

Nov. 10, 1936.

D. L. SUMMEY

2,060,136

ELECTRIC FURNACE

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Fig. 3f

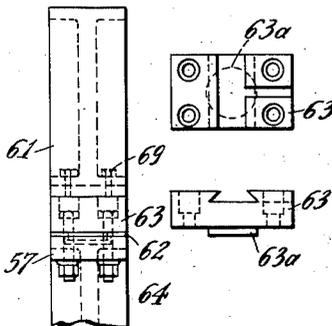


Fig. 3d

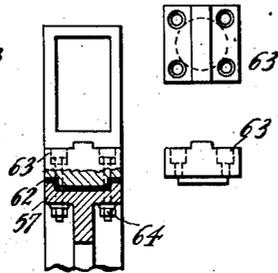


Fig. 3b

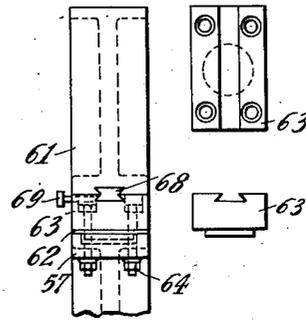


Fig. 1a

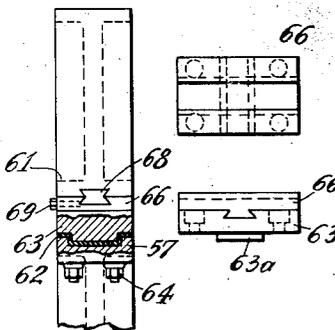


Fig. 1c

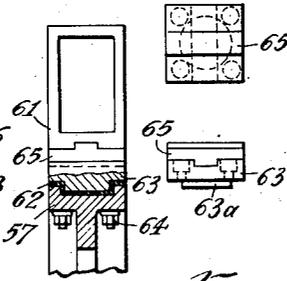


Fig. 1e

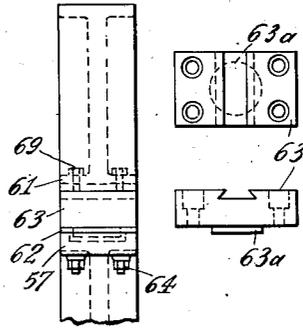


Fig. 4a

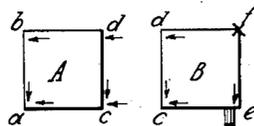


Fig. 4b

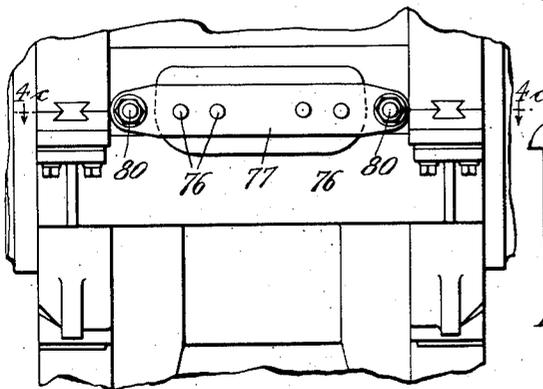
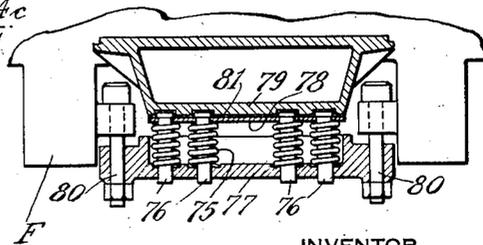


Fig. 4c



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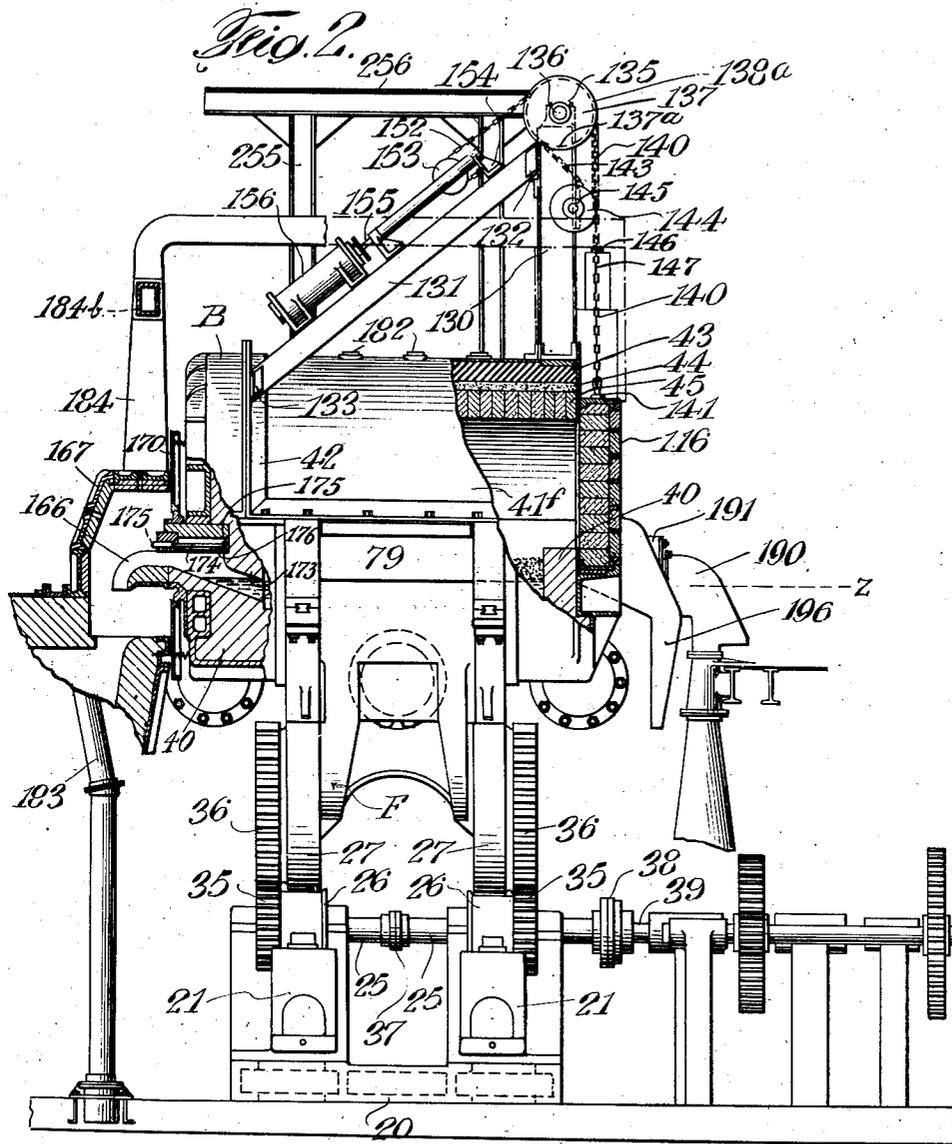
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ELECTRIC FURNACE

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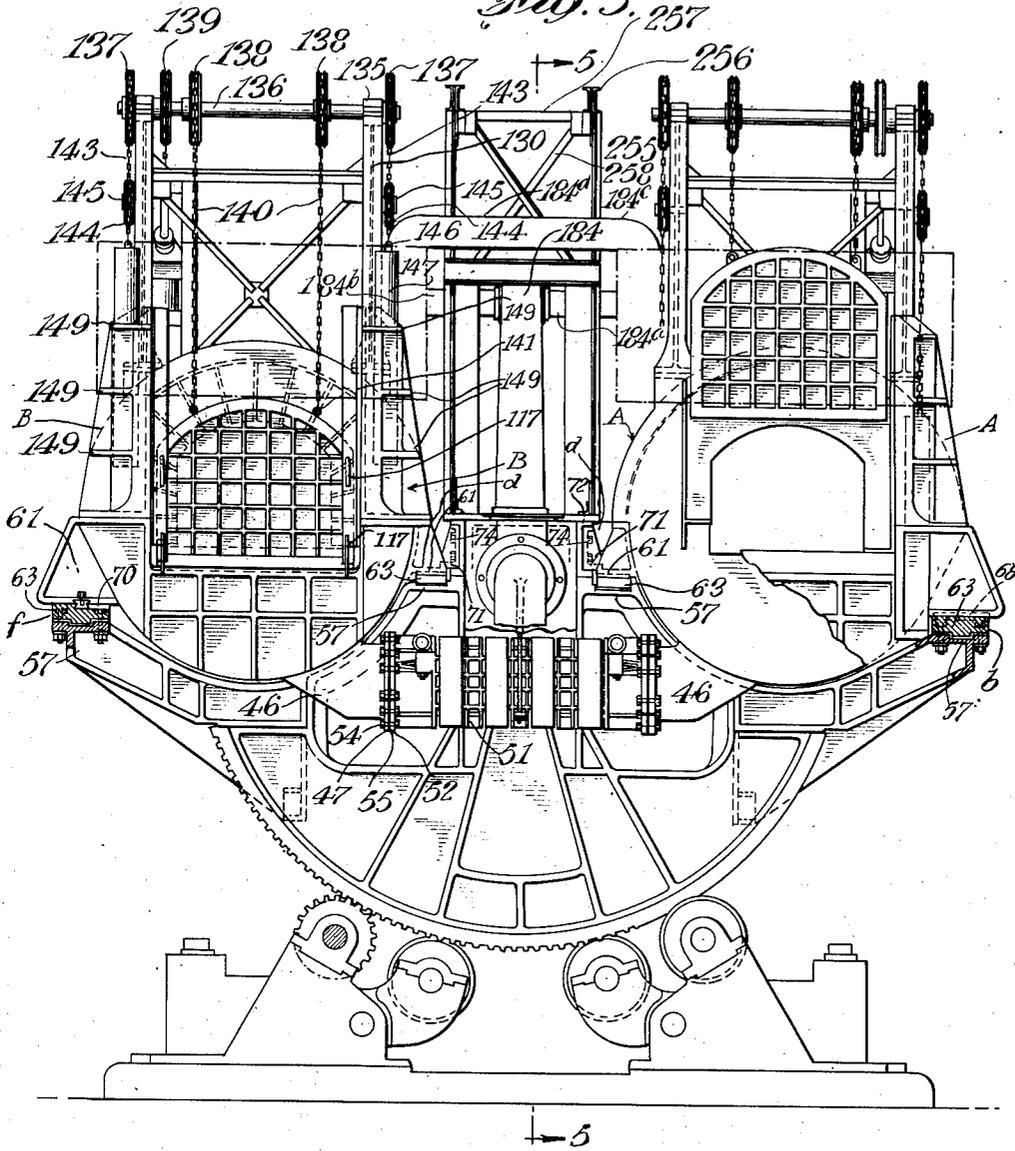
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Fig. 3.



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Fig. 4.

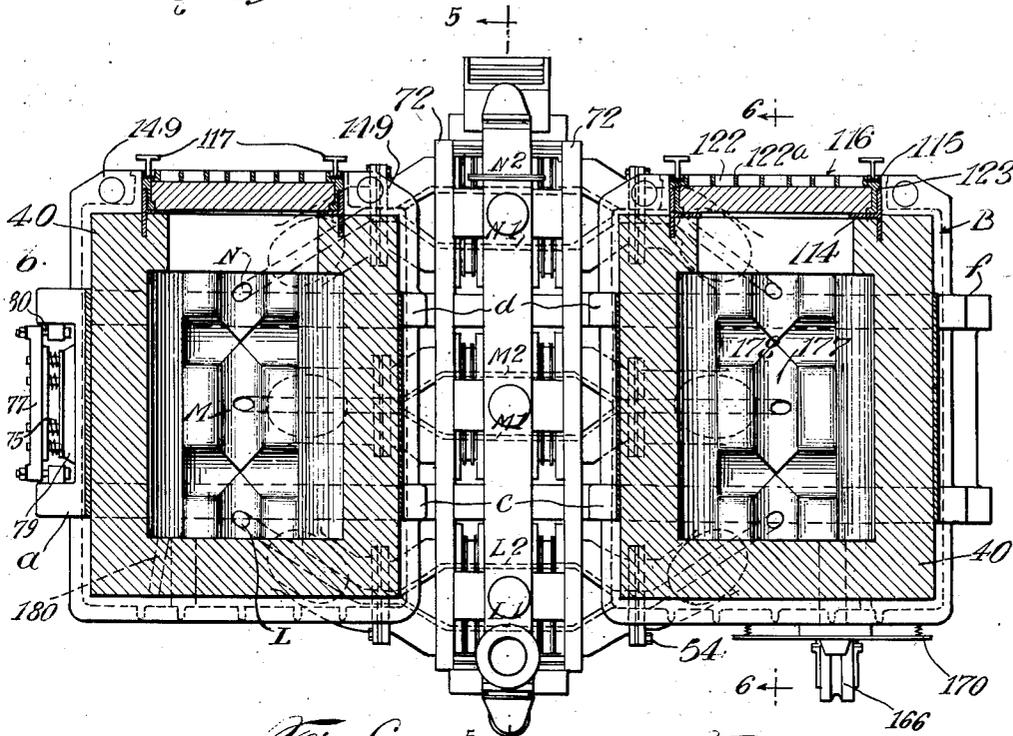


Fig. 6.

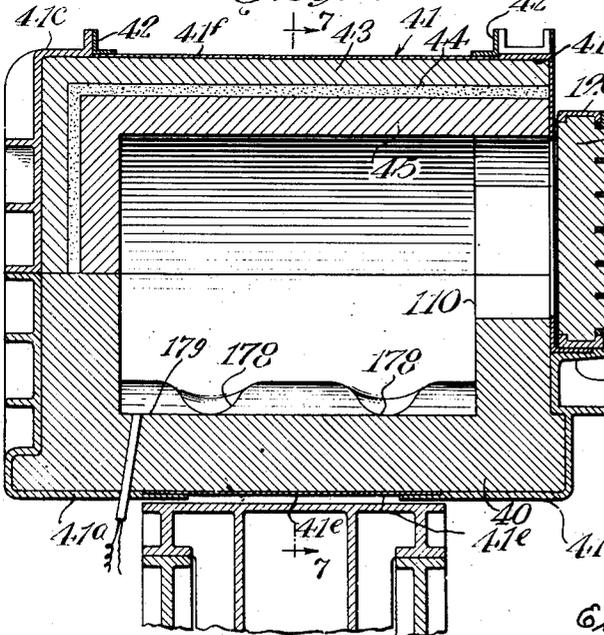
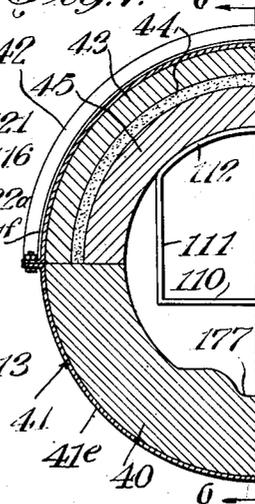


Fig. 7.



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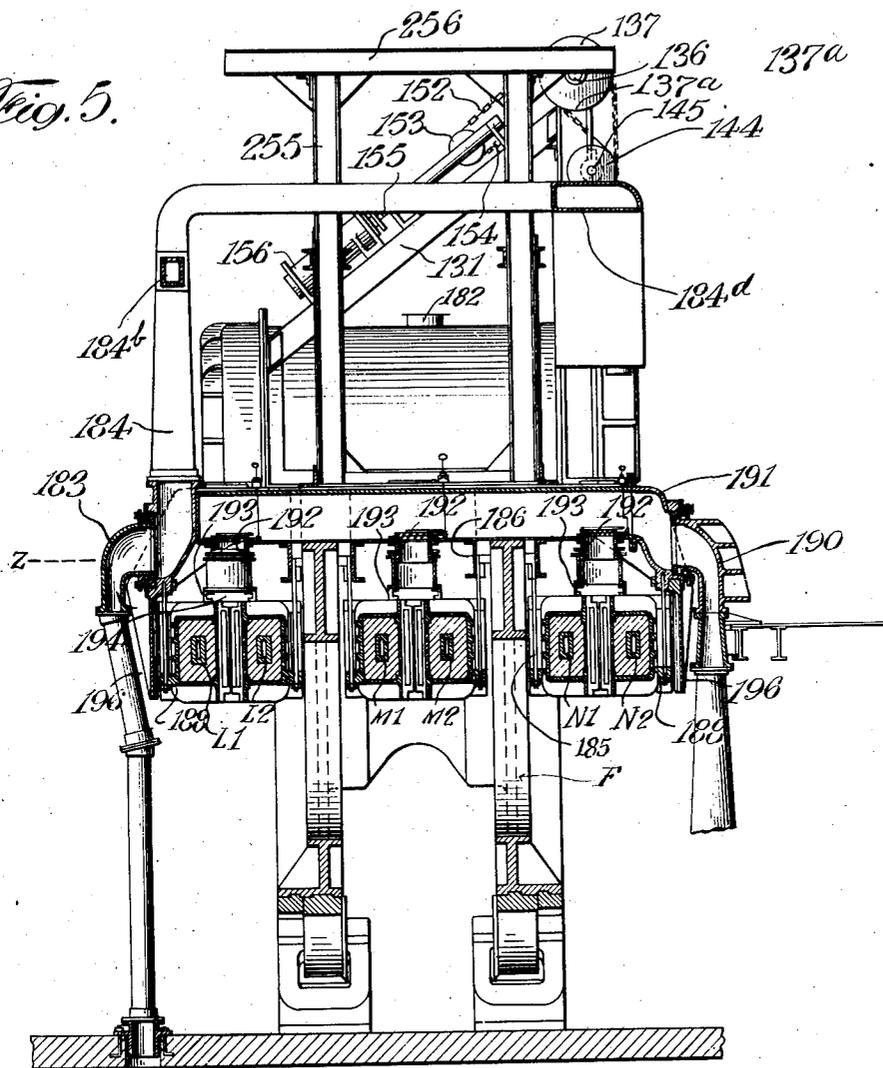
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Fig. 5.



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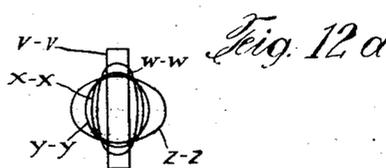
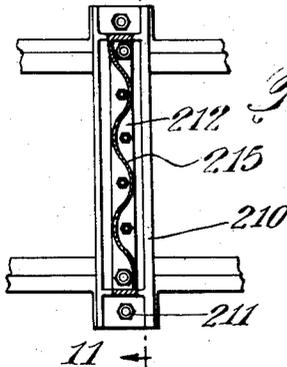
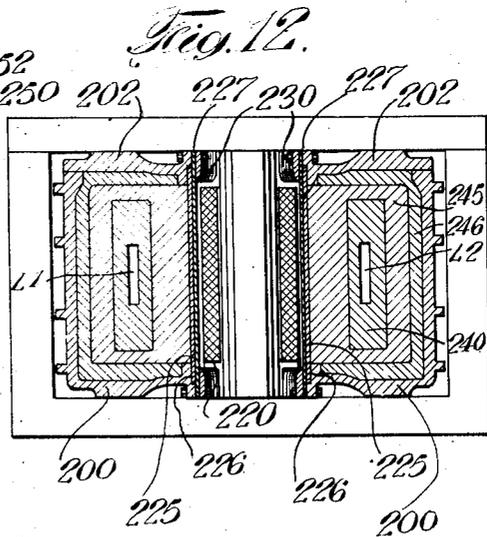
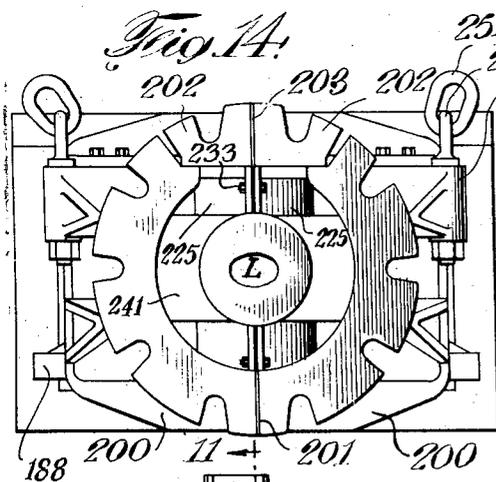
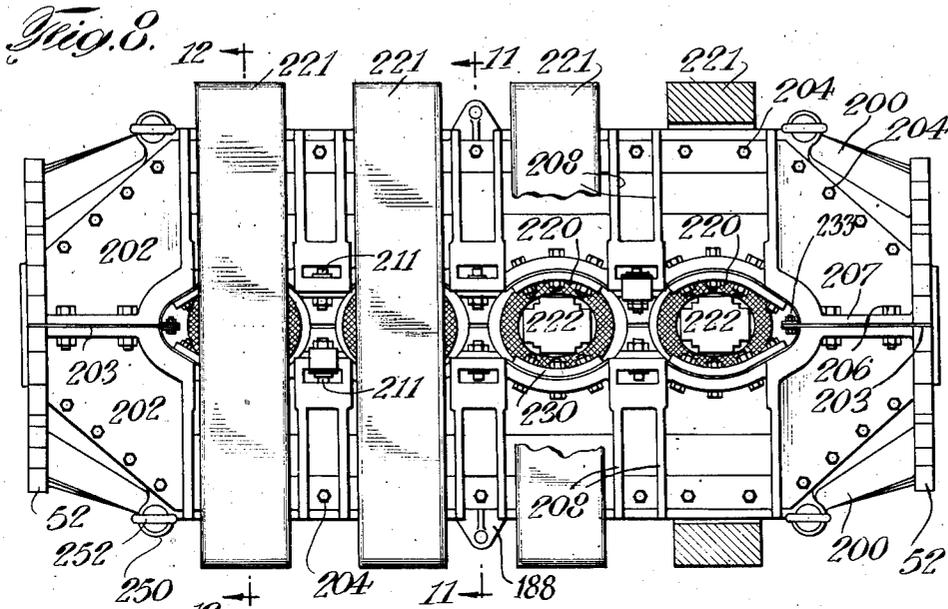
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Fig. 9.

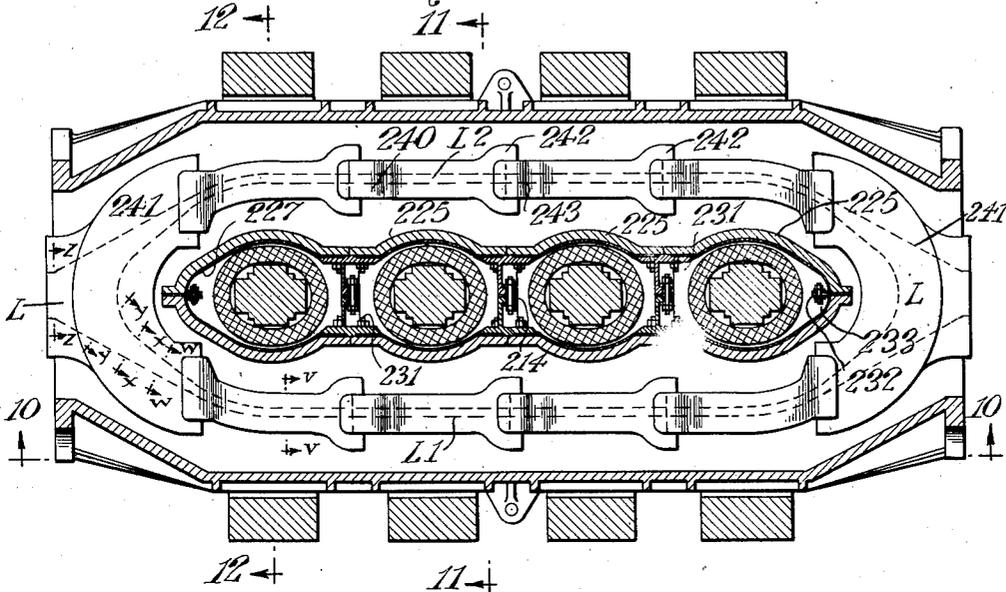


Fig. 10.

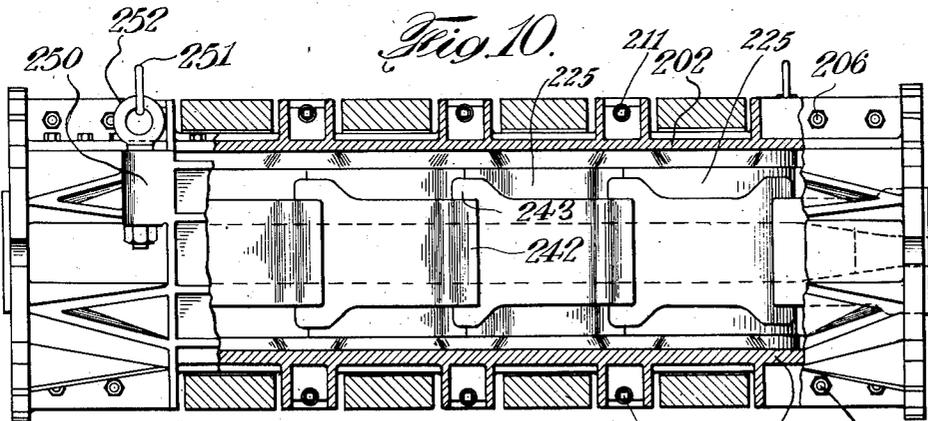
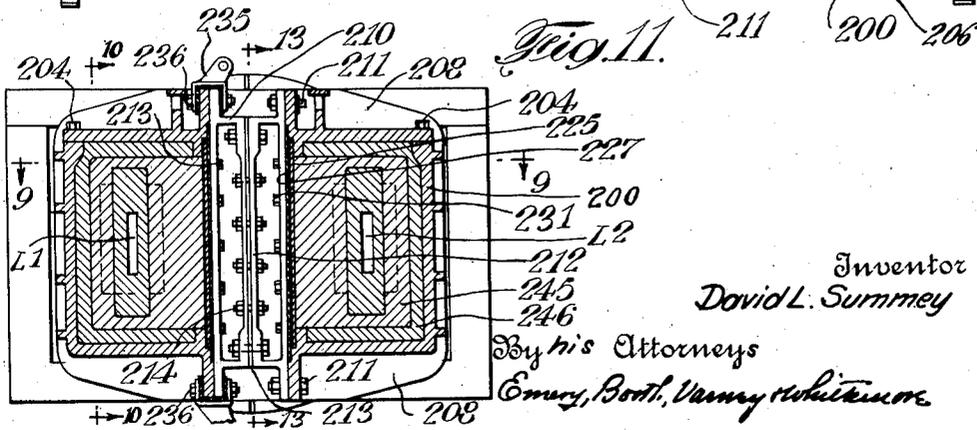


Fig. 11.



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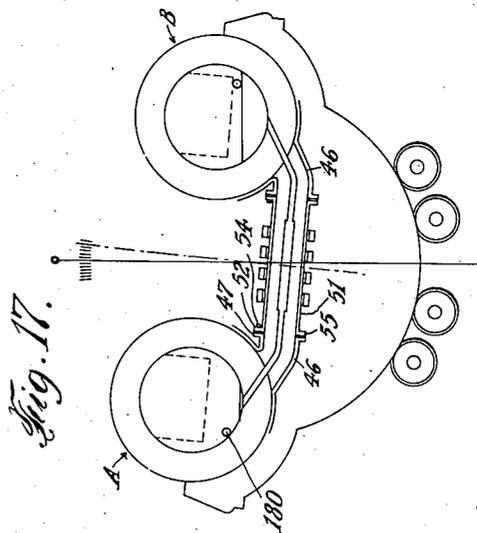
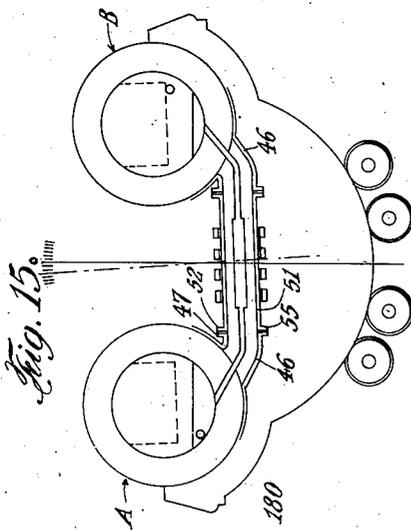
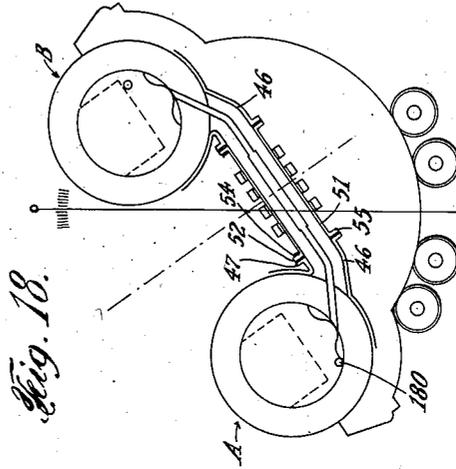
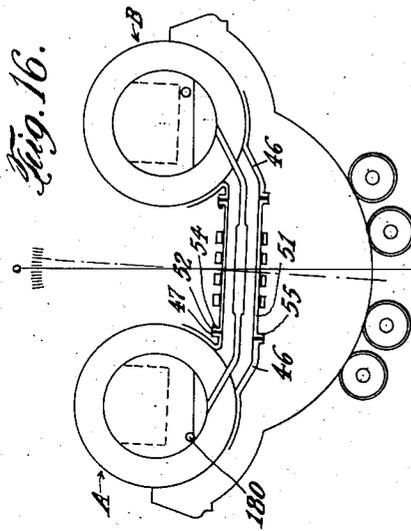
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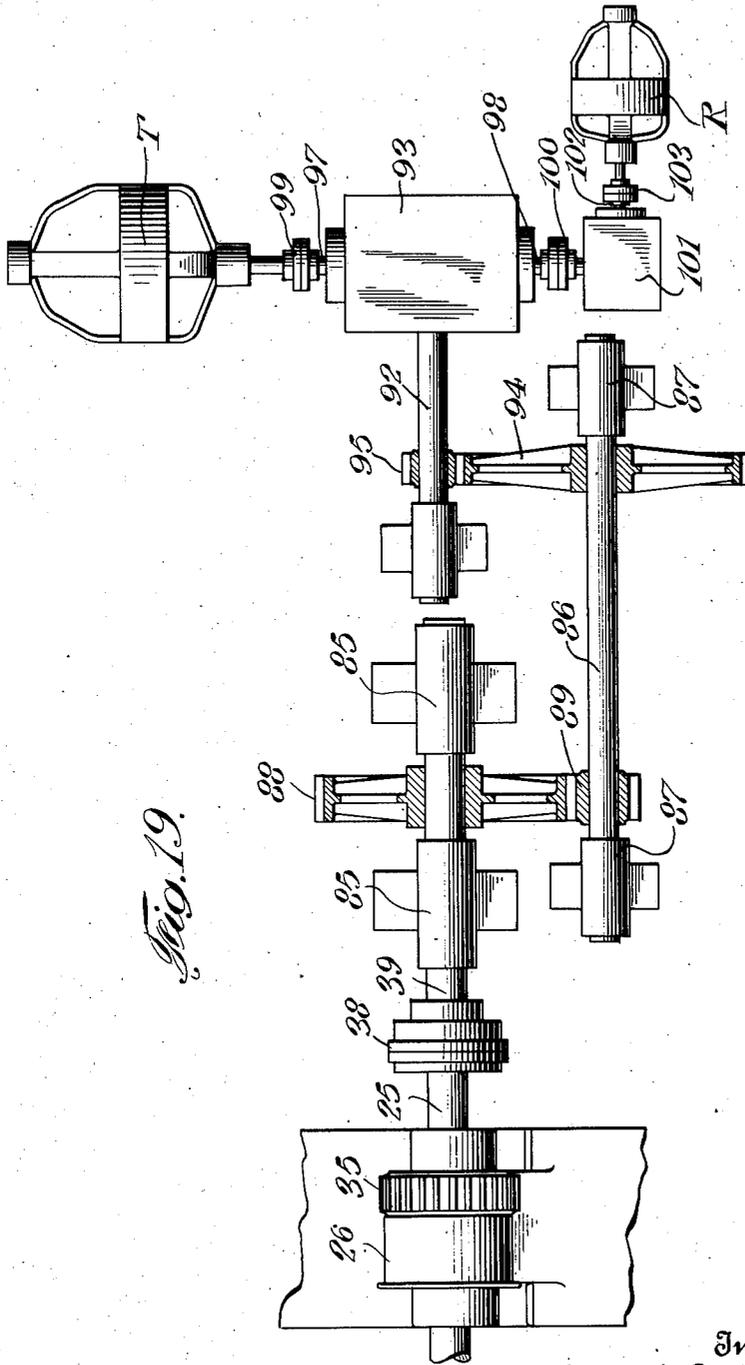


Fig. 19.

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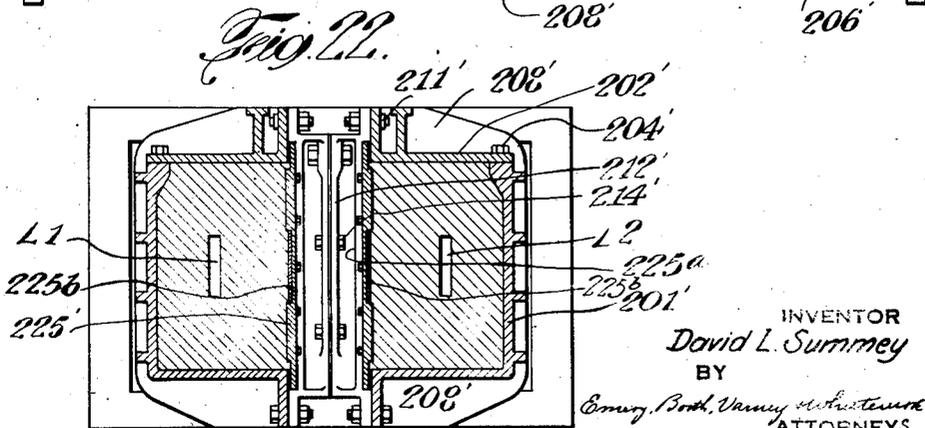
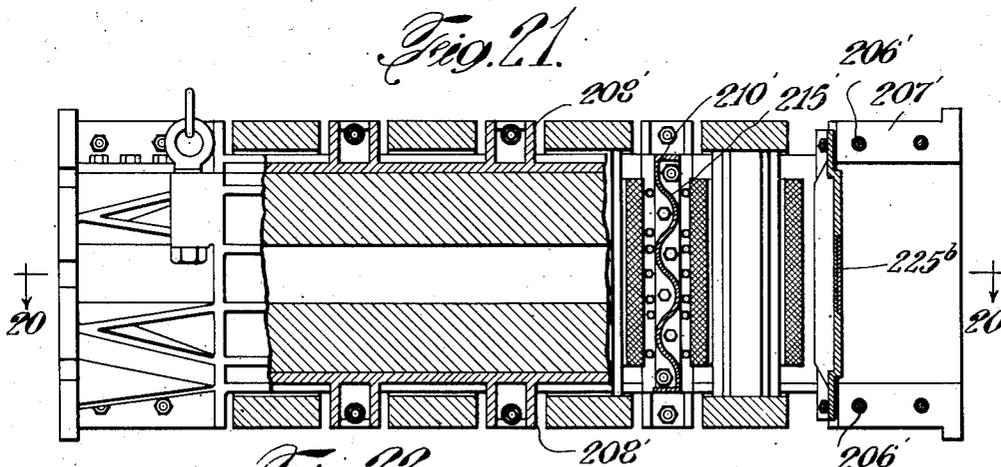
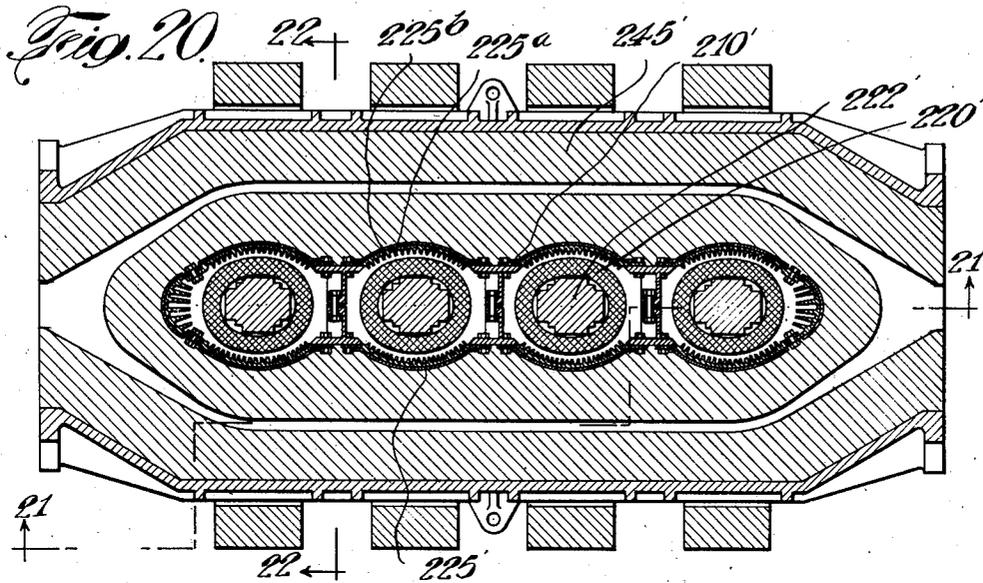
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2,060,136

ELECTRIC FURNACE

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Application March 5, 1932, Serial No. 596,980
Renewed February 21, 1935

28 Claims. (Cl. 13—26)

This invention relates to electric furnaces, more particularly to electric induction metal melting furnaces, and has for an object the provision of improvements in this art. This application is a divisional in part of my copending application, Serial No. 535,829, filed May 8th, 1931.

This application in certain aspects is also related to my copending applications, Serial Number 605,147, filed April 14, 1932, Serial Number 608,177, filed April 29, 1932 and Serial Number 619,474, filed June 27, 1932 and insofar as patentable subject matter may be disclosed but not claimed in the present application, it is claimed in the copending applications referred to.

The objects and advantages of the invention will be apparent from the following description and accompanying illustration of an exemplary embodiment of the invention. In the drawings:

Fig. 1 is an elevational view of the furnace, parts being broken away, looking at the pouring end;

Fig. 1a shows a support detail indicated at "a" in Figs. 1 and 4;

Fig. 1c shows a support detail indicated at "c" in Figs. 1 and 4;

Fig. 1e shows a support detail indicated at "e" in Figs. 1 and 4;

Fig. 2 is an elevational view, parts being broken away, looking at the right side of Fig. 1;

Fig. 3 is an elevational view, parts being broken away, looking at the charging end;

Fig. 3b shows a support detail indicated at "b" in Figs. 3 and 4;

Fig. 3d shows a support detail indicated at "d" in Figs. 3 and 4;

Fig. 3f shows a support detail indicated at "f" in Figs. 3 and 4;

Fig. 4 is a horizontal section taken principally on line 4—4 of Fig. 1;

Fig. 4a is a diagrammatic plan view;

Fig. 4b is a partial elevation looking at the left end of Fig. 4;

Fig. 4c is a horizontal section taken on the line 4c—4c of Fig. 4b;

Fig. 5 is a vertical longitudinal section taken on line 5—5 of Figs. 1 and 4;

Fig. 6 is a vertical longitudinal section taken on line 6—6 of Figs. 4 and 7;

Fig. 7 is a vertical transverse section taken on line 7—7 of Fig. 6;

Fig. 8 is a top plan view of a channel-transformer unit, parts being shown in section;

Fig. 9 is a horizontal section through the channel-transformer unit taken on line 9—9 of Fig. 11;

Fig. 10 is a vertical section taken on line 10—10 of Figs. 9 and 11;

Fig. 11 is a transverse vertical section taken on line 11—11 of Figs. 8, 9, and 13;

Fig. 12 is a transverse vertical section taken on line 12—12 of Figs. 8 and 9;

Fig. 12a is a diagrammatic view showing in superposed relation the cross sectional shape of the channel at several points which are indicated on Fig. 9;

Fig. 13 is a fragmentary section taken on line 13—13 of Fig. 11;

Fig. 14 is an end elevation of a detached channel-transformer section, certain parts being omitted;

Fig. 15 is a diagrammatic view showing the position of the furnace and metal level at the end of rocking movement in counter-clockwise direction, the view being taken looking at the pouring end of the furnace;

Fig. 16 is a similar view at the end of rocking movement in clockwise direction;

Fig. 17 is a similar view after a normal draught of molten metal has been poured from the right hand spout;

Fig. 18 is a diagrammatic view showing the position of the furnace when it is being emptied;

Fig. 19 is a plan view of certain mechanism employed for oscillating the furnace;

Fig. 20 is a horizontal section through a modified channel-transformer unit taken on the line 20—20 of Fig. 21;

Fig. 21 is a vertical section taken on the line 21—21 of Fig. 20; and

Fig. 22 is a transverse vertical section taken on the line 22—22 of Fig. 20.

Referring to the drawings and especially Figs. 1 and 2, two spaced hearths A and B are shown mounted on opposite ends of a rocking frame F supported upon a base cradle generally designated by the letter D.

As best shown in the lower portion of Figs. 1 and 2, the cradle D comprises a base plate 20 surmounted near the four corners thereof by two pairs of chairs 21 forming bearing supports for shafts 22, 23, 24, 25, at least one of which (25, as shown) may be a live shaft adapted to cause oscillation of the frame F. The shafts are each provided with a flanged roller 26 supporting parallel spaced arcuate rocker rails 27 of the rocking frame F.

The shafts 22 and 25 are mounted in fixed bearings while the shafts 23 and 24, as best shown at the lower right hand corner of Fig. 1, are mounted upon levers 31 which are pivoted inter-

mediate their ends by journals 32 upon the chairs 21. The ends of the levers 31 opposite the shaft-supporting ends are pressed downward by strong springs 33 adjustable by bolts 34 to press the rollers 26 firmly upward against the rocker rails 27 thereby causing them to take a portion of the load.

The power driven shafts 25 are equipped with pinions 35 rigidly secured thereon beyond the rollers 26. The pinions are in mesh with arcuate racks 36 which are rigidly attached to the rocking frame F adjacent the arcuate rocker rails 27. The two shafts 25 may be connected (see Fig. 2) by a flexible coupling 37; and one of the shafts—that one shown on the right or charging side in Fig. 2—may be connected by a similar flexible coupling 38 to a drive shaft 39 forming a part of the furnace oscillating mechanism later to be described. The frame F thus supported is adapted to have a controllable oscillatory movement about a definite horizontal axis indicated in the central portion of Figs. 1 and 2 by the letter Z.

The hearths A and B are generally cylindrical in cross section, as may be observed in Fig. 7, and each comprises an outer metallic shell 41 and suitable refractory interior lining which, as shown in Figs. 4, 6, and 7, includes a rammed refractory material 40 in the lower portion of the hearth, and at the upper portion of the hearth includes an outer layer of insulating material 43, an intermediate layer of rammed asbestos-containing material 44 and an inner layer of firebrick 45, the latter lining being shown in conventional section lines in all views except Fig. 2 where it is more particularly delineated.

The shell 41, as shown in Figs. 2, 4, and 6, comprises semi-cylindrical lower end castings 41a, 41b, semi-cylindrical upper end castings 41c, 41d, and semi-cylindrical lower and upper steel girth plates 41e and 41f, one of which 41e is secured to and embraced within the edges of the lower end castings 41a, 41b, as shown at the bottom of Fig. 6, and the other 41f is secured to and embraced within angle-bar straps 42 carried by the upper end castings 41c, 41d, as shown at the top of Fig. 6 and in Fig. 2. The end castings and girth plates meet their mating parts at approximately the horizontal central plane of the hearths, as shown in Fig. 7, and may be secured together by bolts or other appropriate devices acting upon flanges supplied on the mating parts.

As shown in the diagrammatic Figures 15 and 16, each of the hearths A and B is adapted to hold a pool of molten metal, these spaced pools being joined at several places (see Fig. 4) along the bottom by generally horizontal bodies of molten metal enclosed in refractory lined channels L, M, N, which in turn are enclosed by tubular metal casings. The casings comprise flanged tubular extensions 46 attached to the shells of the hearths, and central flanged tubular sections 51, hereinafter termed channel-transformer units, removably secured to the extensions 46 by bolts or set screws 54 passing through mating external flanges 47, 52 on the hearth extensions 46 and the units 51 respectively. Desirably the flanges are separated by insulation 55 and the bolts are separated from the flanges by suitable insulating sleeves and washers (not shown).

Since the tubular casings enclosing the channels L, M, N (Fig. 4) which join the hearths A and B and the hearths themselves are subject to expansion and contraction under varying degrees of temperature, means are herein provided for permitting movement of this assembly relative

to the supporting frame F. As shown near the mid-height of Fig. 1, the rocking frame F is formed with ledges 57 upon which the hearths are supported through lugs 61 secured to the sides of the hearths in any suitable manner. Insulating plates 62 and overlying metal plates 63 are preferably interposed between the adjacent faces of the frame ledges 57 and the hearth lugs 61, the insulating plates 62 serving to prevent electrical grounding to the frame F and the plates 63 serving to take the sliding movement between parts wherever present to prevent injury to the insulating plates. If desired, the hearths, the channel transformer units and other parts of the furnace may be directly grounded in any suitable manner.

As shown in Fig. 4, each of the hearths A and B is supported upon the rocker frame F at four points, the hearth A at the points a, b, c, d and the hearth B at the points c, d, e, f the supporting structures of the hearth B at the points c and d being the reverse duplicates of those for the hearth A at the points c and d.

The supporting structure at the point f for hearth B is best shown at the left of Fig. 3 and in Fig. 3f. Here the metal plate 63 is shown to have a circular boss 63a fitting within a larger socket formed in the supporting ledge 57, the insulating plate 62 being correspondingly cupped to fit the boss and separate it from the socket walls. Bolts 64 insulated by suitable sleeves and washers secure the plate 63 upon the ledge 57. A V-edged key 68 engages mating under-cut grooves formed in the plate 63 and in the hearth lug 61 respectively to prevent their separation, the key being retained by set screws 69. A second key 70 fits within mating grooves also formed in the plate 63 and the lug 61 and at right angles to the grooves for the V-edged key 68 to prevent endwise sliding movement, i. e. across the frame F, between the parts. In effect, the hearth B is rigidly fixed at the corner f and expansive movement of the furnace in any direction will originate at this fixed point. At every other point of support relative movement of appropriate character is provided between supported and supporting parts.

The joint d for hearth B and the joints d and b for hearth A which are aligned along one of the rockers of the frame F with joint Bf need to provide only for expansion in one direction, i. e., along the rocker. Accordingly, the joint d for hearth B is constructed as shown in Figs. 3 and 3d, the same construction serving for joint d of hearth A, which, as stated, is a reverse duplicate of that for hearth B. Here the plate 63 is insulated from and secured to the ledge 57 in the same manner as for joint Bf but is provided upon its upper surface with a rib disposed in a groove of the lug 61 for permitting expansion along the length of the rocker—i. e. toward the right, Fig. 3. The parts are restrained from vertical separation by a shoe 71 mounted upon and insulated from a cross-rocker channel beam 72. The beam is attached to an upstanding pedestal 73 of the rocker by suitably insulated bolts 74, the shoe being slidable upon the upper surface of the lug 61.

The joint at b for hearth A is shown in Figs. 3 and 3b to comprise a plate 63 mounted upon the ledge 57 as in joint Bf. The plate at joint b, however, has only the V-edged key 68 and in this instance the key is aligned with the rocker instead of across it, and is secured to the plate 63 by set screws 69, so as to provide for expansive

sliding movement in that direction but to prevent sliding movement across the rocker and also to prevent vertical separation of parts.

The joint at *e* for hearth B, shown in Figs. 1 and 1c is seen to be identical in all respects with the joint at Bf except that in the joint Be the key 70 is omitted to permit sliding movement transversely of the rocker.

Joint *c* for hearth B (and this applies equally to joint *c* for hearth A) must provide for sliding along two coordinates. As shown in Figs. 1 and 1c it has a thinner plate 63 than the joints previously considered but the plate is secured to and insulated from the rocker ledge 57 just as before.

The upper surface of the plate 63 is grooved transversely of the rocker to accommodate the lower rib of an auxiliary plate 65. The plate 65 on its upper surface is provided with a rib disposed at right angles to the rib on its lower surface and this upper rib slidably fits in a groove in the hearth lug 61. A shoe 71 mounted as that for joint Bd prevents vertical separation of parts.

Joint *a* for hearth A must also provide for sliding along two coordinates and, as shown in Figs. 1 and 1a, has like joints Bc and Ac a thin grooved plate 63 provided upon its upper surface transversely of the rocker with an undercut groove for the mating rib of an auxiliary plate 66. The latter upon its upper surface is supplied with an undercut groove facing a similar groove in the lug 61 for the reception of a V-edged key 68. The key may be retained in the plate 65 by set screws 69 or equivalent devices.

The hearth and channel assembly, i. e., the furnace proper, as thus mounted is fixed adjacent and behind the pouring spout but free to expand in all directions in a horizontal plane from the fixed joint Bf. Nevertheless, the assembly is firmly retained upon the rocking frame F regardless of the oscillating movements.

Resilient abutment means are provided at the end of the rocker frame remote from the point of fixed attachment between the furnace assembly and frame. Such means will permit expansion of the furnace assembly in that direction but will strongly resist the same and will partly support the lower hearth when the furnace is tilted to the extreme position for emptying shown in Fig. 18. This will reduce the strain which would otherwise be imposed upon the channel-transformer units and their connecting flanges.

The abutments comprise, (Figs. 4, 4b, 4c) heavy springs 75 disposed between the hearth A and an abutment 77. The abutment 77 is attached to the frame F by adjustable bolts 80. The springs 75 are mounted upon plungers 76 guided in the abutment 77, the ends of the springs opposite those engaged with the abutment 77 being engaged with a spring plate 78 connected to a longitudinal rib 79 fast on the side of the shell 41 of the hearth A. The plungers 76 and spring plate 78 are insulated from the rib 79 by sheet insulation 81.

In removing a channel-transformer unit the metal is first drained from the furnace as shown in Fig. 18. Then the furnace is returned to the horizontal position and one end of all units is suspended. The flange bolts for that end are removed. The bolts 80 are loosened to take tension off the springs 75. The hearths are next forced apart by any appropriate means. The other end of the unit which it is desired to remove is suspended and its flange bolts are removed. The unit is then pushed away from its hearth flange and lowered to the floor.

Means are herein provided for imparting to the furnace its required movements, whether for rocking to circulate metal through the channels (Figs. 15, 16), for tilting to pour metal in the normal operation of the furnace (Fig. 17) or for tilting to the extreme angle for emptying the furnace (Fig. 18).

As previously explained in connection with Fig. 2, the drive shaft 39 is connected to the shafts 25 which carry the driving pinions 35. Referring to Fig. 19, the shaft 39 is mounted in fixed bearings 85 and is driven from a jack shaft 86 mounted in fixed bearings 87 through a gear 88 on shaft 39 and a pinion 89 on the jack shaft. The jack shaft 86 in turn is driven by the low speed shaft 92 of a reduction gear train housed in a gear casing 93 through a gear 94 on the jack shaft and a pinion 95 on the low speed shaft.

On the high speed side of the gear train housed in the casing 93 there are two drive shafts 97 and 98, the one 97 being directly connected with the shaft of a tilting motor T through a flexible coupling 99 and the other 98 being connected with the shaft of a rocking motor R through means including a magnetic clutch 100, a second gear train housed in a gear casing 101, a shaft 102, and a flexible coupling 103.

The rocking of the furnace to circulate the metal may be quite slow relative to its tilting movement for pouring. Also the angle of movement may be quite small. So the motor R may be of relatively small power. But the tilting of the furnace for pouring must be quite rapid and requires a greater angle of movement so the motor T must be of relatively greater power. The use of two motors of different operating characteristics has been found to give more satisfactory results than could be obtained by the use of a single motor with the concomitant change-speed gearing entailed.

In operation, the magnetic clutch 100 is automatically engaged whenever the tilting motor T is off and the rocking motor R is on, and the rocking motor drives the free rotor of the tilting motor when it rocks the furnace. The gearing in both gear casings 93 and 101 is non-back-driving so the shaft 92 connected with the furnace is never turned except by operation of one or the other of the motors R and T. Limit and reverse means of any suitable type will be employed in connection with the motors T and R to control the movement of the furnace and such means will be adjustable to vary the points of stoppage and reversal as desired.

Referring especially to Figs. 6 and 7, each of the hearths A, B is provided at one end with a restricted charging opening formed with a raised breast 110, parallel sides 111 and an arched top 112. The breast is sufficiently high to retain a pool of molten metal of considerable depth in a basin thus formed within the hearth. The hearth casing at this end forms a frame comprising a sill 113 and parallel vertical sides (Fig. 4) having interior guide flanges 114 and exterior flanges 115 for retaining a vertically slidable door 116 over the aperture. The door when closed serves to seal the hearth gastight or sufficiently so for all practical purposes. Referring to Figs. 3 and 4, clamp bolts 117 threaded into the door retaining flanges 115 are provided for clamping the doors closely over their openings.

As shown in Figs. 4 and 6, the door 116 comprises an enclosing metal rim 120 flanged interiorly to retain a refractory lining such as fire brick or fire clay 121 and a front plate 122

which may be strengthened by grid ribs 122a. Exteriously the rim 120 may be provided with side ribs 123 cooperating with the flanges 115 of the frame to retain the door closely over the opening and in proper alignment at all times.

Suitable means are provided herein for actuating the doors 116. Referring to Figs. 2, 3, and 5, each hearth is surmounted at the end adjacent the door by spaced columns 130 attached to the hearth casing at their lower ends in any approved manner and held upright by inclined braces 131 attached to gusset plates 132 carried by the upper ends of the columns. At their lower ends the braces are attached to the casing of the hearth by suitable angle plates 133.

The columns 130 are provided adjacent their upper ends with bearings 135 rotatably supporting a transverse shaft 136 having rigidly secured thereupon a pair of end pulleys 137, a pair of intermediate pulleys 138 and a power pulley 139.

To the intermediate pulleys 138 (Fig. 2) there are attached, at a point 138a on their periphery, cables or chains 140 which are wound upon the pulleys and pass over the front side of the pulleys downwardly to points of attachment 141 with the door 116 which they support.

To the end pulleys 137 (Fig. 5) there are attached, as at a point 137a on their peripheries, cables or chains 143 which are wound upon the pulleys and pass over the rear side of the pulleys then downward and forward over idler pulleys 144, supported upon stub shaft 145 fast on the columns 130, to points of attachment 146 to balance weights 147 which partially balance the weight of the door. The weights may be guided (Figs. 3 and 4) within apertures formed in fins 149 of the hearth casing.

To the pulley 139 (Fig. 2) at a suitable point on its periphery, there is attached a cable or chain 152 which passes over the upper side of the pulley thence around a movable pulley 153 to a point of attachment upon a block 154 fixed to one of the inclined braces 131.

The movable pulley 153 is reciprocated to wind and unwind the cable about the pulley 139 by the piston rod 155 of a fluid pressure cylinder 156 secured by suitable mountings upon transverse girders 158 (Fig. 1) attached to the inclined braces 131. Desirably, as is also shown in Fig. 1, the braces 131 are angularly strengthened by cross strips 159.

When the furnace is to be charged the desired door is opened by admitting pressure fluid to the upper end of the cylinder 156 for that door, whereupon the piston rod 155 is moved inward carrying with it the movable pulley 153. One end of the cable 152 which passes over the pulley 153 is thereby pulled down and, this end being attached to the periphery of the power pulley 139 of the pulley shaft 136, causes left hand rotation of that shaft (as viewed in Fig. 2). Since the door supporting cables 140 which pass over the intermediate pulleys 138 are wound in the same direction as the power cable 152 is wound over the power pulley 139, the door is raised by left hand rotation of shaft 136. When pressure is relieved from the cylinder the door returns to closed position.

Means are provided for drawing off molten metal from the furnace. Such means (Figs. 1, 2, and 4) are provided at the end of the hearth or hearths opposite the charging doors. The furnace is adapted and intended to be used for the production of metal of extremely high quality, especially with respect to its freedom from

oxygen and oxides. For example, it may be used for producing oxygen-free copper. For such use there is provided a structural housing or enclosure to exclude atmospheric air from the molten metal between the place where it becomes molten and the place where it becomes solidified. This furnace may be utilized in a plant such as that shown in my copending application Serial Number 535,829, filed May 8, 1931, or may be used to supply purified metal directly into molds. Herein the furnace is illustrated as a unit of a plant.

The pouring opening for the hearth B, Figs. 1, 2, and 4, is provided with a spout 166 which is enclosed by a hood 167 belonging to another unit of the plant. There is relative movement between the spout 166 of hearth B and the hood 167 so a bearing plate 170 which is sealed about the spout 166 is resiliently pressed against the end of the hood 167 to accommodate the movement and keep the space closed off.

The throat to the spout 166 slopes upward and a baffle 173 extends downward to isolate the metal in the spout from that in the furnace. This not only prevents the passage of gases but also prevents escape of the material which covers the metal pool in the furnace. Since the metal in the spout becomes isolated from the main body of metal in the furnace it may tend to solidify to some extent by cooling. The spout is not conveniently accessible because of the enclosing hood, so if incrustations of metal are formed in the spout it is difficult to remove them. It is, therefore, desirable to heat the metal as it flows through the spout. For this purpose resistors 174 are mounted in a space above the spout. They are supplied with current through resilient electrodes 175. The resistors are composed of a non-metallic material such as silicon-carbide and are subject to injury by splashing metal. Oxygen-free copper is especially likely to splash and attack them. To prevent this a thin sheet 176 of earthen material such, for example, as alundum is placed between the resistors and the stream of metal. The heat is transmitted through the plate to the metal.

Means are provided for automatically or manually controlling the supply of current to the resistor heaters 175 as well as to the large induction heaters for the channels by thermoelectric devices acting in response to the heat produced by the heating units. Automatic regulators of this character are disclosed in my copending application, Serial Number 535,829. One of the thermostats 179 of the temperature control apparatus is shown in Fig. 6.

As previously explained and as best shown in Figs. 4, 5, and 15, the basins of the hearths A and B are joined by a plurality of elongated channels L, M, N enclosed within a casing of a channel-transformer unit 51, whereby the spaced pools of metal in the hearth basins are connected by generally horizontal bodies of liquid metal in the channels, each channel being divided to form a loop around the middle legs of the transformer cores. The central one of these units (Figs. 4 and 5) is disposed between the rocker rails 27 of the frame while the two outer units are located outside the rockers.

All of the channels may, if desired, terminate (Fig. 4) within the hearths in a shallow longitudinal trough 177 formed in the bottom of the hearth basin. This provides that the ends of the channels will be connected by a body of

molten metal even though there may be only a small quantity of metal in the hearth. It also provides that the ends of the channels will not be stopped up when a heavy charge of solid metal is introduced, even though it settles to the bottom of the pool of molten metal. The narrow trough prevents the unmelted metal from settling upon the ends of the channels. In Figs. 6 and 7 it is seen that the lining material at the bottom of the hearth is built up from within the circular outline of the hearth chamber on either side of the longitudinal vertical plane to form the trough. Intersecting the trough 177, a plurality (two as shown) of transverse gutters 178 are formed in the built up hearth basin, the bottoms of these transverse gutters being curved and disposed in the circular inner surface of the hearth. Thus by tilting the furnace sufficiently (Fig. 18) metal will be drained from the transformer channels and even from the trough 177 into the lower ends of the gutters 178 to completely empty the furnace.

An auxiliary pouring spout opening 180 (Figs. 15-18) is provided for use when the furnace is to be completely drained. The opening leads to the outer ends (lower end in Fig. 18) of the transverse gutters 178 in the hearth basin which is the lowest point when the furnace is tilted. The opening is normally kept completely filled with fire clay or similar material which may be punched out when the opening is to be used. In order to permit the plug to be removed quickly—and this is necessary since it must be removed while the furnace is tilted to the opposite side and before the metal has had time to freeze—it is formed of a thin inner layer of refractory material such as aluminum brick or a rammed sand and a soft outer layer such as crushed insulating brick. A metal cap 181 covers the outer end of the opening.

As explained above, special precautions are taken to keep the molten metal of the furnace out of contact with an oxidizing atmosphere. Air is excluded from the furnace by having the charging doors fit closely and keeping them closed except when it is necessary to open them for charging, as well as by keeping all other openings closed against the entry of atmospheric air. Additional means are provided for keeping a treating and/or protecting atmosphere in at least one of the hearths if desired. As shown in Fig. 2, hearth B at the top is provided with a plurality of nipples openings 182 for the injection of the desired gas, for example, carbon monoxide, nitrogen or such other neutral or de-oxidizing gas as may be appropriate to give the desired treatment or protection to the molten metal. Also a de-oxidizing or protecting covering such as carbon may be maintained over the bath of metal in one or both of the hearths. Carbon is preferred because it leaves no objectionable residue in the metal.

Before metal is put into it the furnace is thoroughly heated throughout the chambers and channels. This is in addition to the heating to bake the linings. For example, the furnace may be sealed up and heated alternately in opposite hearths by oil burners. Hot gases pass through the channels and are removed from the unheated hearths by suction conduits 184a, 184b provided with suitable dampers.

Molten metal may be supplied for starting the furnace. The hearths and channels will be thoroughly preheated, as described, before the metal is introduced. If desired, molten metal may be

charged exclusively, the furnace merely refining it.

Means are herein provided for starting the furnace when molten metal is not available for this purpose. This may be accomplished by tilting the furnace far over on one side and melting metal by the oil burners in the lower hearth. The hot gases pass through the transformer channels and heat them as in preheating. After the metal has been thoroughly melted the furnace is turned back to normal position to cause the metal to flow into the connecting channels and through them into the other hearth. The current is now supplied to the primary coils of the transformers to keep the metal in the channels molten. After starting the oil burners will be removed and the suction openings closed up as by plugging them.

Means are provided for withdrawing hot gases from the suction conduits 184a, 184b and from about the charging doors. If cathodes are charged the latter are not needed but may be needed if scrap metal is charged because the latter may contain grease and other combustible material. As shown in Figure 5 a conduit 183 is connected by a turning joint with a conduit 184 fixed to the ends of the cross channel beams 72. The center of movement is in the axis of oscillation Z of the furnace. The conduit 184 is connected with the branch conduits 184a, 184b and with other branch conduits 184c, 184d leading to open hoods at the charging door openings for the hearths A and B respectively (Fig. 3).

There are, as previously mentioned and as shown in Figs. 4 and 5, three channel-transformer units, one for each phase of a three-phase alternating current supply circuit. Further, each channel-transformer unit comprises a plurality of distinct transformer elements arranged along the length of the channel. In the present embodiment there are four such elements, each including a primary winding 220 and a core 222. The channels L, M, N (Fig. 4) are divided into pairs of secondary channels L1, L2, M1, M2, N1, N2, each pair being separated sufficiently to accommodate the coils of the transformer elements.

This general arrangement is believed to have distinct advantages both electrically and mechanically. An enumeration of all such advantages together with a detailed technical explanation of their origin is not thought to be in keeping with the purposes of the present description but a few of the advantages may well be briefly noted. The provision of a number of transformer elements distributed over some length of the molten metal secondary channel instead of a single large element provides easier cooling of the transformer elements; permits closer association of primary and secondary conductors; allows some of the elements to be shut off in case it is not desired to melt actively but merely to maintain the molten state or to prevent freezing in the channels; permits the design of a more rigid and substantial casing in which, for example, the parts housing the separated secondary channels may be braced together between each element; renders the handling of the elements easier; and makes the replacement of disabled elements less expensive.

Besides being attached by flanges at their ends the channel-transformer units are further supported, as seen in Fig. 5, by eye bolts 185 supported in whole or in part by longitudinal beams 186 attached (Fig. 4) beneath the cross-rocker

beams 72 mentioned above. The bolts 185 support the channel-transformer units through apertured lugs 186 formed integral with the latter. This suspension permits free horizontal expansive movement of the furnace proper from the corner B/ as an origin point, the bolts either swinging about their supports if the expansive movement is along the rockers or bending slightly if the movement is across the rockers.

The transformer elements may be cooled by air. A conduit 190 (Fig. 5) receiving a supply of air from any suitable source, is connected by a turning joint with a horizontal header 191 supported across the top of the rocker frame F. The center of movement is in the axis of oscillation Z of the furnace. Branch conduits 192 opening beneath the header 191 supply air to spreaders 193 disposed above each of the channel-transformer units. The spreaders are provided with discharge openings 194 for directing air upon the cores and primary coils of the heating units.

Referring to Fig. 5, aprons 186 at the ends of the furnace protect the channel-transformer units from injury by moving machines, by material falling from cranes, and the like. These aprons are secured to the ends of the cross-rocker beams 72 and their castings may comprise portions of the conduits.

One of the three channel-transformer units 51 is shown in detail in the enlarged views 8 to 13 inclusive. The enclosing casing of the unit, by reference to Figs. 8 and 12, is seen to comprise two major side-and-bottom-forming shells 200 of non-magnetic metal such as bronze fitting together at their ends along the meeting edges of the flanges 52 (previously described) and at their bottoms along vertical flanges (similar to flanges 207 for the top shells to be described presently) which extend for a short distance back from the end flanges. The bottom shells are spaced apart intermediate their ends to receive the transformer primaries and cores. Insulating plates 201 and insulation for the clamping bolts 206 electrically separate the two shells along their joints. Mating covers 202 close the top of the casing. These covers are secured to the shells 200 along their outer edges by cap bolts 204. They fit together at their ends (forming a part of the flanges 52) and at their tops along vertical flanges 207 which extend for a short distance back from the end flanges. They are secured together by bolts 206 passing through the flanges 207 thereon. Insulating plates 203 and insulation for the joining bolts electrically separate the two parts of the cover. The covers are spaced apart intermediate their ends like the bottom shells for the reception of the central legs of the transformer cores and the primaries.

At several points (Fig. 8) along their spaced intermediate portions, the bottoms of the shells 200 and the covers 202 curve inward toward the central vertical plane and at these convergent points (Fig. 11) they are provided with transverse strengthening ribs 208. At these places the mating parts of the shells and covers are united by spacers 210, the spacers and the parts united thereby having flanges taking bolts 211 for this purpose.

The spacers 210 fit together along flanges 212. They are electrically separated by insulating plates 213 and held together by insulated bolts 214 which pass through the flanges 212, the bolts being disposed (Fig. 13) on alternate sides of sinuous webs 215 composing the intermediate portions of the spacers 210.

Again reverting to Fig. 8, the casing between the spacers 210 widens in oval shape for the accommodation of the oval-shaped primary coils 220 and the central legs 222 of the closed E-shaped transformer cores 221 which fit within the primary coils.

Interiorly the enclosing casing comprises (Figs. 9, 10, 11, 12) curved shell plates 225 of non-magnetic metal fitting along their upper and lower edges within notches 226 formed in the covers 202 and in the bottom the shells 200. Over the inner faces of these curved shell plates protecting sheets 227 of high melting point metal, for example, non-magnetic steel, are secured to prevent molten metal ever reaching the transformer coils in case the lining and other parts of the casing should be melted.

Curved retaining strips 230 hold the shell plates 225 and the protecting sheets 227 in position around the transformer openings. The ends of the protecting sheets 227 are held between the plates 225 and the spacers 210, as seen in Fig. 9, and are fastened to the spacers by bolts 231 provided with heads which are countersunk into the sheets 227.

At each end opening of the channel-transformer unit the sheets 227 are electrically separated by plate insulation 232 and are held together by insulated bolts 233.

In Fig. 11 terminals 235 for attachment of electrical conductors are shown. These terminals are insulated from the casing and are attached thereto by bolts 236 which are also insulated. The connections between the terminals and the transformer primaries are not shown.

The casing as thus constructed provides a divided enclosure for the secondary channels L1 and L2, or M1, M2 or N1, N2) and a converging enclosure at each end for the common channel L. It is also seen that the two halves of the casing are electrically insulated from each other so that no appreciable eddy currents may be set up in them. The entire enclosing casing, as stated, is of nonmagnetic material.

The channels for metal, if not rammed up of continuous material, may be formed (Fig. 9) by refractory branch conduit blocks 240 and junction conduit blocks 241. The blocks are held at their joints by alternate side lugs 242 and edge lugs 243 on opposite ends of the blocks. The joints may be cemented by any suitable plastic substance to make the channels fluid tight.

The refractory blocks may be enclosed in a rammed bed of fire clay, asbestos cement, or other heat resistant insulating material as indicated by the numeral 245. The latter may be at least partially enclosed by a second layer of heat resistant insulating material 246. In some of the views such as Figs. 9, 10, and 14 the rammed material is omitted in order to show the other parts more clearly.

The channels, as shown in Figs. 9 and 12a, are rectangular along their straight secondary portions, the greatest diameter being vertical, then become vertically elliptical as they approach the junction points, and then in the single channels become somewhat elliptical horizontally. The secondary channels, though varying in shape remain of uniform cross sectional area throughout their length. The elliptical shape toward the junctions reduces radiation of heat from the molten metal. The area of the single end channels is considerably greater than the combined cross-sectional areas of the two secondary chan-

nels. This promotes smooth flow of metal from the secondary heating loop to the hearths. Here it may be particularly noted that all of the heating takes place in the secondary loops and none in the single channels. The electrical heating circuit therefore does not depend upon the maintenance of metal in the hearths or in the channels leading thereto and the secondaries are so located that they will always remain filled in all normal operations of the furnace. There are also other advantages in the selected construction.

The junction block, as shown in Figs. 9 and 10, may project from the end of the enclosing casing to form a joint with a mating conduit block in the tubular extension 46 of the hearth, the projection, however, being only slight—for example, half the thickness of the joint insulation—so as to offer no obstruction to the insertion or removal of the channel-transformer unit. The end joints are not illustrated in detail since their formation may be fully understood by reference to the above described construction.

A channel transformer unit constructed as described above is easy to assemble. The channel linings and surrounding rammed insulation may, for example, be placed in the assembled side and bottom shells 200 before the covers 202 are put on. This not only facilitates thorough packing of the lining but permits ready inspection to insure that the work is well done. Inasmuch as leakage of molten metal usually necessitates the stoppage of an electric furnace for replacement of the lining it will be understood that the thorough packing of the channels is a matter of extreme importance.

Not only is the unit designed for convenient assembly whereby ready inspection may assure a good channel lining but the metallic structure of the unit is designed to furnish the maximum support to the lining. This permits the use of a thin lining which places the primary coils at a minimum distance from the molten metal secondary yet furnishes ample protection for the primary coils.

Further, the high melting point sheets 227 placed immediately around the primary coils will prevent molten metal reaching the coils even in case the curved shell plates 225 should be melted by molten metal escaping through fissures in the channel lining. Here it is to be noted that the sheets 227 are bolted directly to the spacers 210 and the spacers are positioned inside the sheets where the danger of being melted is small.

A modified channel-transformer unit is illustrated in Figs. 20 to 22. This modified unit is identical in all respects with the unit already described in most of its parts so these parts are here designated by the same reference numerals as they are in the preceding figures except that a prime (') is added. Thus there are found the bottom shells 200' covers 202', their securing cap bolts 204', etc.

The channel lining material 245' is disposed directly about the channels and the preformed refractory blocks are not employed. The refractory lining material may, for example, be rammed up about shaped cores which are later melted, burned or removed in some other appropriate manner. Preferably a form is used which will burn out completely and leave no obstruction in the channels. For example, a built up hollow laminated wooden core may be wrapped with sheet celluloid until the channel shape is produced. Later resistance ribbons are threaded

through the form and heated by current to ignite the form. The channel shape is the same as that for the first form. This is of such a nature that it permits a full view of the straight sections of the secondary channels by holding a mirror at the end of the straight section, placing a light at the remote end of the channel and sighting through the other end of the channel.

Another departure of the modified channel-transformer unit from the one already described is found in the interior shell plates 225'. The heat which is generated in the molten metal secondary in the channels is very intense. The primary coils according to the present invention have been placed very close to the hot molten secondaries for higher efficiency. The tendency is for the primary coils to become overheated so air cooling means have been provided for the primary and the adjacent parts of the channel enclosing shell. The cooling air may convey away considerable heat, which is an operating loss, but the loss from this cause is overbalanced by the benefits gained by having the primary and secondary close together. Further, a safer and more permanent construction of the entire unit is realized.

It may occur, however, that smooth-surfaced shell plates may not radiate heat fast enough, even when air is forced past them, to keep from buckling, melting or permitting excessive heating of the primary coils. The plates 225' are therefore modified by providing vertical fins 225a thereon. Air entering above the unit may flow down along and between the fins giving the best possible cooling effect. Preferably the fins are machined on the plates rather than cast thereon so as to give a clean active surface upon which the cooling air may impinge. Manganese bronze metal is thought to be best for making the plates because it is strong and has good radiating qualities, i. e., high conductivity of heat.

The upper and lower retaining strips 230 are not used with the ribbed plates for these plates are rigid and strong enough to take the fastening bolts directly.

The ribs of the two opposite end plates are considerably wider than the ribs of the side plates. This gives greater radiation near the junction of the branch channels where the heat is greatest.

Directly between the primaries and molten metal secondaries the plates 225' are recessed on their outer sides and in these recesses are secured strips 225b of non-magnetic steel having a high melting point. Small bolts (not shown) may constitute the means for securing the steel strips to the bronze plates. If a crack develops in the channel lining it is most likely to develop in a line between the channel and the primary, in which case escaping metal would first come into contact with the high melting point steel strips and be checked, thus protecting the bronze cooling plates and the primaries.

As best shown in Figs. 10 and 14, lifting lugs 250 are formed on the casings of the channel-transformer units and to these lugs lifting links 251 are secured by eye bolts 252. For convenient lifting of the units (Figs. 1, 2, 3, and 5) a superstructure comprising vertical columns 255 resting on the frame F and top beams 256 may be provided for mounting block and tackle, power hoists or other like apparatus. The superstructure may be braced by cross bars 257 and angle braces 258. The units are lowered from their attached positions down between the rockers and

new units are raised into position in the same way.

The operation of the furnace will vary according to the kind of metal which is treated and the function which this furnace is designed to have in the entire plant. In any case, however, it will be rocked from side to side by the rocking motor to circulate metal through the secondary heating channels. There it is heated inductively and when it reaches the hearths will melt fresh charges of solid metal placed therein. Inasmuch as mechanical circulation is employed no reliance need be placed upon electrical effects for producing circulation.

Metal may be charged at either or both doors and while the doors are usually kept closed, particularly if a treating gas is maintained in the hearths, there is no harm in having them opened from time to time if a carbon covering is maintained upon the pools of metal in the hearths. The doors may be sealed by the devices herein provided for that purpose when they are kept closed long enough to warrant it. When metal is to be poured the rocking motor is stopped and the tilting motor is started. Normally the furnace will be tilted to pour metal through the hood-enclosed spout of hearth B. When the furnace is to be shut down or when a channel-transformer unit is to be removed the furnace is tilted far enough toward the hearth A to drain all the metal through the opening 180 as previously explained. Some of the pouring hood parts may be removed to permit of this movement. After the furnace is restarted it is again put under the influence of the rocking motor.

From the above description it will be apparent that the improved electric furnace in its design and operation has many practical advantages. It will produce metal in a highly purified state; is easy to operate; may without any material change in design be built either in small or very large sizes, the one illustrated having a holding capacity of thirty tons of copper. It has heretofore been considered impossible to operate large induction furnaces for non-ferrous metals but the present furnace has produced hundreds of tons of copper at a single run and at times at the rate of five tons per hour. The copper produced was also of a superior quality heretofore thought impossible of production by commercial methods. It also provides a very strong and efficient transformer heating arrangement; permits convenient and effective relining of the channels of the units; and in numerous other respects constitutes a distinct advance in the art.

The invention, however, is not limited to the exact embodiment described but may have various other embodiments within the scope of the subjoined claims.

I claim:

1. In an electric furnace in combination, a tiltable frame, a furnace assembly mounted upon said frame, connecting means between said assembly and frame designed to allow movement of the assembly relative to the frame under expansion and contraction but maintaining it securely against removal from the frame in all tilted positions, said connecting means comprising a corner joint rigidly securing the assembly to the frame, joints permitting slidable movement in one direction along each of two coordinates through said fixed joint, and joints at other places permitting slidable movement in any direction in the plane defined by the two coordinates and the fixed joint.

2. In an electric furnace, in combination, a tilting frame, a furnace assembly mounted on said frame, and means to retain said assembly upon and insulate it from said frame while permitting free expansive movement thereon, said means comprising a plurality of joints each including an insulating plate and a metal plate for preventing injury to said insulating plate.

3. In an electric furnace, in combination, a tilting frame, a furnace assembly mounted on said frame and means to retain said assembly upon and insulate it from said frame while permitting free expansive movement thereon in all horizontal directions from a given fixed point of support, said means comprising interfitted and interengaging support joints, each of which except the joint at the fixed point including parts having relative sliding movement.

4. In an electric induction furnace, in combination, a supporting frame, two spaced hearths mounted on said frame, a plurality of channel-transformer units attached to and supported by said hearths, said hearths each being supported upon said frame in four spaced joints, one of said joints forming a fixed anchor for the hearth at that point, one of the joints permitting sliding movement transversely of the frame in a coordinate through said fixed joint, three of said joints permitting sliding movement longitudinally of the frame in a coordinate through said fixed joint, three of said joints permitting sliding movement either transversely or longitudinally of said frame, and all of said joints preventing vertical separation of the hearths from the frame.

5. In an electric furnace in combination, a supporting frame, a hearth rigidly secured thereto in at least one point, a second hearth mounted on said frame so as to be freely slidable rectilinearly from and toward said first hearth, channel casings rigidly connecting both of said hearths, said casings serving to attach said hearths positively together and to take part of the strain imposed by the weight of the second hearth when it is disposed below the first hearth, said casings being freely movable in response to any movements of the hearths, said furnace being tiltable toward said second hearth, and resilient means urging said hearths toward each other.

6. In an electric furnace in combination, a supporting frame, a hearth rigidly secured thereto in at least one point, a second hearth slidably mounted on said frame so as to move rectilinearly from and toward the first hearth, and channel casings rigidly connecting both of said hearths, said casings serving to attach said hearths positively together and to take part of the strain imposed by the weight of the second hearth when it is disposed below the first hearth, said casings being freely movable in response to any movements of the hearths.

7. In an electric furnace, in combination, a flattened oval secondary channel loop for molten metal, a refractory lining for said loop, a metal casing for said channel providing openings within the loop for a plurality of transformer elements, and rigid metal spacers bracing said casing between the openings.

8. In an electric furnace, in combination, a flattened oval channel loop for molten metal, a protecting metal casing for said channel providing oval openings within the loop for a plurality of oval transformer elements, and rigid metal spacers bracing said casing between the openings.

9. A channel transformer casing for an electric induction furnace comprising a bottom-and-

side shell having a central bottom opening therein, a cover having a corresponding opening therein, a plurality of curved plates secured between said bottom and cover and together with the openings of the bottom and cover forming walled passages for the reception of transformer elements, rigid spacers between said casing passages at the adjacent edges of said curved plates, a sheet of high melting point material over each plate held at its ends between said curved plates and spacers, and retaining strips about the ends of said openings bolted to the bottom shell and cover respectively for retaining the edges of said plates and sheets.

10. Apparatus of the character described comprising in combination, a metal furnace, means supporting said furnace for oscillation, said furnace having a plurality of pouring openings, one of said openings extending into said furnace at the lowest point when the furnace is tilted toward the opening for completely draining the metal, said draining opening being plugged during normal operation of the furnace, the plug comprising a thin refractory interior section and a thick soft easily removable exterior section.

11. In a molten metal electric furnace in combination, a pair of spaced horizontally cylindrical hearths connected by metal channels mounted for oscillation to cause the metal level to vary in said hearths, a pouring spout in the head of one of said hearths, said spout being tapered upwardly, and a baffle extending downwardly toward said spout sufficiently to seal the outer end of the spout at the surface of the metal in all normal movements of the furnace.

12. An electric induction furnace comprising casing walls forming a channel for molten metal, the channel being intermediately divided to form an elongated loop-shaped secondary channel, and a plurality of cooperating transformer elements each including a core leg and a primary coil disposed between the spaced sides of the secondary channel and along the length thereof.

13. An electric induction furnace comprising a channel for holding a body of molten metal joining bodies of metal at each end, said channel being divided intermediately its length to form an elongated loop-shaped secondary channel, the sides of said secondary channel being substantially parallel throughout the greater part of their length, and a plurality of transformer elements spaced along and between the sides of the secondary channel.

14. In an electric induction furnace, in combination, basins for holding pools of molten metal, and a plurality of channels joining said basins for carrying bodies of metal connecting the pools, each of said channels comprising a loop-shaped portion forming a transformer secondary, and means for heating metal in the loop portions of said channels.

15. A channel transformer casing for an electric induction furnace comprising an elongated metal shell enclosing an elliptical shaped channel loop and having an opening between the sides of the elliptical shaped channel for the reception of a heating transformer primary, and shell plates forming a wall about said opening, said plates being provided with cooling ribs and the plates near the ends of the loop having deeper ribs than the plates on the side.

16. A channel transformer unit for an induction electric furnace, comprising lining forming

an elliptical shaped secondary loop channel and end channels extending therefrom, said loop channels varying in shape from vertically deep rectangular at the center to thick elliptical at the ends.

17. Apparatus as set forth in claim 16 in which said end channels are each of more than the combined areas of the loop channels.

18. Apparatus as set forth in claim 16 in which said end channels are each of horizontally extended elliptical shape and of greater area than the combined areas of the loop channels.

19. A channel transformer casing for an electric induction furnace comprising a metal shell forming the outside of the channel casing and providing an intermediate opening for a primary coil, bronze shell plates forming a wall about said opening, and thin non-magnetic steel bands secured upon said bronze plates at the region of the channel location.

20. A channel transformer casing for an electric induction furnace comprising a metal shell forming the outside of the channel casing and providing an intermediate opening for a primary coil, shell plates provided with cooling fins forming a wall about said opening and a belt formed of strips of a high melting point metal disposed on the cooling plates to protect them from metal escaping from the channel.

21. A channel transformer casing as set forth in claim 20 in which said strips are recessed into the channel facing side of the cooling plates.

22. In an electric furnace, in combination, a supporting frame, a hearth assembly comprising two spaced hearths rigidly connected by a channel casing resting upon said frame, one of said hearths being rigidly attached to the frame in at least one point and the other hearth being slidable away from and towards the first hearth, and resilient means opposing the sliding movement of said second hearth away from the first hearth, said means including abutments on said frame and second hearth and coil springs disposed between said abutments.

23. In an electric furnace, in combination, a supporting frame, a hearth assembly comprising two spaced hearths rigidly connected by a channel casing resting upon and insulated from said frame, one of said hearths being rigidly attached to the frame in at least one point and the other hearth being slidable away from and towards the first hearth, and resilient means opposing the sliding movement of said second hearth away from the first hearth, the connection between said hearths and frame being established by a plurality of sets of insulating plates and metallic retaining devices, and said resilient means including a spring acting upon abutments on the second hearth and on the frame, there being an insulating plate and metal plate separating the hearth and frame at one end of the spring, whereby movement and insulation between the hearth and frame are provided without direct wear on the insulation.

24. In an electrical furnace, in combination, two spaced chambers adapted to contain pools of molten metal, a substantially horizontal secondary channel connecting said chambers, said channel including an intermediate elliptical loop-shaped portion which constitutes the complete path of the secondary circuit and single-duct end portions connecting the ends of the elliptical portion with the chambers, and electric induction heating means for said channel disposed within said loop-shaped portion thereof, said heating

means being elongated in a plane parallel with the longer axis of said loop-shaped portion for the purposes set forth.

25. Apparatus as set forth in claim 24 further characterized by the fact that the single-duct end portions of the channel are inclined upwardly between the ends of the loop-shaped portion and the larger bodies of metal.

26. Apparatus as set forth in claim 24 further characterized by the fact that the sides of the loop-shaped portion of the channel are straight and substantially parallel throughout the greater part of their length.

27. Apparatus as set forth in claim 24 further characterized by the fact that said induction

heating means comprise a plurality of primary coils and cores aligned with the longer axis of said loop-shaped portion of the channel, each of said coils surrounding that section of each of said cores which is disposed between said loop-shaped portion of the channel.

28. Apparatus as set forth in claim 24 further characterized by the fact that said induction heating means comprise a plurality of elliptical primary coils surrounding elongated core sections, the longer axis of said elliptical coils and elongated core sections being aligned with the longer axis of said loop-shaped portion of the channel.

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