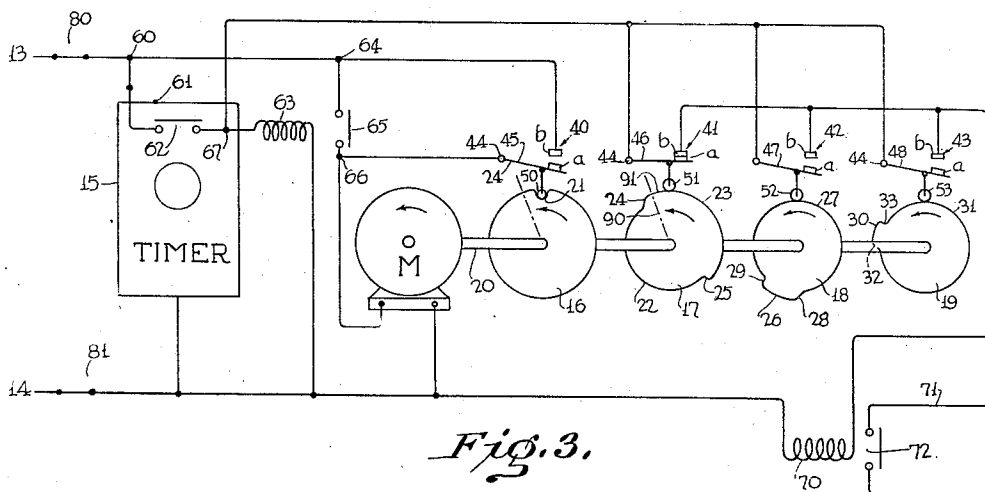
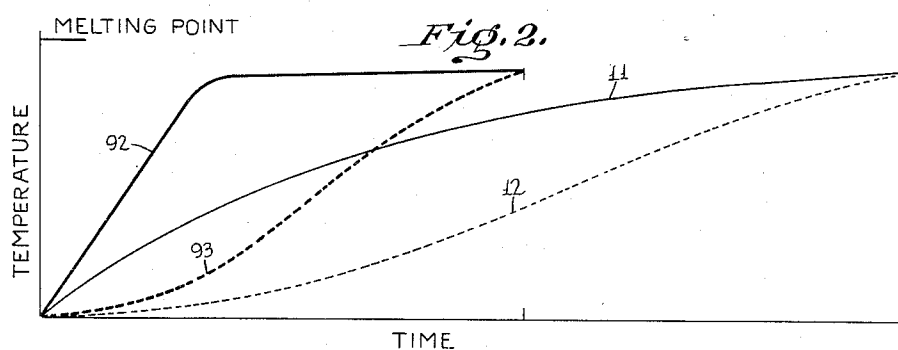
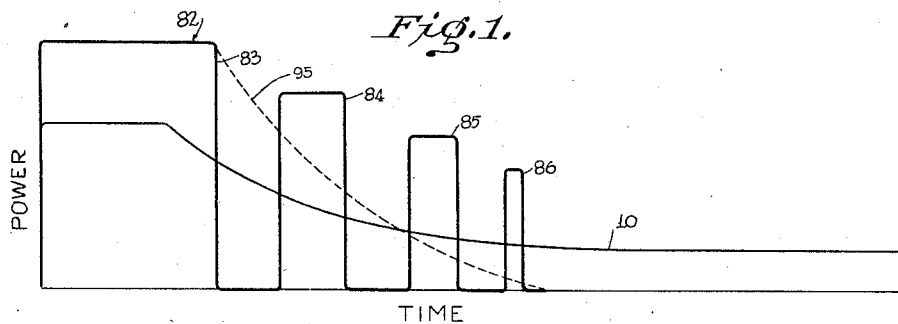


H. A. STRICKLAND, JR

INTERMITTENT BILLET HEATING

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INVENTOR
Harold A. Strickland, Jr.

BY *John P. Tarbox*
ATTORNEY

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INTERMITTENT BILLET HEATING

Harold A. Strickland, Jr., Detroit, Mich., assignor,
by mesne assignments, to Budd Induction Heat-
ing, Inc., Philadelphia, Pa., a corporation of
Michigan

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2 Claims. (Cl. 219—11)

This invention relates generally to the heating of workpieces such as billets or bars and specifically to improved means of heating such articles by electrical induction.

An outstanding object of the invention is to provide a method for heating large size billets by which an important reduction in heating time is secured. Another object is to provide apparatus usable to effect such time reduction in billet heating. Still another object is the provision of power control means for heat treatment of billets and the like which may be readily associated with conventional heat timing control apparatus. An object also is the provision of heat control mechanism which is independent of controlled variation in applied power. Another object is the control of the electrical power input into a charge without substantial variation of the voltage of the applied power. Another object is the simplification of means generally for securing adequate billet heating in a reduced time interval. Important additional objects are to reduce heat losses due to high temperature radiation and to counteract the action of skin effect for the larger size bars or billets.

Other objects will become apparent on examination of the invention as hereinafter described and shown in the accompanying drawing, in which:

Figure 1 is a power-time curve illustrating comparative modes of heat treatment;

Figure 2 is a heat-time curve showing performance of comparable heating methods; and

Figure 3 is a diagrammatical view of the power timing mechanism.

In my copending application Serial Number 384,503, filed March 21, 1941, therein is shown a form of induction furnace wherein use is made of electromagnetic induction from a heating coil to generate eddy currents in a workpiece and thereby heat the same in accordance with the square of the current generated, the effective resistance, and the time period of treatment. In the heating of bars, billets and the like, the rate of continuous application of power is determined by the fact that as the temperature increases the rate of thermal conductivity between bar surface and core diminishes. The essential consideration in such heating is the maintenance of the bar surface at as high a temperature as possible below fusion so that the maximum rate of heat transference between surface and core may be maintained. The initial maximum of power input therefore is determined by the rate of the final input necessary to obtain maximum heating

below the surface fusion point. A power curve of this type is shown at 10 in Figure 1 where, after the period of initial maximum input, the power is progressively diminished to a substantially constant value.

In this connection reference should be made to Figure 2 of the drawing showing curves plotted against a temperature ordinate and time abscissa. The full line 11 indicates the rise in temperature of the surface of a continuously heated bar and the dotted line 12 indicates the rise in temperature of a point at the axis or approximate center of the bar. Obviously the time period of treatment will depend upon the size of the bar and in the case of billets or other large workpiece having a diameter, for example in excess of 5 inches, the time of treatment becomes an important consideration in the efficiency of the furnace. With any billets the time factor is further complicated by the skin effect.

In accordance with my improved procedure it has been found possible to decrease the time period of treatment for billets or other large workpiece over that now required by the continuous heat treatment method, by substantial amounts ranging to as low as 50% or lower, a 70% reduction being possible. This outstanding time reduction in heat treatment is obtained by applying power to the workpiece intermittently and without disturbing the normal voltage of the applied power. The apparatus for accomplishing this improved result is shown diagrammatically in Figure 3 of the drawing. In this figure the numerals 13 and 14 indicate a source of alternating current of commercial frequency which as indicated is connected to the timer 15, by means of which the overall time period in which the power is effective on the heating and control circuits is predetermined. Included in the control mechanism is the motor M which with a series of related cams 16, 17, 18 and 19 are mounted on a common shaft 20. The cam 16 is referred to hereinafter as the motor cam and cams 17, 18 and 19 as power cams. These cams each have for the most part circular camming edges on segments of different radii the exception being the motor cam 16 which is approximately cardioid in shape, the recess 21 however being approximately circular in shape and of a tangential width equal to or greater than that of the coacting cam follower. As shown, cam 17 has circular cam segments of different radii designated as the inner cam segment 22 and the outer cam surface 23. These surfaces are joined by the inclined cam section 24 and the radial

section 25, the inclined cam section leading the cam sector 23 in the indicated direction of rotation. Cam 18 includes the cam segment 26 having a radius of curvature greater than that of the adjoining segment 27, these two segments being joined by the inclined section 28 on the leading edge of sector 26 and the radial section 29. Similarly cam 19 is formed of the cam segment 30 having a radius of curvature in excess of the remaining cam segment 31, the segment 30 being connected to the outer segment by a leading inclined cam section 32 and a radial cam section 33. One complete rotation of the cam includes one normal timer cycle.

Positioned above each of the cams 15, 17, 18 and 19 are the switches 40, 41, 42 and 43, each of these switches having pivot points 44 to which are attached the movable, downwardly spring flexed switch arms 45, 46, 47 and 48. Contacts *a* secured to the upper surfaces of the switch arms adjacent the ends thereof are adapted to be moved into electrical contact with the fixed contacts *b*. Means for closing these switches are provided in a plurality of cam followers 50, 51, 52 and 53 indicated as rollers connected to the bottom surface of the switch arms and adapted to ride over the cam surfaces of the various cams. As indicated these switches are in open position when the cam follower in the case of the motor cam 16 moves into the recess 21 and in the case of the power cam 17, 18 and 19 when the cam followers are riding over the cam segment of lesser radius. It follows also that when these cam followers are riding on the cam surfaces of greater radius the various switches are in closed position.

The circuits connecting the described timer and motor cam unit may now be detailed. Power is applied from the mains by closure of switches 80 and 81. At the point 60 on the power main 13 the circuit divides, one branch passing into the timer at 61 and through the same to main 14, another branch contacting with one of the timer switches 62 and passing through this switch and the relay coil 63 to the other power main 14. Still another branch passes from the point 60 to a junction point 64 where it divides one branch passing through to a contact switch 65 normally open but adapted for closure on energization of the coil 63 and thence through contact point 66 to the motor *M* and to the power main 14. The other branch proceeds to the fixed contact *b* of the motor cam switch 40. Also a connection is formed between the pivot point 44 of motor cam switch 40 and point 66 in the motor circuit.

Intermediate normally open timer switch 62 and the relay cam 63 is a junction point 67 from which a circuit leads to the switch arm pivot points 44 of each of the three power cam switches 41, 42 and 43. Also the stationary contacts *b* of the power cam switches are joined and connected through a relay coil 70 to the main 14. The load circuit 71 which normally is connected to an induction heating apparatus, a resistance welder or other translating unit is energized through activation of the relay 70 and closure of the normally open contact switch 72. A voltage of 800 and frequency of 3000 cycles may be employed in the load circuit.

It is now apparent that we have described a control assemblage including the timer, the motor and the related motor and power cams together with the connecting circuits, switches and

coils which may be inserted in any desired electrical system to control the application of power from main load lines to a load circuit. The operation of the described arrangement of apparatus will now be detailed. The timer 15 is of one of the well known commercial types and is so designed as to set the limits of the time in which the power is effective on the control system and load circuit. Consequently when main switches 80 and 81 are closed and power is effective on the timer 15, the normally open timer switch 62 is closed bringing about energization of relay coil 63 and closure of relay coil contacts 65. Immediately the motor *M* is energized causing rotation of the same in the direction indicated by the arrow and simultaneous rotation of motor cam 16, movement of which through action of cam follower 50 closes contacts *a* and *b* of switch 40. Because of the relatively long camming action of the motor cam 16 it is at once perceived that switch 40 is retained in closed position for practically the complete timing cycle and consequently the motor cam serves as a lock on the relay contact switch 65. When the cam follower 50 of cam 16 at the approximate end of the cycle rides into the depression 21 the switch 40 opens and when at the same time contact switch 65 is also open due to the shorter timer cycle, the motor stops, the speed of rotation being such, combined with the spring action of the switch arm 45, to permit a stoppage of rotation as described.

Following closure of timer switch 62, also, current passes through the circuit from junction 67 to the various power cam switches. At the zero point of rotation switch 41 is closed and hence relay coil 70 is energized, contact switch 72 is closed and the load circuit made effective. As the cam 17 rotates in the direction indicated the follower 51 will ride over the radial offset 25 and switch 41 will open thus completely de-energizing the load circuit. This condition is maintained, however, for only a brief time interval, cam follower 52, bearing on cam surface 27 of cam 18, riding over the inclined cam surface 28 to the segment 26 of increased radius thus closing switch 42 and again applying power to the load circuit. Power is applied in this second instance until the cam follower 52 moves to the section 27 of lesser radius and opens the switch 42 thereby de-energizing the load circuit until cam follower 53 of power cam 19 moves over the section 30 of greater radius to close switch 43 and again energize the load circuit. This is followed by a period of de-energization until cam follower 51 of cam 17 after moving over the section 22 of reduced radius again contacts with the section 23 of increased radius thus closing switch 41 and reapplying power in the load circuit. This power is effective until the cam reaches a point roughly indicated by the radial line 90 in cams 16 and 17 which defines, with the vertical through the center of cams 16 or 17, a segment 91 in which the timer 15 is de-energized having completed the predetermined time period of power supply. It is in the small interval of time indicated by the segment 91 that the relay coil 63 is de-energized opening contact 65 and conditioning the motor circuit to be opened upon movement of cam follower 50 into the recess 21 of motor cam 16. Thereupon the motor and its associated cams cease rotation this being the approximate zero point of the cycle and the operator removes the heat treated load.

Casual inspection of the lengths of the segments of the power cams 17, 18 and 19 reveals

that these camming sections are of decreasing length the angular values in the diagrammatic showing being roughly 150°, 45° and 34°. As previously described the larger segment of cam 17 includes two active sections one from the zero point extending approximately 126° clockwise and the other extending counterclockwise about 12° from the power end line 90. The segment 91 between these two active sections and adjacent the zero line covers the de-energized or neutral area. These approximate measurements of the effective segments of the cams are paralleled in the power curve of Figure 1 which shows a power line 82 having a series of rectangular sections or peaks 83, 84, 85 and 86. The width of section 83 corresponds to the time period of power activation of cam 17 from the zero point to the end 25 of the outer cam segment, the width of section 84 corresponds to the camming segment 26 of cam 18, the width of section 85 corresponds to the width of cam segment 30 of cam 19 and the width of section 86 corresponds to the section of segment 23 of cam 17 defined by the dotted line 90 which is determined by timer 15 and the inclined camming surface 24. The time spaces intermediate the rectangular power sections of Figure 1 correspond to the time periods when the cams 17, 18 and 19 are ineffective. The dotted line 95 indicates the approximate average value of the blocked power curve 82.

It is pointed out that the ordinates of the rectangular sections exceed in each instance the corresponding high point of the compared power line 10 for ordinarily continuous power application. This is done by redesigning the load coil to draw more power. Interpreted, this curve means that power is applied to the load circuit intermittently in comparatively excessive amounts, these time periods being separated by other periods in which the power applied is zero. It is pointed out further that the height of these rectangular power sections diminishes from left to right when heating magnetic steels at constant coil voltage indicating that the rate of power application diminishes with the time. Further, the width of the sections diminishes from left to right indicating that the time period of application decreases as the cycle progresses, this being in agreement with the indicated sizes of the cam segments. Also the time period of interruption of the power progressively diminishes. In explanation of these curve characteristics it is first noted that the rate of power input for the complete cycle must not be such as to cause surface fusion. Where power is applied continuously, as indicated in curve 10 of Figure 1, the rate is reduced to prevent fusion. By applying the power intermittently, however, it is possible to increase not only the initial maximum input but the successive applications, so that the desired condition of larger temperature difference between billet surface and core is made possible earlier in the cycle. By so doing the total applied power is not increased but, on the contrary, is reduced, due to the greater efficiency of treatment at high surface temperatures.

Relative to the progressive reduction in the ordinate of the power curve 82, this is due to changing load impedance caused by loss of magnetism in steel. The reduction in peak width with time is used to further reduce the energy input to the reduced value necessary to maintain the surface temperature at its maximum value, as the temperature of the billet rises.

Thus it appears that by applying the power

excessively and intermittently, and initially for such a time interval as to bring the surface temperature rapidly to a point adjacent the fusion temperature—and following this initial power application by successive shorter applications separated by zero power, to maintain the outer surface temperature, the total power applied not being in excess of that used in continuous heating, the time of heat treatment is substantially reduced.

The effectiveness of the described procedure is clearly illustrated in Figure 1 in relation to the timer period of the heating cycle. In case of curve 82 the time is shown to be approximately one-half that required for the continuous heating method of curve 10. The effect on the temperature is shown in Figure 2 wherein, by employing the intermittent method of heating, the external temperature 92 is quickly brought up to a point close to the melting point in the first period of power application and in this same period the core temperature 93 has definitely turned upward. Succeeding the first power application the external temperature of the billet is maintained approximately constant at the maximum point because of the reduction of power application as shown in Figure 1. In this manner the greatest possible difference of temperature is maintained between the surface and core of the billet and thus the maximum rate of heat transference is maintained.

In addition to the important and outstanding advantage of the intermittent procedure as described in reducing the time of treatment another advantage to be noted is that there is no necessity of modifying the voltage of the power input. This makes unnecessary apparatus for power control the procedure requiring merely a control of the time period of application. In addition the simplicity of the method of time control by means of cams is to be noted, this apparatus being inexpensive and easily applied and controlled. As previously suggested the integrated value of the power of the intermittent curve 82 is somewhat less than that of the curve 10. This is due to the greater efficiency of the intermittent method in that use is made of higher surface temperatures and therefore of greater heat conductivity. Further by the intermittent method the time period of heat radiation is reduced in even greater proportion than the time period of the continuous method. This is important since radiation heat losses vary as the fourth power of the temperature and by cutting the high temperature time period by at least one-half a substantial loss of energy is eliminated.

The intermittent method of heating as above described has particularly advantageous uses in connection with induction heating of billets and the like having a relatively large diameter. However it is apparent that the principle of intermittent heating as described may be applied with equal facility to different heating methods and to workpieces of varied type and form, wherever heat flow time is significant. It is also apparent that the billet or workpiece may be of aluminum, brass, iron or steel or any other metallic material which would be usable in connection with the described heating procedure. In view of the possible modifications of the apparatus and circuits to meet particular objectives it is not intended that the invention be confined to the showing as made, the limitations of the invention being defined only in the claims as hereto appended.

What is claimed is:

1. A process of heat treating a workpiece which comprises supplying heat to said workpiece at a rate substantially in excess of the maximum rate of continuous heat treatment until the workpiece surface is at approximate fusion temperature, interrupting the heat flow, re-applying heat for another time interval prior to substantial reduction in the workpiece surface temperature below fusion temperature and repeating said heat applications until the workpiece has the desired temperature.

2. A process of heat treating a workpiece which comprises supplying heat to said workpiece for a

first time interval at a rate substantially in excess of the maximum rate of continuous heat treatment until the workpiece surface is substantially at fusion temperature, interrupting the heat flow for a second time interval, re-applying heat for a third time interval of lesser duration than the first interval prior to substantial reduction of workpiece surface temperature below fusion temperature and equalization of surface and core temperature, and repeating said heat applications at progressively reduced time intervals of application and interruption respectively until the workpiece has the desired temperature.

HAROLD A. STRICKLAND, JR.