electrodes and which because of its higher conductivity allows sufficient current to pass between the electrodes to cause an initial melt. As the salt begins to melt, the pool thus formed becomes conducting, heats, and spreads the melt to the whole of the bath. The conducting particles used for starting, float to the surface and are removed by a skimmer or they sink to the bottom of the bath, away from the electrodes. While the chiseled out depression in the solid salt is helpful it is not necessary as the conducting particles will serve the same purpose if packed between the electrodes at the surface of the bath and without the advantage of the cup shaped depression.

Applicant has described but one main form of electrode arrangement useful in this type of furnace. It is obvious from the disclosure that an effective electromagnetic circulation can also be obtained by other arrangements, such as electrodes projecting into the bath at different angles, as from the sides or bottom of a pool; or by electrodes toeing in at the bottom toward each other, or at the top. The electrodes may also be bent or curved through an angle to effect a different but perhaps practical stirring effect. It is also evident that in deep baths the electrodes need not be run parallel and close from the top to the bottom, which would result in poor heating distribution and poor power control. They may be inserted at a widely spaced distance at the top; paralleling each other only for the required distance at a point in the center or lower part of the bath. Tests have shown that in arrangements of this sort the widely spaced parts of the electrodes account for only a negligible increase in total power. If the electrodes were to be paralleled over their whole length, in an abnormally deep bath, the impressed voltage would have to

be so low and the spacing so limited, to get the necessary current density, that the construction would be entirely impractical.

By applicant's construction the liquid in such a deep bath is effectively heated and stirred near the bottom, and the bath temperatures throughout the whole body are kept uniform. There is no tendency for the bottom portion to be cold.

Applicant desires that United States Letters Patent be granted to him for all that is claimed.

What is claimed is:

1. In an electric furnace of the submerged electrode type a group of electrodes extending from a current source into the bath said electrodes being substantially parallel to each other over a portion of their length and sufficiently closely spaced in conjunction with the current passing through and between them to insure an effective electromagnetic circulation and substantial uniformity of temperature throughout the bath and around the position of a charge to be heated therein.

2. In an electric furnace of the submerged electrode type a pair of electrodes extending from a current source into the bath said electrodes being substantially parallel to each other and sufficiently closely spaced to insure a reaction between the current flowing through and between them and the electromagnetic fields around them of sufficient intensity to produce by motor effect a circulation of the heated bath over and above that obtainable by normal thermal convection circulation and sufficient to maintain substantial uniformity of temperature throughout the bath and around the position of a charge being heated therein.

3. In an electric furnace of the submerged electrode type a group of electrodes extending from a current source into the bath, the electrodes being sufficiently closely spaced and substantially parallel to each other for a distance of at least six inches below the bath surface to insure an effective electromagnetic circulation of the bath due to the current passing through and between them and the electromagnetic fields around them, the spacing between the electrodes being considerably wider at other points.

4. An electric furnace of the submerged electrode type having a bath charge in combination with a group of electrodes extending into the bath and a source of current feeding said electrodes during the intended operation of the furnace to heat a charge, the electrodes being sufficiently closely spaced so that the flow of current down one and up another, and between them results in electromagnetic circulation of the molten bath.

5. An electric furnace of the submerged electrode type having a bath charge in combination with a group of electrodes extending into the bath and a source of current feeding said electrodes during the intended operation of the furnace to heat a charge, the electrodes being sufficiently closely spaced so that the flow of current down one and up another, and between them results in electromagnetic circulation of the molten bath, the electrodes being of magnetic material below the bath surface to enhance by proximity effect the current crowding in them and thereby to increase the resultant stirring of the bath.

WILLIAM ADAM, JR.