Jan. 26, 1954 L. DREYFUS ET AL 2,667,524

INDUCTION HEATING FURNACE

Filed Dec. 29, 1950 5 Sheets-Sheet 1

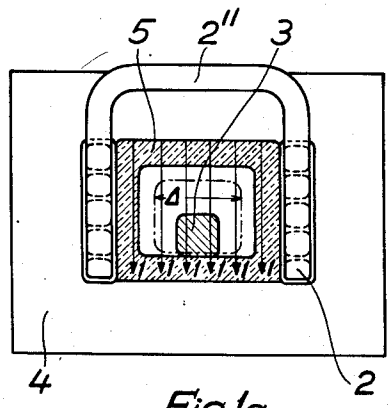


Fig.1a

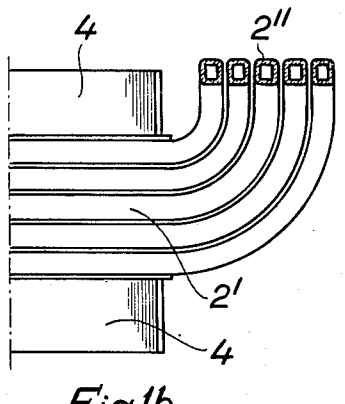


Fig.1b

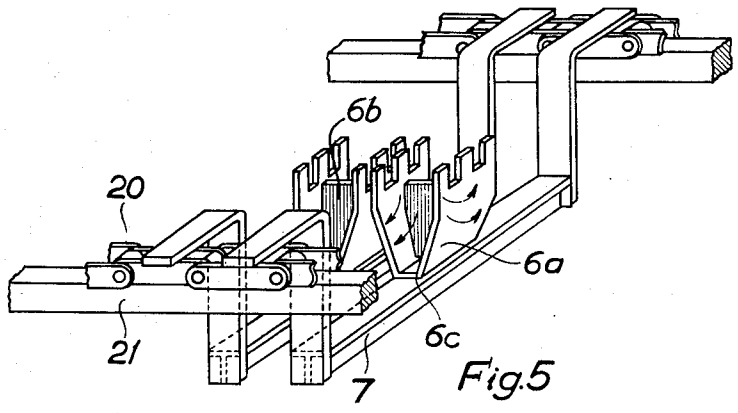


Fig.5

Inventors
Ludwig Dreyfus
Thor Thelemarck
Ivar Beckius and
Hugo Lindström
By Cameron Dixon
Attorney.

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INDUCTION HEATING FURNACE

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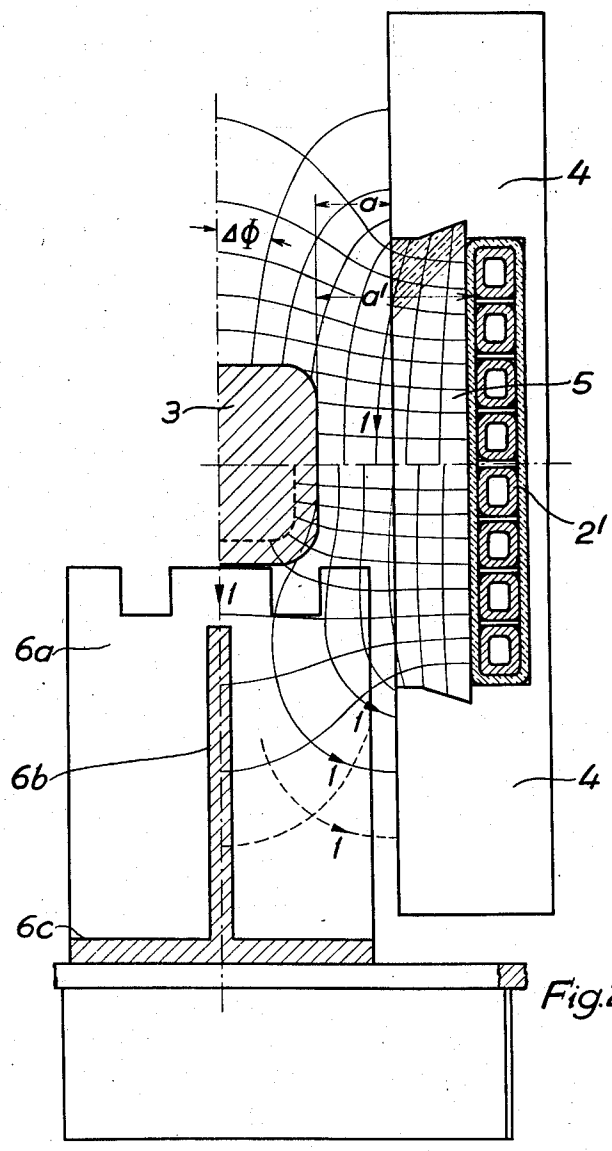


Fig.2a

Inventors
Ludwig Dreyfus
Thor Thelemarck
Ivar Beckius and
Hugo Lindström
By James Aikon
Attorney.

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INDUCTION HEATING FURNACE

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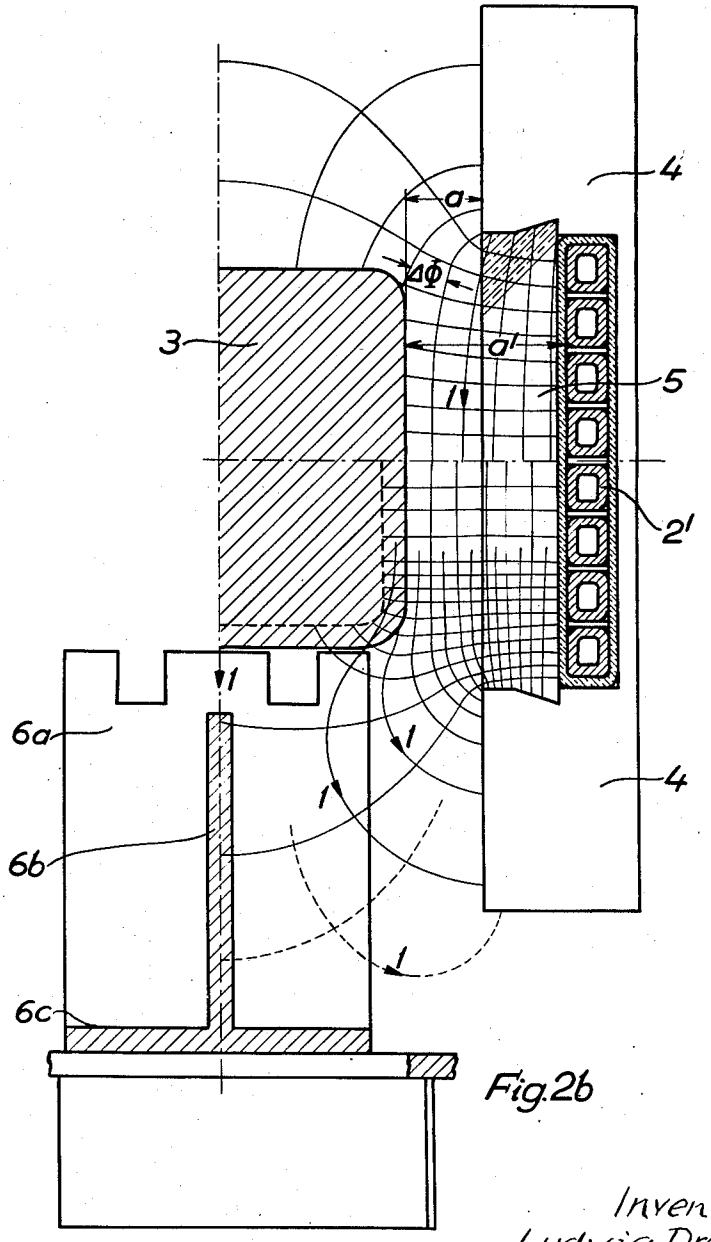


Fig.2b

Inventors
Ludwig Dreyfus
Thor Thelemarck
Ivar Beckius and
Hugo Lindström
By Owen Dixon
Attorney.

Jan. 26, 1954 L. DREYFUS ET AL 2,667,524

INDUCTION HEATING FURNACE

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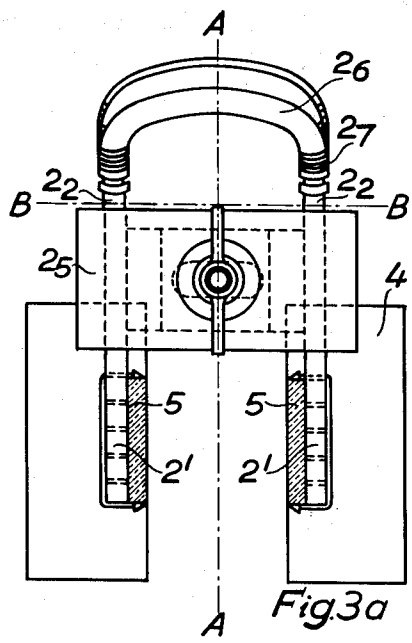


Fig.3a

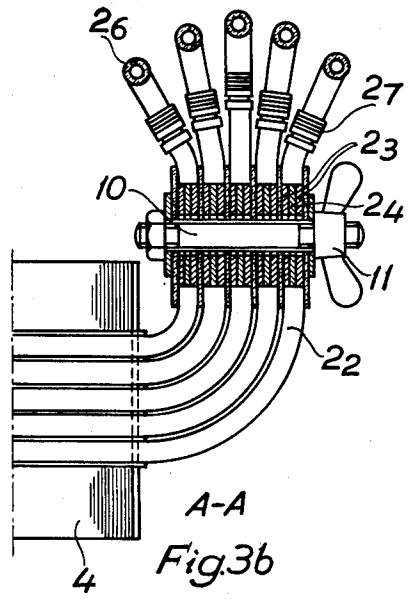


Fig.3b

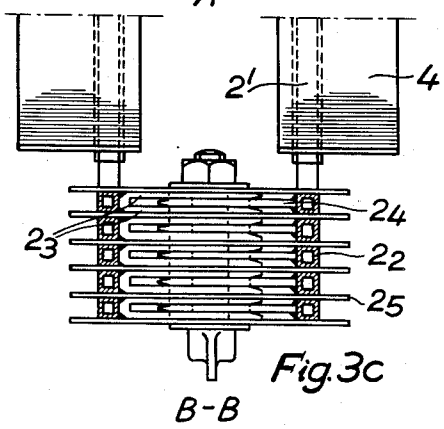


Fig.3c

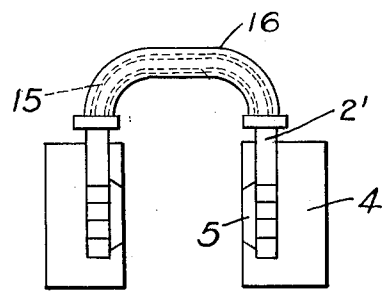


Fig.6.

Inventors
Ludwig Dreyfus
Thor Thelemarck
Ivar Beckius and
Hugo Lindström
By Eaton & Cikon
Attorney.

Jan. 26, 1954 L. DREYFUS ET AL 2,667,524

INDUCTION HEATING FURNACE

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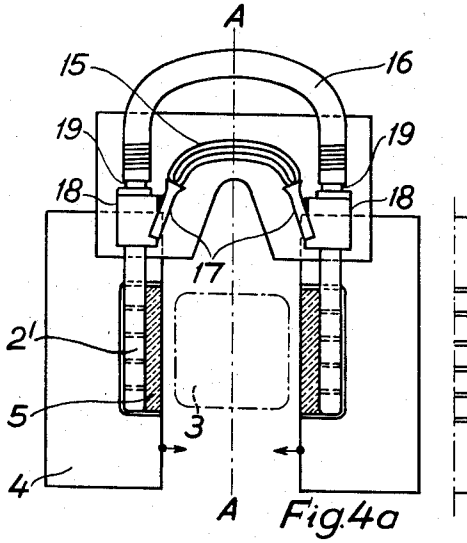


Fig.4a

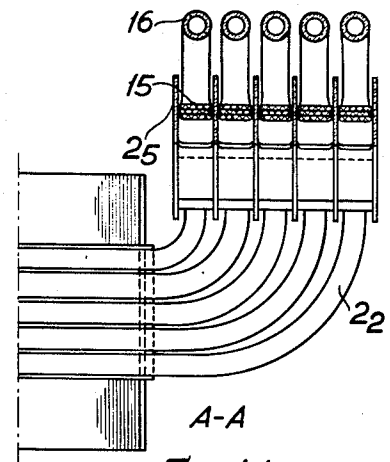


Fig.4b

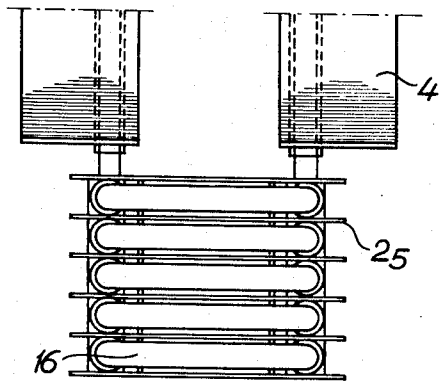


Fig.4c

Inventors
Ludwig Dreyfus
Thor Thelemarck
Ivar Beckius and
Hugo Lindström
By Emery Dixon
Attorney.

Patented Jan. 26, 1954

2,667,524

UNITED STATES PATENT OFFICE

2,667,524

INDUCTION HEATING FURNACE

Ludwig Dreyfus, Thor Thelemarck, Ivar Beckius, and Hugo Lindström, Vasteras, Sweden, assignors to Allmanna Svenska Elektriska Aktiebolaget, Vasteras, Sweden, a corporation of Sweden

Application December 29, 1950, Serial No. 203,255

Claims priority, application Sweden January 14, 1950

7 Claims. (Cl. 13—26)

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Eddy current furnaces for heating rolled stuff or ingots which have to be fed in a continuous sequence through a heating chamber seldom are arranged as cross field furnaces, since the use of cross field furnaces for this purpose involves certain drawbacks. This will be evident from the following argumentation with reference to the accompanying Figs. 1*a* and 1*b* showing the conventional cross field furnace. This is an eddy current furnace in which the main direction f (see Fig. 1*a*) of the field is perpendicular to the longitudinal extension of the coil. The active portion of the furnace consists of the coil 2, the longitudinal sides 2′ of which are parallel to the longitudinal direction of the article 3 to be treated, while the short sides 2″ are substantially at right angles to the longitudinal sides even though often in a higher or lower plane for not being in the way of the charge 3 while fed in and out. If the coil is surrounded by a closed laminated yoke 4 which confines a furnace space of rectangular section, the cross field f will have approximately the same intensity all over the void furnace space which, of course, is advantageous, because in a homogenous alternating field articles of rather different cross sections and thickness may be heat-treated.

However, this construction has, as mentioned above, some drawbacks. The voltage of the furnace is proportional to the flux in the furnace space, and in the most usual design of the furnace as a high frequency furnace with full skin effect within the charge the interior of the charge is practically free from field. The greater the width Δ of the charge is at right angles to the direction of the field the smaller becomes the flux within the furnace chamber at a given intensity of field, and the lower becomes therefore the voltage of the coil of the furnace for a given current. But the product of the current and the voltage of the coil is equal to the power of the condenser battery. Therefore, the paradoxical result is obtained that the smaller the weight per meter of the ingots or rolled stuff, the greater must be the condenser battery to be switched in parallel to one and the same furnace. Since this is unecomonical, one and the same furnace can only be used for a very limited range of magnitude of the articles to be treated.

Another drawback is that in a cross field furnace according to Figs. 1*a* and 1*b* the whole weight of the charge must be borne by the furnace chamber which also has to be lined with a muffle 5 of heat insulating ceramic material. The roof and the bottom of this muffle, however,

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cannot be made thick, for this would involve an increase of the path of the cross field which would require a greater number of ampere turns and therewith greater current losses due to the heat within the furnace coil. Heat insulating materials, however, are not particularly lasting, so that the lining soon becomes worn as heavy articles continuously are fed in and out or through the heating chamber.

The object of the present invention is a cross field furnace which does not have the above mentioned disadvantages. The principal feature of the invention is that the bottom of the heating chamber is replaced by a feeding means of heat resisting steel and lifted into the alternating field itself in an embodiment which will be described later, and that the longitudinal sides of the furnace coil are made movable horizontally relative to one another in such a manner that the minimum horizontal distance between the vertical longitudinal sides of the coil and articles of different size can be maintained substantially constant.

The invention will now be described with reference to the accompanying drawings whereon:

Figs. 1*a* and 1*b* show schematically sectional views of a furnace known heretofore.

Figs. 2*a* and 2*b* each shows a sectional view of one half of a furnace according to the present, invention with work-pieces of different dimensions.

Figs. 3*a*, 3*b* and 3*c* show in three sectional views an example of the end connections of the heating conductors according to this invention.

Figs. 4*a*, 4*b* and 4*c* show in three sectional views another example of the end connections of heating conductors according to this invention.

Fig. 5 is a perspective view showing a part of the conveyor means according to this invention.

Fig. 6 is an end view of the furnace, showing a modified form of connections.

In Figs. 2*a* and 2*b* there is shown schematically a furnace according to the invention, wherein Fig. 2*a* shows one half of the furnace accommodating within the field a minor article, whereas Fig. 2*b* shows the same half of the furnace with a major article lying within the field. The upper part of the figures shows the distribution of the field as long as the articles are magnetic, while the lower part of the figures illustrates the distribution of the field the articles having become so warm that they become unmagnetic. In Figs. 2*a* and 2*b* the articles have square cross sections and different side lengths but the same distance *a′* from the longitudinal sides 2′ adjacent

the coil. The articles rest on transport or conveyor means 6 consisting of U-shaped bails 6a of heat resisting sheet, the sides of which are stayed by cross plates 6b. These bails are conducted between the side yokes 4 on a conveyor means indicated schematically in Fig. 5, which is arranged in such a manner that the bails may be advanced between the yokes and the sides of the coils on a lower or higher level. The long sides of the coil each are embedded within a slot in the laminated side yokes 4. Against heat radiation from the charge they are protected by ceramic slot wedges or muffles 5. The longitudinal sides 2' and the side yokes 4 of the coil are movable horizontally and are adjusted suitably in such a manner (independent of the width of the charge) that the distance a' and a, respectively, between the vertical side surfaces of the coil and the yokes and the article 3 to be treated remain approximately constant. The diagrams of lines of force show that in this case also the same coil reactance may be expected in all charges. Therefore the both diagrams of magnetic fields in the first heating interval, where the charge is still magnetic, show equal partial fluxes $\Delta\Phi$ per half the cross section of the furnace and equal partial fluxes $\Delta\Phi$ in the second heating interval beyond the magnetic transformation point where the charge becomes non-magnetic. In the use of stationary coil sides and side yokes as shown in Figs. 1a and 1b, the number of the partial fluxes would have been 30–40 per cent greater at the minor cross section of the article, and the power of the condenser battery would have been increased in the same degree for the same current through the coil, i. e. for the same field intensity.

Figs. 3a, 3b, 3c, 4a, 4b, and 4c illustrate in three views at right angles to each other partly in section two different constructions of the short sides of the coil enabling the displacement of the longitudinal sides and yokes. Now the problem arises not only to secure a reliable electrical contact for each one of the numerous turns of the coil despite of their movability but also to bring the indispensable artificial cooling so close to the ends of the coils that their over-temperature, despite of the high density of current occurring always in high frequency furnaces, is held within allowable limits.

In the arrangement according to Figs. 3a, 3b and 3c, the mutual movability of the coil sides is obtained in that the upright tubular conductors 2_2 of the coil are joined on one side thereof with double horizontal contact bars 2_3, between which single contact bars 2_4 intrude as a continuation of opposite upright conductors. The "coil ends" formed by these contact bars engaging each other are isolated from each other by the intermediance of sheets of insulating material 2_5. The bars 2_3 and 2_4 have longitudinally extending holes made therewithin and are held pressed against each other by a bolt 10 with a wing nut 11. The cooling water is passed from turn to turn by means of rubber tubes 2_6 fixed by nipples 2_7.

In the arrangement according to Figs. 4a, 4b and 4c, the connection between the longitudinal sides is made by means of superflexible copper cables 15 (flat or round so called stranded wires). The fixtures of the flexible conductors are hard soldered directly on the heads 18 traversed by the cooling water, to which heads the conductors of the longitudinal sides are connected. The cooling water is led from turn to turn by means of nipples 19 and rubber tubes 16. In the occurrence of long coil ends, it may be necessary to place the stranded copper wire 15 within the rubber tubes 16 as shown, for example, at Fig. 6 in which the conducting cables 15 are enclosed within the flexible rubber tubes 16.

It will be seen, when comparing Figs. 1a and 1b with Figs. 3a, 3b and 3c and Figs. 4a, 4b and 4c, that the yoke and muffle of the conventional field furnace have been broken up, not only over the little distance which is required for making the side yokes movable, but over such a great distance that the weight of the charge not at all will load the construction of the furnace itself. Instead, the charge is supported and transported according to the invention by a feeding means of heat resisting steel so that all previous trouble with the wear of ceramic support is avoided. It is true, this metallic support has to be lifted into and placed within the very zone of the cross field, but, according to the invention, this may be carried out in such a manner that it nevertheless only involves eddy current losses not worth mentioning.

In Fig. 5, two of the bails are shown in detail, which bails serve for the support of the articles while travelling through the furnace. These bails are supported by cross beams 7 below the furnace which are advanced below the furnace by conveyor chains 20 which run on bars 21. The transport means may be made movable in vertical direction relative to the yokes or vice versa. The arrangement for effecting such movement is not shown on the drawings but it will be noted from a comparison of Figs. 2a and 2b that the spaces between the yokes and the conveyor means are different, indicating that these two means are movable with respect to each other in a vertical direction. These bails are formed and orientated within the alternating field in such a manner that the latter nowhere has to cross any surfaces of considerable width at a right angle to the direction of the field. Therefore, the side pieces 6a consist of so narrow lamellae, that the field in these lamellae cannot produce any eddy current losses worth mentioning. The same applies to the cross-plate 6b within the middle plane of the furnace, which is known to coincide there with the direction of the lines of force. Finally, the bottoms 6_c of the bails are drawn downwards—below the lowermost edge of the side yokes—to such an extent that they travel within a very feeble alternating field, the direction of which besides does not much differ from the plane of the bottoms. As a conclusion, the construction of the links may be described as consisting of a cross-plate in the middle having two semi-opened pockets on both sides, the lines of force of the field entering and leaving these pockets without crossing the limiting surfaces of the pockets in a degree worth mentioning. By this shaping, it has been possible to enable the links without intermediance of ceramic material to support directly the charge and to place hard-wearing transport means substantially free from losses within the heating chamber itself. Of course there will be nothing to prevent the insertion of a ceramic piece between the links and the charge, if this should be required. In a furnace having movable side yokes the width of the links of course has to be adapted to the distance of the side yokes for heating the narrowest articles for which the furnace is designed.

We claim as our invention:

1. An induction furnace for heating metallic

articles while such articles are being fed successively and continuously therethrough, comprising two longitudinally extending laminated iron yokes arranged in spaced relation to each other, hollow fluid-cooled current conductors located in slots in said yokes, means for moving the yokes towards and away from each other in accordance with the different widths of the articles being treated, means located outside and above the space between said yokes for connecting the ends of said conductors, conveying means for the articles being treated, said means being adapted to travel at different levels with respect to the yokes in accordance with the different heights of the articles being treated, and means for supporting the articles being treated, the said supporting means being fixed to said conveying means and being adapted to project from below into the space between the yokes, and said supporting means consisting of bails formed by U-shaped bent sheets of heat resisting material with upwardly extending legs stayed by cross pieces located between such legs in such a position that the side surfaces and the bottoms of said bails are substantially parallel to the direction of the alternating current field between the yokes for preventing eddy currents in said bails.

2. An induction furnace for heating metallic articles while such articles are being fed successively and continuously therethrough, comprising two longitudinally extending yokes of magnetic material arranged to form therebetween a space for the passage of the articles being treated, means for moving said yokes towards and away from each other, slots in said yokes, hollow current conductors located in said slots, bars located outside and above the space between said yokes and attached to the ends of said hollow conductors to electrically connect the conductors within one of the yokes with the conductors within the other yoke, means for insulatingly and movably holding the bars together, and flexible insulating pipe means also located outside and above the space between the yokes for the passage of cooling fluid between said conductors.

3. An induction furnace for heating metallic articles while such articles are being fed successively and continuously therethrough, comprising two opposed longitudinally extending laminated yokes of magnetic material arranged to form therebetween a space for the passage of the articles being treated, means for moving said yokes towards and away from each other, slots in said yokes, hollow current conductors embedded within said slots, flexible conductors located outside and above the space between said yokes and electrically connecting the conductors in the slots in opposed yokes, and flexible insulating pipe means for interconnecting and conveying cooling fluid between said embedded conductors.

4. An induction furnace for heating metallic articles while such articles are being fed successively and continuously therethrough, comprising two opposed longitudinally extending laminated yokes of magnetic material arranged to form therebetween a space for the passage of the articles being treated, means for moving said yokes towards and away from each other, slots in said yokes, hollow current conductors located in said slots, flexible conductors located outside and above the space between said yokes and electrically connecting the conductors in the slots in the opposed yokes, and flexible insulating pipe means enclosing said flexible conductors and supplying cooling fluid to the hollow conductors in said slots.

5. An induction furnace according to claim 1, comprising wedges of refractory material covering the hollow conductors within the slots in said yokes.

6. An induction furnace according to claim 1, comprising hollow flexible means for connecting the ends of said hollow conductors and for the conveyance of cooling fluid between said conductors.

7. An induction furnace according to claim 1, comprising insulating flexible pipe means serving to convey cooling fluid from the current conductors in one yoke to the current conductors in the other yoke, the said means for electrically connecting the ends of the hollow conductors being arranged within said insulating flexible pipe means.

LUDWIG DREYFUS.
THOR THELEMARCK.
IVAR BECKIUS.
HUGO LINDSTRÖM.

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