

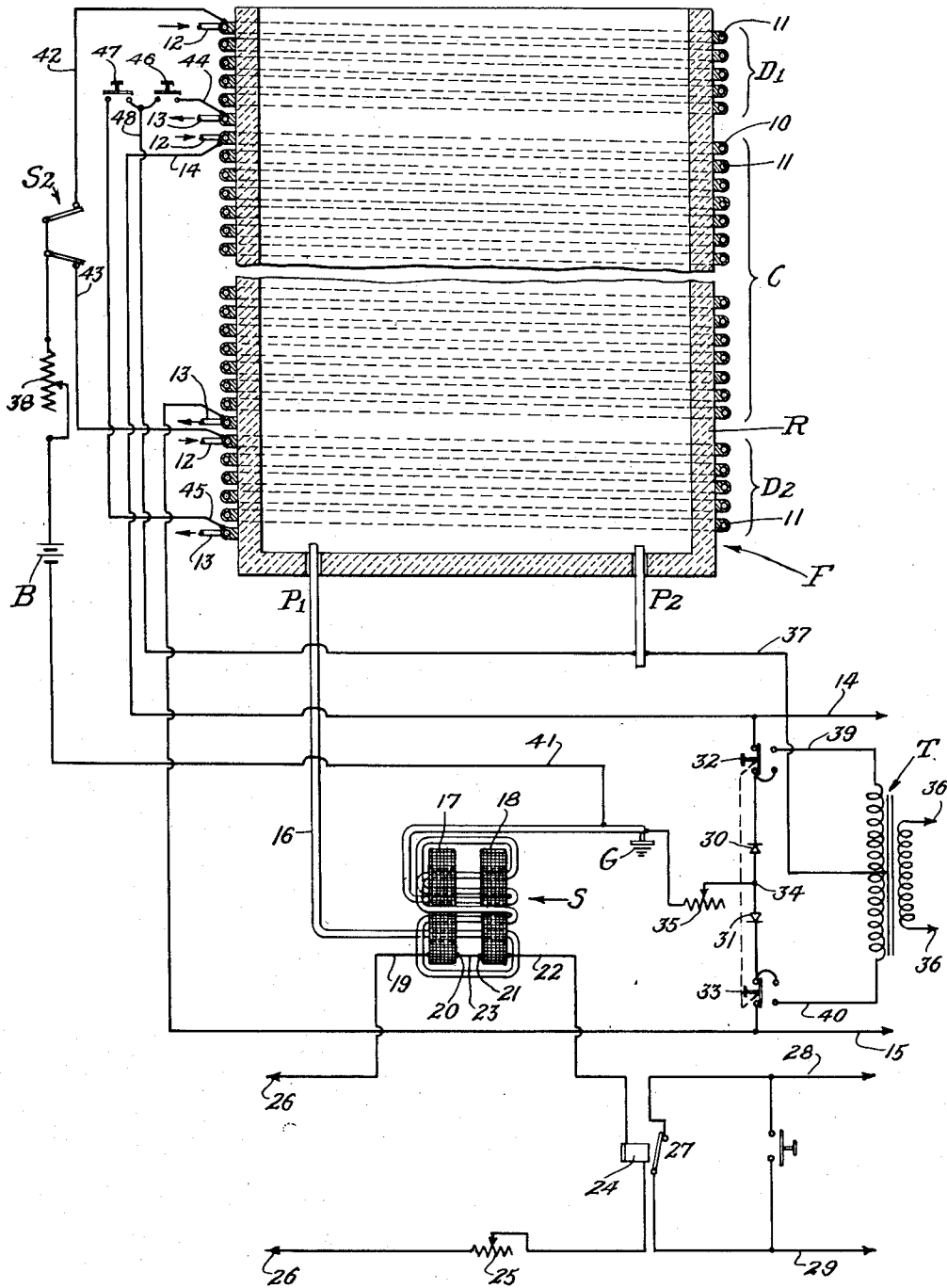
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PROTECTIVE DEVICE FOR INDUCTION FURNACES

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PROTECTIVE DEVICE FOR INDUCTION FURNACES

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1 Claim. (Cl. 340-242)

This invention relates to protective circuits for induction heating furnaces and is particularly concerned with indicating and/or controlling circuits which are responsive to abnormal conditions permitting or threatening to permit contact between molten metal in the furnace and the induction coil thereof, but which circuits are not responsive to faults occurring in the power supply system.

Induction furnaces intended for use in melting metal generally comprise a refractory lined container surrounded by a coil, in contact with the refractory, which is connected to a source of alternating current power. In one type of induction furnace, the coil is wound from an elongated conductor having a water passage therein. Cooling water is circulated through the water passage, both to dissipate the heat developed by the resistance of the conductor to the passage of electric current there-through, and also to maintain the refractory material at a safe temperature.

In such an arrangement, there is always the possibility that the refractory material comprising the wall of the furnace may be cracked as a result of thermal stresses, or be dissolved by chemical action, to the point that the molten metal comes in contact with the coil. In addition to the fact that such an occurrence prophesies the end of the useful life of the furnace, it presents two immediate dangers to operating personnel and the furnace structure.

In the first place, the melt will immediately attain the electrical potential of the coil at the point of contact and hence a potential most probably different from the potential of the surrounding environment. Accordingly, operating personnel will be exposed to the danger of electrocution by so innocent an act as inserting a ladle into the melt.

In the second place, once the molten metal comes in contact with the metal of the coils, there is danger of releasing cooling water into the melt, the consequences of which would be comparable to an explosion.

One of the objects of my invention is to provide for the giving of an alarm or the interruption of the supply of power to the induction coil whenever the melt comes in contact with the coil.

Another object of the invention is to maintain the melt at ground potential at all times.

A further object of the invention is to provide an alarm or current-interrupting circuit which will respond to contact between the melt and the coil, but which will not respond to faults occurring in the power supply circuits.

A still further object of the invention is to provide an alarm or current-interrupting circuit which will respond to contact between the melt in the furnace and the coil regardless of what point on the coil is involved.

Still another object of the invention is to provide an indicating circuit which will indicate the point on the coil where undesirable contact has occurred.

How the foregoing and other objects are attained will be more fully understood upon reference to the accompanying description and to the drawing of the invention.

The drawing illustrates an induction furnace generally indicated at F, having a refractory wall R and a main

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induction coil C consisting of an edge-wise electrically wound conductor 10 provided with a water passage 11.

Coil C, in addition to providing for heating of the furnace contents by electro-magnetic induction, also functions to maintain the refractory wall R at a desired temperature by means of circulating water, which is introduced into coil C through a pipe 12 and removed therefrom through a pipe 13.

Coil C is connected to a source of alternating current power by means of the conductors diagrammatically indicated at 14 and 15, connected respectively to the upper and lower ends of coil C.

The furnace F illustrated in the drawings also includes a pair of dummy coils D₁ and D₂, which are not electrically energized but whose physical construction is identical to that of coil C, and which are provided with water passages 11 and in-flow and out-flow pipes 12 and 13.

According to the invention, the furnace is provided with a probe P₁ extending through the refractory wall into engagement and electrical contact with the melt within the furnace, which probe is connected by means of an electrical conductor 16 to a point of ground potential G. Conductor 16 is of a size and electrical conductivity sufficient to effectively ground the melt and thereby prevent the melt from attaining a potential above the potential of the environment.

Conductor 16 is wound around a pair of magnetically saturable core members 17 and 18, and, in cooperation therewith, forms part of a saturable reactor generally indicated at S. Conductor 16 makes four passes through and around core members 17 and 18.

Each core member 17 and 18 is separately wound with a coil of about 175 turns of relatively small diameter wire, the ends of the coil wound on core 17 being shown at 19 and 20, and the ends of the coil wound on core member 18 being shown at 21 and 22. Ends 20 and 21 are interconnected by conductor 23, the interconnection being made in a manner to provide maximum back E.M.F. in opposition to an alternating current passed through the two coils in series.

The two coils are connected in series with a relay 24, a current-limiting variable resistor 25, and a source of alternating current indicated by the arrows 26-26. The reactor coils, relay 24, and variable resistor 25 are proportioned so that the current flowing through relay 24 when core members 17 and 18 are unsaturated is negligible and much less than the current required to operate relay 24. However, when a current is caused to flow through conductor 16 in a manner to be described herebelow, thereby saturating cores 17 and 18, the impedance of the reactor coils to the flow of alternating current there-through is drastically reduced, with the result that the current through relay 24 is large enough to operate the relay and open contacts 27 which are connected by means of leads 28 and 29 to an alarm device and/or to circuit breakers for interrupting the flow of power through conductors 14 and 15 to coil C.

Direct current for operating the circuit above-described is derived from the main power circuit, comprising conductors 14 and 15, through rectifier devices 30 and 31 connected back to back across the power supply circuit through normally closed push-buttons 32 and 33. The conductor 34, connecting like terminals of rectifier devices 30 and 31, is connected through variable resistor 35 to the point of ground potential G.

Because of the back-to-back connection of rectifiers 30 and 31, no current can flow from conductor 14 through the rectifiers to conductor 15. However, if a connection is made between conductor 34 and either conductor 14 or conductor 15, unidirectional current will flow through one or the other of rectifiers 30 and 31. Since conductor

34 is connected through resistor 35 to ground and since the melt is connected to ground through conductor 16, this means that a current will flow if the melt comes in contact with coil C, which is connected between conductors 14 and 15.

The nature of the current flowing through conductor 16 (and hence through saturable reactor device S and the rectifier circuit) will depend upon what portion of coil C makes electrical contact with the melt.

If it is assumed that the melt comes in contact with the electrical mid-point of coil C, it will be seen that a full-wave rectifier circuit will be established. Under these circumstances the melt, and hence conductor 16, will be at the unvarying potential of the center of coil C, while conductors 14 and 15 are periodically varying above and below the potential thereof. Accordingly, equal currents will flow through rectifiers 30 and 31.

If the fault occurs at an end of coil C, for example at the upper end of the coil, to which conductor 14 is secured, a half-wave rectifier circuit will be formed from conductor 14, through the melt, to probe P₁, through conductor 16, resistor 35, rectifier 31 and power supply conductor 15.

On the other hand if the fault occurs at the lower end of coil C, i.e. at the point of connection to conductor 15, a similar half-wave rectifier circuit will be formed but this time involving rectifier 30.

If the fault occurs between the electrical center of coil C and one of the ends thereof, unbalanced full-wave rectification will take place.

It will thus be apparent that a current will flow through conductor 16 and hence through saturable reactor S regardless of the location of the fault connection between the melt and coil C.

It will be apparent that the alarm circuit will be unaffected by faults in the power supply circuit, for completion of the fault-sensing circuit of the invention depends upon conductor 16 which interconnects ground and the melt, which last is normally completely isolated from the power circuits.

If desired, one of the two rectifier devices may be replaced by a resistance having a value about equal to that of resistor 35. If, for example, rectifier 31 is replaced by a resistor, the operation will be as follows: A continuous unidirectional pulsating current will flow from conductor 15, through the resistor just mentioned and rectifier 30, to conductor 14. If a fault occurs anywhere on coil C except at the end to which conductor 15 is connected, an A.-C. fault current will flow from conductor 15, through the resistor just mentioned, resistor 35, conductor 16, probe P₁, the melt, the fault, and coil C to conductor 14. The A.-C. current will saturate the core of saturable reactor S, and activate the fault circuit.

If the fault occurs at the end of coil C connected to conductor 15, no A.-C. current will flow through conductor 16, since both ends thereof will be at the same A.-C. potential. However, the fault, conductor 16, and resistor 35 will now form a shunt path for the above-mentioned continuous current, which path is effectively in parallel with the resistor replacing rectifier 31. Accordingly, a portion of said continuous current will flow through saturable reactor S, operating the fault circuit above-described.

The disadvantage of the foregoing arrangement is the existence of the steady state current above referred to; this is eliminated by the use of the two back-to-back rectifiers in the preferred embodiment of the invention.

My invention also includes means for determining whether or not the alarm circuit is in operating condition. This is accomplished by means of the probe P₂, which is connected to the center tap of a transformer T adapted to be energized, through conductors 36—36 from a source of alternating current. Probe P₂ is connected to the secondary center tap of transformer T through conductor

37. When it is desired to test the circuit, ganged push-buttons 32 and 33 are depressed, connecting rectifiers 30 and 31 to conductors 39 and 40, which are in turn connected to the secondary of transformer T. Under these conditions, a full-wave rectifier circuit is established beginning at the center tap of the secondary winding of transformer T and passing through conductor 37, probe P₂, the melt in furnace F, probe P₁, conductor 16, saturable reactor S, variable resistor 35, conductor 34 and then alternately through rectifier 30, push-button 32, and conductor 39, or rectifier 31, push-button 33 and conductor 40. This test simulates a fault occurring at the electrical mid-point of coil C, and opening of relay contacts 27 demonstrates that the rectifiers, saturable reactors and relay 24 are in operating condition and that both probes are in electrical contact with the melt.

I have also illustrated in the drawing the manner in which the invention serves to provide an alarm in the event that either of dummy coils D₁ or D₂ is brought into contact with the melt. This portion of the circuit includes a conductor 41 connected to ground, a battery or other source of direct current B, current-limiting adjustable resistor 38, isolation switch S₂, conductors 42 and 43 interconnecting switch S₂ and the upper ends respectively of dummy coils D₁ and D₂; and conductors 44 and 45 respectively connecting the lower ends of the dummy coils D₁ and D₂ through push-buttons 46 and 47 to a conductor 48 which is connected to probe P₂.

This circuit operates to detect contact between the melt and one of dummy coils D₁ and D₂ as follows:

If the melt is in contact with coil D₂ and isolation switch S₂ is closed, current will flow from battery B through resistor 38, switch S₂, conductor 43, coil D₂, thence through the fault to the melt, thence to probe P₁, through conductor 16, saturable reactor S to ground, and thence through conductor 41, back to battery B. Since the current passes through saturable reactor S, the reactor will become saturated and the relay 24 will respond in the manner described above.

The circuit just described may be tested by depressing push-button 47, which will artificially establish contact between dummy coil D₂ and the melt through conductor 48 and probe P₂.

It will be understood that the circuits associated with coil D₁ operate in the same manner.

I claim:

For an induction furnace having a melt-containing refractory wall, a surrounding induction coil, and means for supplying alternating current to said coil: a circuit for detecting failure of the refractory wall resulting in electrical contact between a melt and a point on the coil, comprising a probe in electrical contact with a melt in the furnace, a conductor connecting said probe to a point of ground potential, said probe and said conductor having sufficient current carrying capacity to effectively ground a melt in the furnace, and said conductor comprising the control winding of a saturable reactor, a pair of rectifier devices, one terminal of the first such device being connected to the like terminal of the second such device, said connected terminals being connected to ground through a current-limiting resistor, and the other terminals of said first and second devices being respectively connected to first and second points on said coil, said points being points of different electrical potential.

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