

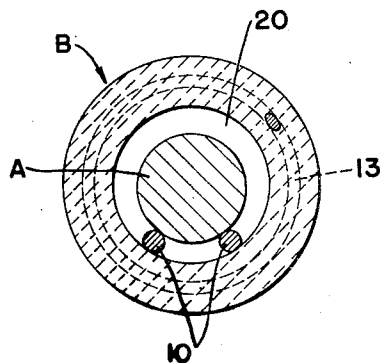
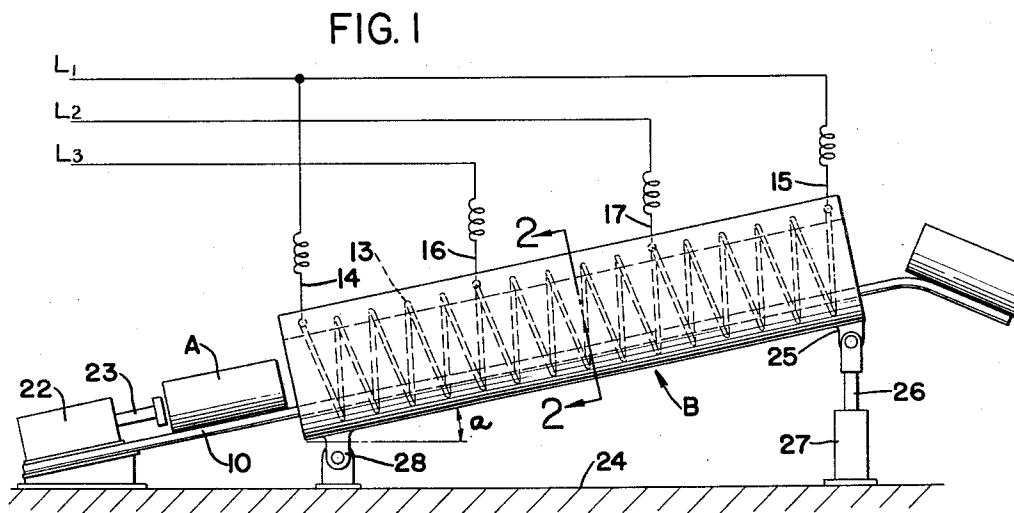
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POLYPHASE INDUCTION HEATING APPARATUS

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POLYPHASE INDUCTION HEATING APPARATUS

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1 Claim. (Cl. 219—10.67)

This invention pertains to the art of induction heating and, more particularly, to the heating of metallic articles using multiphase, alternating electric currents.

The invention is particularly applicable to the art of induction heating of steel, aluminum, or other metallic work pieces employing 60 cycle 3 phase electrical power, and will be described with particular reference thereto although the invention has broader applications.

In the art of induction heating, it has long been conventional to surround a metallic work piece with a single or multi-turn electrical coil or winding. Alternating electric currents circulated in this winding induce similar but opposite flowing electric currents to flow in the metallic work piece. These electric currents generate heat in the work piece and if the induced currents are high enough will rapidly raise the work piece to an elevated temperature. 60 cycle alternating current for industrial purposes is ordinarily supplied as 3 phase electrical energy. In effect, such energy is supplied from three different equi-frequency power sources with the phase of the voltage or current from each power source being displaced, or spaced in time from that of the other power sources. Thus, one winding must be employed for each phase if 3 phase electrical power is to be employed for induction heating.

Heretofore, one of the problems with multiphase induction heating has been that the multiphase electrical energy produces a magnetic field which appears to move from one end of the plurality of coils to the other. Such movement of the magnetic field exerts a force on any work pieces within the coils tending to move them out of the coils.

It has been proposed, heretofore, to provide a stop at one end of the coils to hold the work pieces within the coil against the forces created by the moving magnetic field. Such a stop is complicated, is itself within the magnetic field and thus tends to be heated, is deteriorated by the heat from the work pieces themselves which are always in contact therewith, and apparatus for moving it out of the way and simultaneously de-energizing the coils must be provided.

The present invention contemplates multiphase induction heating apparatus comprised of a plurality of coils energized from a multiphase, alternating current power source which is simple in construction, easily operated, employs the forces created by the moving magnetic force to advantage, and eliminates all of the objections of the prior art.

In accordance with the invention, there is provided a plurality of electrical windings all having aligned work piece receiving openings therein, which are adapted to be connected to a multiphase, alternating current power source. The axis of the work piece receiving space is inclined upwardly in the direction of the magnetic force to an amount such that the magnetic force tending to move work pieces in that direction is, at least in part if not entirely opposed.

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Thus, the force of gravity is employed to oppose the magnetic forces on the work piece.

The amount of inclination of the axis of the work piece receiving space will vary in accordance with the magnetic force involved, which in turn will depend upon the metal of the work piece and the number of turns in the windings and the strength of current therethrough.

The amount of inclination will also vary in accordance with the friction of the work pieces on its supports within the coils.

If desired, the angle of inclination may be readily adjustable and power means may be provided to affect such adjustment.

The work pieces may be advanced in either direction through the work piece receiving space of the coils and in either direction relative to the inclination.

The principal object of the invention is the provision of a new and improved arrangement for opposing the forces on a work piece within an induction heating coil energized from a multiphase power source which is simple in construction, economical to build, and positive in operation.

Another object of the invention is the provision of a new and improved means whereby the forces imposed on a workpiece by multiphase induced currents can be beneficially employed.

Still another object of the invention is the provision of a new and improved induction heating furnace employing multiphase electrical energy employing induction coils having aligned work piece receiving openings wherein the axis of the work piece receiving openings may be inclined at an angle.

Still another object of the invention is the provision of a new and improved multiphase, multicoil, induction heating apparatus wherein the angle of the work piece receiving opening is inclined relative to the horizontal and such angle may be varied at will to control the movement of the work pieces through the openings.

The invention may be embodied in certain parts and arrangements of parts, a preferred embodiment of which will be described in such detail as will enable anyone skilled in the art to use the invention, and which is illustrated in the accompanying drawing which is a part hereof; and wherein:

Figure 1 is a side elevational view, somewhat schematic, of apparatus embodying the present invention.

Figure 2 is a cross-sectional view of Figure 1 taken approximately on the line 2—2 thereof.

Referring now to the drawings wherein the showings for the purposes of illustrating the invention only and not for the purposes of limiting same, Figure 1 shows a plurality of metallic work pieces A, supported on elongated skid rails 10 and being advanced from left to right through induction heating apparatus, indicated generally at B, where the work pieces are heated to elevated temperatures and then discharged as shown at the right of Figure 1.

The metallic work pieces A may be of any known metallic material, such as aluminum, steel, cast iron, brass, or the like, and may have any desired cross-sectional configuration. They are shown in Figure 2 as having a circular cross-sectional shape, which shape is generally conventional in the induction heating art and is a shape which is readily adapted to induction heating. The induction heating apparatus, itself, B is comprised of a single multi-turn, helical winding 13 having end terminals 14, 15 and intermediate terminals 16, 17. These terminals 16, 17 will generally be tapped into the coil 13 at points equally spaced from the terminals 14, 15. However, they need not be so located and can be otherwise placed within the scope of the invention. Terminals 14, 15 are shown as being connected to the line L₁ leading

to a multiphase, alternating current power source. In a like manner, the taps 16, 17 are connected respectively to the line L_3 , L_2 of the same multiphase, alternating current power source. This is preferably a 60 cycle alternating current power source, as such frequency is conventional and standard throughout the United States. Obviously, the frequency may be otherwise within the scope of the invention. The voltage of the power source may be as desired and if the voltage required by the coil 13 is not the same as that of the power source voltage step-up or step-down transformers may be employed to provide the proper and appropriate voltages.

The physical construction of the induction heating furnace, or apparatus, may be as desired or as is known in the art and the exact details of its construction will not be specifically set forth herein. Normally, the coil 13 will consist of a plurality of turns of heavy, water-cooled copper tubing with the individual turns electrically insulated one from the other. These turns are then generally imbedded in a cast refractory material by forming a proper mold, placing the windings 13 within the mold and casting a refractory material therearound, but with a mandrel therethrough to provide a work piece receiving opening 20, which opening 20 is continuous from one end of the furnace B to the other.

The guide rods 10, of which two in the embodiment shown are employed, extend around the lower surface of the opening 20 in spaced relationship and in the embodiment shown extend for a substantial distance on both sides of the induction heating apparatus B. On the left-hand end of the apparatus B the guide rods 10 extend to the left in a linear direction. A hydraulic feed mechanism 22, having a hydraulically operated push rod 23, is mounted on the left end of the guide rod 10 and serves to advance work pieces A from left to right through the induction heating apparatus B. The right-hand end of the guide rods 10 where they extend from the apparatus B may either be straight or curved downwardly as shown whereby to assist work pieces in a heated condition as they are moved from the right-hand end of the apparatus B to fall away therefrom into a pan, not shown. If desired the work pieces can be removed by means of tongs or the like.

Generally, what has been described to here is relatively conventional in the induction heating art.

As is known, when the coil 13 is energized from a multiphase, alternating current power source, a moving magnetic field is created which tends to exert a force on the work pieces A within the field. In accordance with the invention, the terminals 14, 15, 16 and 17 are connected to the lines L_1 , L_2 , L_3 of the power source such that the force on the work pieces A is from left to right. That is, the force is tending to move the work pieces in their normal direction of movement through the apparatus B.

As heretofore pointed out, such force created by the moving magnetic field is sufficient to eject the work pieces from the apparatus B unless steps are taken to prevent this.

In accordance with the present invention, the axis of the work piece receiving space 20 is inclined upwardly in the direction of the force on the work pieces A. Thus, the apparatus B is pivoted by means of a bracket 23 on a base support, shown schematically at 24. The right-hand end of the furnace B is raised above the left-hand end of the furnace by means of eyelet 25 supported on the upper end of a vertical pushrod 26 of a hydraulic piston-cylinder arrangement 27. By extending or retracting the push rod 26 the angle α of the axis of the chamber 20 relative to the horizontal may be varied at will.

If it be assumed for the moment that the angle α is equal to zero and the coil 13 is energized so as to exert a force from left to right on the work pieces A, the only force tending to resist this magnetic force is that of the

friction between the work pieces A and the guide rails 10. This frictional force is directly proportional to the weight of the individual work pieces per unit length and the coefficient of friction between the work pieces and the guide rails 10. This coefficient of friction may vary somewhat with different materials and as the work pieces change in temperature. For practical purposes it may be assumed as .15, that is to say, in order to move 100 lbs. of work pieces through the coil 15 lbs. of force are required. With aluminum and steel billets on a coil 13 energized so as to have high electrical current flowing therethrough this force is easily and readily exceeded.

By tilting the axis of the passage 20 upwardly in the direction of the magnetic force exerted by the currents in the coil 13 this magnetic force may be readily opposed by using the force of gravity. Thus, as the angle α is increased from zero the force of gravity has a component of force from right to left proportional to the sine of the angle α . This force is in opposition to the magnetic force of the coil 13.

It will be noted that as the angle α is increased the normal force between the work pieces A and the guide rods 10 will decrease proportionately to the cosine of the angle α , so that the frictional forces opposing movement of the work pieces A from left to right are reduced slightly as the angle α is increased.

Thus, in accordance with the invention and for any given electrical energization of the coil 13 and any size, shape, or metal of the work piece A is adjusted such that the weight per unit length of the work piece times the quantity (sine of the angle $\alpha + .15 \times$ the cosine of the angle α) must always equal or exceed the magnetic force developed on the work pieces per unit length of work piece in the coil. This defines the minimum angle α . The maximum angle α which may be employed under the same set of conditions whereby the work pieces A will remain in the coils without external restraining means is related to the minimum angle α , above defined, as a function of the coefficient of friction, which has above been assumed to be .15. Thus, the maximum angle α is equal to the weight per unit length of the work piece times the quantity (sine of the angle α —the coefficient of friction $\times$ the cosine of angle α). Above this angle the work pieces will fall from right to left through the coils unless restrained by the pushrod 23. This is normally an undesirable condition.

It is preferred to so adjust the angle α to or adjacent the minimum volume above indicated. When so adjusted the amount of work required to advance the work pieces A through the coil is at a minimum, and in theory can approach zero. This latter, though, is an unstable condition and not to be preferred.

The preferred embodiment of the invention shows the work pieces being advanced upwardly through the passage 20. Obviously, if desired, the work pieces can be advanced from right to left by simply reversing the position of the guide rods 10 and the hydraulic feed mechanism 22 shown from that in the drawing. With such an arrangement the work pieces are advanced in opposition to the magnetic force and, in effect, the magnetic force is employed to prevent the work pieces from falling out of the lower end of the coil. When it is desired to feed a new work piece into the coil the hydraulic feed mechanism operates to advance work pieces against the magnetic forces and drop a work piece from the left end of the coil.

It will be noted that in all embodiments of the invention the magnetic force is always in the direction of upwards inclination. The direction of movement of the work pieces from feed to discharge is unimportant.

It will also be appreciated that by operating the hydraulic mechanism 27 the angle α may be varied at will. At times the mechanism 27 may be operated to lower the angle α and allow the magnetic force to force work pieces out of the coil. When one or more work pieces,

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as desired, has been advanced out of the coil the angle α can then be increased to prevent further ejection of work pieces.

As above pointed out, the magnetic force varies with the characteristics of the coil, the electric currents flowing in the coil, the metal of the work piece A, their shape and temperature. The hydraulic mechanism 27 allows for ready and quick adjustment of the angle α to thereby readily compensate for any of the above variables.

Obviously, other types of mechanisms may be employed than that of the work piece feed apparatus 22 shown, or the raising and lowering mechanism 27. They are shown as being hydraulic members for the purposes of illustration only.

It will be appreciated that in the embodiment shown the entire weight of the work pieces A within the apparatus B will be supported between the ears 23 and 25. Obviously, auxiliary strengthening means for the coil 13 can be provided intermediate these two members. Also, the location of the members 23, 25 is relatively unimportant so long as the angle α is provided. This angle can be fixed if desired at any calculated value. Such fixed angle, however, is generally only employable where the specific set of conditions under which the apparatus will operate is known prior to the manufacture thereof.

The invention has been described with particular reference to a preferred embodiment. Obviously, modifica-

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tions and alterations of the specific embodiment disclosed will occur to others upon a reading and understanding of this specification and it is my intention to include all such modifications and alterations, insofar as they come within the scope of the appended claim.

Having thus described my invention, I claim:

Induction heating apparatus adapted to heat a plurality of metallic work pieces, said apparatus comprising in combination a multiturn electrical winding having a work piece passage therein, said winding being energized from a multiphase alternating current power source, such that work pieces in the passage will have a magnetic force exerted thereon in one predetermined direction, said work pieces in said passage having a coefficient of friction with supporting surfaces for the work pieces in said passage, the axis of said passage being inclined upwardly in the direction of said magnetic force by an angle α , such that the magnetic force per unit length of work piece will equal the weight of work piece per unit length of coil times the quantity (sine of $\alpha \pm$ the coefficient of friction $\times$ cosine α).

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