

Sept. 16, 1958

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2,852,586

MAGNETIC STIRRING APPARATUS

Filed Jan. 17, 1957

2 Sheets-Sheet 1

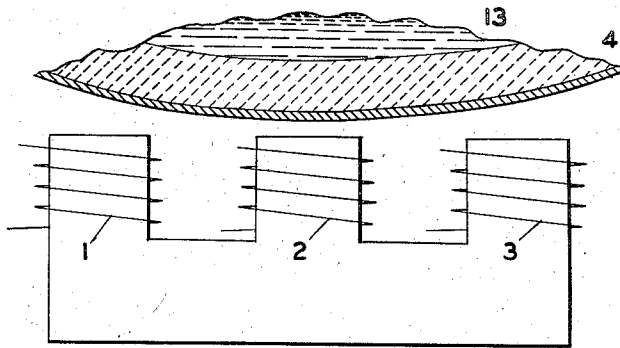


Fig. 1

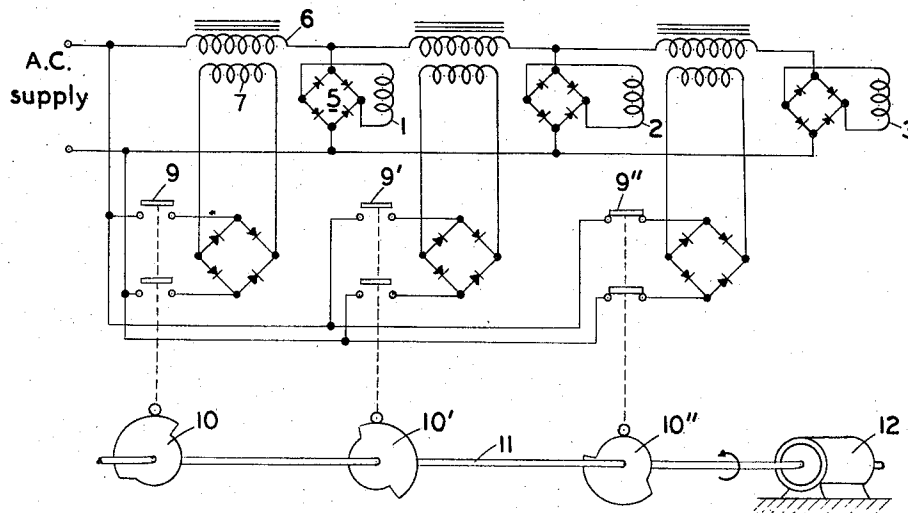


Fig. 2

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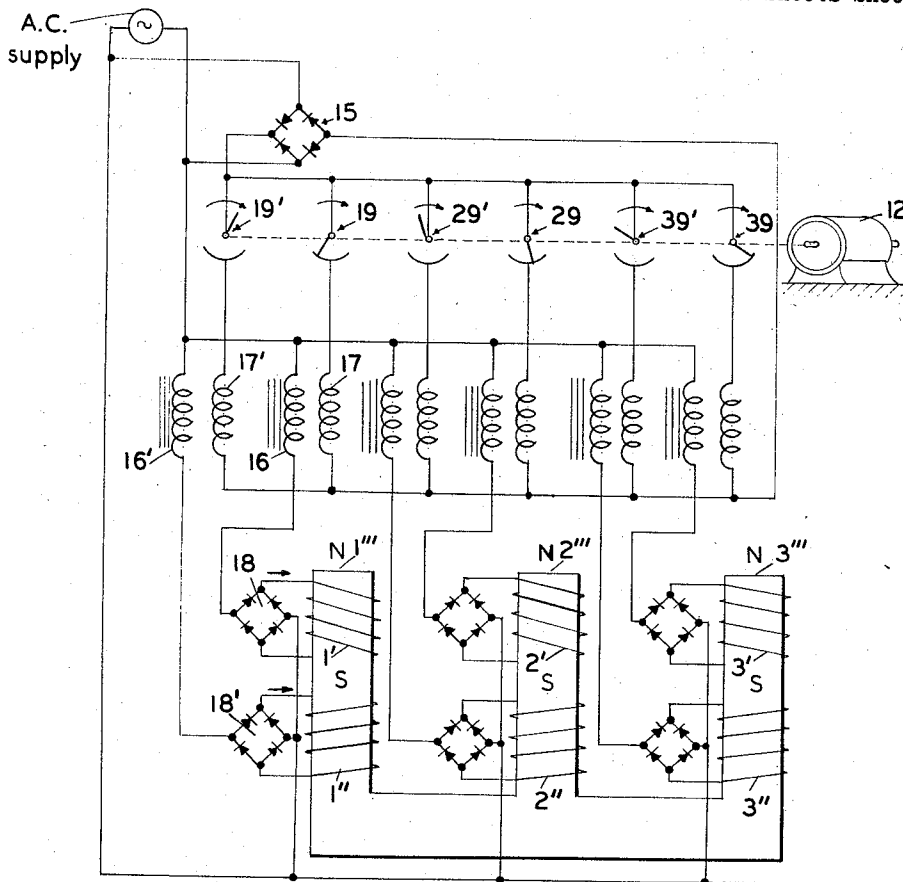


Fig. 3

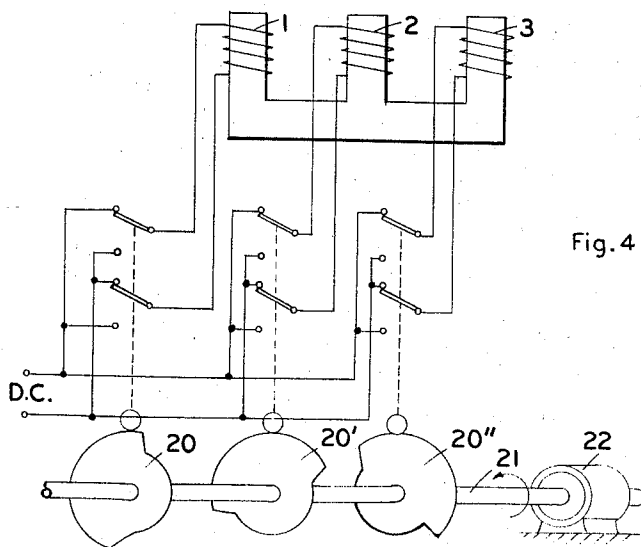


Fig. 4

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1

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MAGNETIC STIRRING APPARATUS

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Application January 17, 1957, Serial No. 634,712

7 Claims. (Cl. 13—26)

My invention relates to an improved apparatus for stirring molten metal and in particular to a magnetic stirring apparatus having application in metallurgical furnaces.

Stirring of the molten contents of a furnace by virtue of a magnetic field acting upon current induced in the molten metal are well known, but heretofore it has involved magnets which move with respect to the receptacle containing the metal, or alternatively stationary poly-phase windings, to which is applied a low frequency alternating voltage.

In the latter arrangement the characteristics of the metal determine the optimum frequency, and this is usually of the order of half a cycle per second. To obtain an alternating voltage of this frequency requires a rotating machine operating either as a frequency changer, or as an alternator, and this is undesirable from the point of view of maintenance and cost.

The object of the present invention is to provide an improved apparatus for stirring molten metal by means of magnetic fields induced therein.

In accordance with the aforesaid object, I practice my invention by providing an apparatus for stirring the molten metal contents of a container comprising a plurality of stationary electromagnets situated adjacent the container so as to produce magnetic flux inside said container, together with means for applying pulses of unidirectional current sequentially to the windings of the electromagnets, whereby a travelling magnetic field is produced in the metal.

The pulses applied to the electromagnets are displaced in time with respect to one another, and the combined pattern may be a series of isolated pulses, or alternatively interlacing or overlapping of the pulses may be preferred. The repetition rate will be determined by the characteristics of the molten metal and the disposition of the magnets and would normally be in the range of 10 to 50 per minute.

Preferably each of the windings is fed from a common supply and respective switch means associated with each winding are provided which are operated in sequence to pass current pulses to said windings. The supply source may be A.-C., in which case rectifiers are provided to change the A.-C. current to unidirectional current.

In a preferred embodiment of the invention each switch means comprises a saturable reactor which is located in the A.-C. supply lead to the rectifier associated with each winding. Each reactor has a D.-C. control winding which, in operation, is periodically energized to allow current to pass through the main winding of the saturable reactor to the rectifier and thence to the electromagnetic winding. The control windings are energized by means of mechanical switches operated in sequence from a rotary cam device.

Thus, it can be appreciated that an apparatus has been provided which eliminates the costly low frequency rotating machine and which is capable of economically

2

providing low frequency energization to field producing electromagnets in a magnetic stirring apparatus.

The features of this invention which are believed to be novel are set forth with particularity in the appended claims. The invention itself may be better understood as to organization and construction as well as to further objects and advantages by reference to the following description taken in conjunction with the accompanying drawings in which:

Figure 1 is a diagrammatic view of three electromagnets situated adjacent a metallurgical furnace;

Figure 2 is a schematic diagram of the control system for energizing the three electromagnets of Figure 1 in a sequential overlapping cycle;

Figure 3 is a schematic diagram illustrating another embodiment of the invention; and

Figure 4 is a schematic diagram illustrating still another embodiment of the invention.

In Figure 1, three stationary electromagnets have separate energizing windings, 1, 2, and 3, and are so positioned that their magnetic flux will pass through the metallurgical furnace 4 and its molten metallic pool 13. It will be appreciated that successive pulses of unidirectional current applied to windings 1, 2, and 3 will produce an effective travelling field, the continuity of which is enhanced if overlapping of the pulses applied to adjacent windings, and to windings 3 and 1, is arranged. The sequence of excitation would then be field 1 alone—fields 1 and 2 together—field 2 alone—fields 2 and 3 together—field 3 alone—fields 3 and 1 together—field 1 alone. The fact that the effective field is not constant in magnitude is an advantage, as additional turbulence is thereby produced within the molten metal. It should also be noted that the durations of the pulses need not necessarily be all equal to one another.

A means for applying pulses of unidirectional current to the magnet windings is shown in Figure 2. The pulse applying means is identical with respect to each magnet and accordingly in the interests of brevity only the pulse applying means with respect to the winding 1 will be described in detail. Accordingly with reference to Fig. 2, the magnet winding 1 is supplied through a bridge rectifier 5, and a saturable reactor 6, from a source of A.-C. supply. On the saturable reactor is a control winding 7, which is connected, through a bridge rectifier 8 and contacts 9, preferably to the same A.-C. supply. When the contacts 9 are open, the saturable reactor 6 is unsaturated, and only a small current passes through the winding 1. During the time that the contacts 9 are closed the saturable reactor 6 becomes saturated, its impedance value falls and the exciting current flows in the winding 1.

For each of the electromagnets there is a similar associated circuit and contacts for the control windings. Periodic and sequential operation of the contacts 9, 9', and 9'' associated with the windings 1, 2, and 3, respectively is obtained preferably by three rotary cams 10, 10', and 10'' adapted to be driven simultaneously through shaft 11 by a drive means 12 such as an electric motor. Each of the cams 10, 10', and 10'' is contoured to maintain the associated switch on and off for predetermined intervals and the cams are offset angularly relative to each other whereby the desired pulse duration and time displacement between the current pulses in the electromagnets are obtained.

In the embodiment of the invention shown in Fig. 3 it is possible to provide for reversal of the flux produced by the electromagnets.

In Fig. 3 it can be seen that each of the three magnets has two windings 1' and 1'', 2' and 2'', 3' and 3'', respectively with the two windings on each pole being wound in the opposite sense. Energisation of windings 1', 2'

and 3' by passing current into the top of the coils as indicated by the arrow will cause the next adjacent poles 1'', 2'', and 3'' of the electromagnet to become N poles, while energisation of windings 1'', 2'' and 3'' by passing current into the top of the coil as indicated by the arrow will cause the poles 1'', 2'', and 3'' of the electromagnet to become S poles. With reference to the magnet having the coils 1' and 1'', the coils are connected, respectively, by bridge rectifiers 18, 18', through the main coils of saturable reactors 16, 16' to a main A.-C. supply. The control windings 17, 17' of the saturable reactors are connected by rotary switches 19, 19' through a bridge rectifier 15 to the main A.-C. supply. A similar circuit is provided for the coils 2', 2'', and the coils 3', 3'' with the rotary switches 29, 29' and 39, 39', respectively, controlling excitation of these coils. The switches are driven by a suitable drive means, such as a motor 12, and the contactors of the switch are offset relative to each other to provide the desired switching sequence for the magnet coils.

In operation current pulses are circulated round the two windings on each magnet in opposite directions in sequence so as to magnetise the poles 1'', 2'', and 3'' with alternately opposite polarities. This reversal of polarity may be achieved either by having the two windings wound in opposite senses, or else passing positive and negative current pulses through two windings wound in the same sense.

In the embodiment of Figure 3, the movable contactors of the rotary switches are offset relative to each other and the length of the fixed contactors of the switches are selected to provide a switching sequence in the electromagnets comprising the following eight steps applied cyclically:

electromagnet	1	2	3
step 1.....	N	N	N
step 2.....	S	S	S
step 3.....	S	S	S
step 4.....	N	N	N
step 5.....	N	N	N
step 6.....	S	S	S
step 7.....	S	S	S
step 8.....	N	N	N
step 1.....	N	N	N

Alternatively, if desired, the following switching sequence of six steps can be used:

electromagnet	1	2	3
step 1.....	N	N	N
step 2.....	S	S	S
step 3.....	S	S	S
step 4.....	N	N	N
step 5.....	N	N	N
step 6.....	S	S	S
step 1.....	N	N	N

If it is desired to economise in the number of windings, a single winding can be provided on each magnet to which current pulses of opposite polarity are applied in sequence to produce north and south poles. Such an arrangement is shown in Figure 4 wherein the single windings 1, 2, and 3 of the three electromagnets are each connected through a pair of double-pole, single-throw switches to a suitable source of direct current. Each pair of switches respectively associated with each of the coils is operated respectively by cams 20, 20', and 20'' mounted on a shaft 21 and driven by a motor 22. In the embodiment shown in Figure 4, the cams are offset angularly relative to each other and are configured so as to actuate the switches, and thus energize the coils, in the six-step switching sequence described immediately above.

Therefore, while particular embodiments of the subject invention have been shown and described herein, it is in the nature of description rather than limitation,

and it will occur to those skilled in the art that various changes, modifications, and combinations may be made within the province of the appended claims, and without departing either in spirit or scope from this invention in its broader aspects.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination with a receptacle for use with furnace apparatus and adapted to contain a molten pool, means for stirring a molten pool in said receptacle comprising a plurality of stationary electromagnets situated adjacent said receptacle so as to produce a magnetic flux in a molten pool therein and means for applying pulses of unidirectional current sequentially to the windings of said electromagnets whereby a travelling field will be produced in the receptacle.

2. In combination with a receptacle for use with furnace apparatus and adapted to contain a molten pool, means for stirring a molten pool in said receptacle comprising a plurality of stationary electromagnets having energizing windings, said electromagnets being situated adjacent said receptacle so as to produce a magnetic flux in a molten pool therein, and means including a plurality of switching means operatively connected to said windings for applying pulses of unidirectional current sequentially thereto.

3. In combination with a receptacle for use with furnace apparatus and adapted to contain a molten pool, means for stirring a molten pool in said receptacle comprising a plurality of stationary electromagnets having energizing windings, said electromagnets being situated adjacent said receptacle so as to produce a magnetic flux in a molten pool therein, means including a plurality of switching means operatively connected to said windings and adapted to supply unidirectional current thereto, and means operatively connected to said switching means to actuate said switching means periodically and in sequence to provide pulses of unidirectional current to said windings.

4. In combination with a receptacle for use with furnace apparatus and adapted to contain a molten pool, means for stirring a molten pool in said receptacle comprising a plurality of stationary electromagnets having energizing windings, said electromagnets being situated adjacent said receptacle so as to produce a magnetic flux in a molten pool therein, and means including a plurality of switching means operatively connected to said windings for supplying pulses of unidirectional current thereto, said switching means comprising a plurality of saturable reactors having D.-C. control windings and means for periodically energizing said control windings in a sequential manner.

5. In combination with a receptacle for use with furnace apparatus and adapted to contain a molten pool, means for stirring a molten pool in said receptacle comprising a plurality of stationary electromagnets having energizing windings, said electromagnets being situated adjacent said receptacle so as to produce a magnetic flux in a molten pool therein, and means including a plurality of switching means operatively connected to said windings for supplying pulses of unidirectional current thereto, said switching means comprising a plurality of saturable reactors having D.-C. control windings, and mechanical switches operated in sequence from a rotary cam device for periodically energizing said control windings.

6. In combination with a receptacle for use with furnace apparatus and constructed and arranged to contain a molten pool, means for stirring a molten pool in the receptacle comprising a plurality of stationary electromagnets situated adjacent the receptacle so as to produce a magnetic flux in the receptacle, and means to apply pulses of unidirectional current to the magnets sequentially and to reverse periodically the direction of flux in the magnets including switching means operatively connected to the magnets.

5

7. In combination with a receptacle for use with furnace apparatus and constructed and arranged to contain a molten pool, means for stirring a molten pool in said receptacle comprising a plurality of stationary electromagnets having energizing windings and pairs of poles, the magnets being situated adjacent said receptacle so as to produce a magnetic flux therein, and means including the windings of the magnets and switching means operatively connected to said windings to energize the electromagnets sequentially with pulses of unidirectional

5

10

6

current and to reverse the polarity of the poles of the magnets periodically.

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