Aug. 13, 1940. M. C. LEIFER ET AL 2,211,017

MAGNETIC HARDNESS CONTROL DEVICE

Filed July 27, 1937

Fig. 1

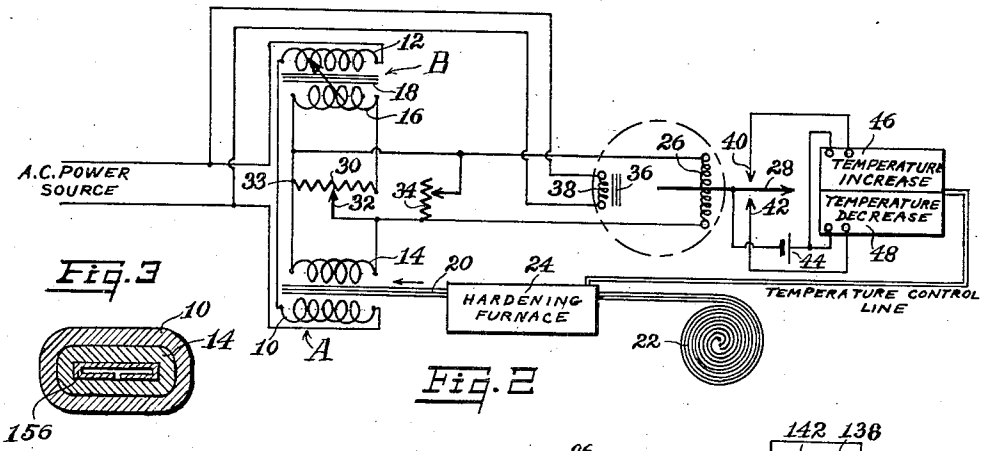
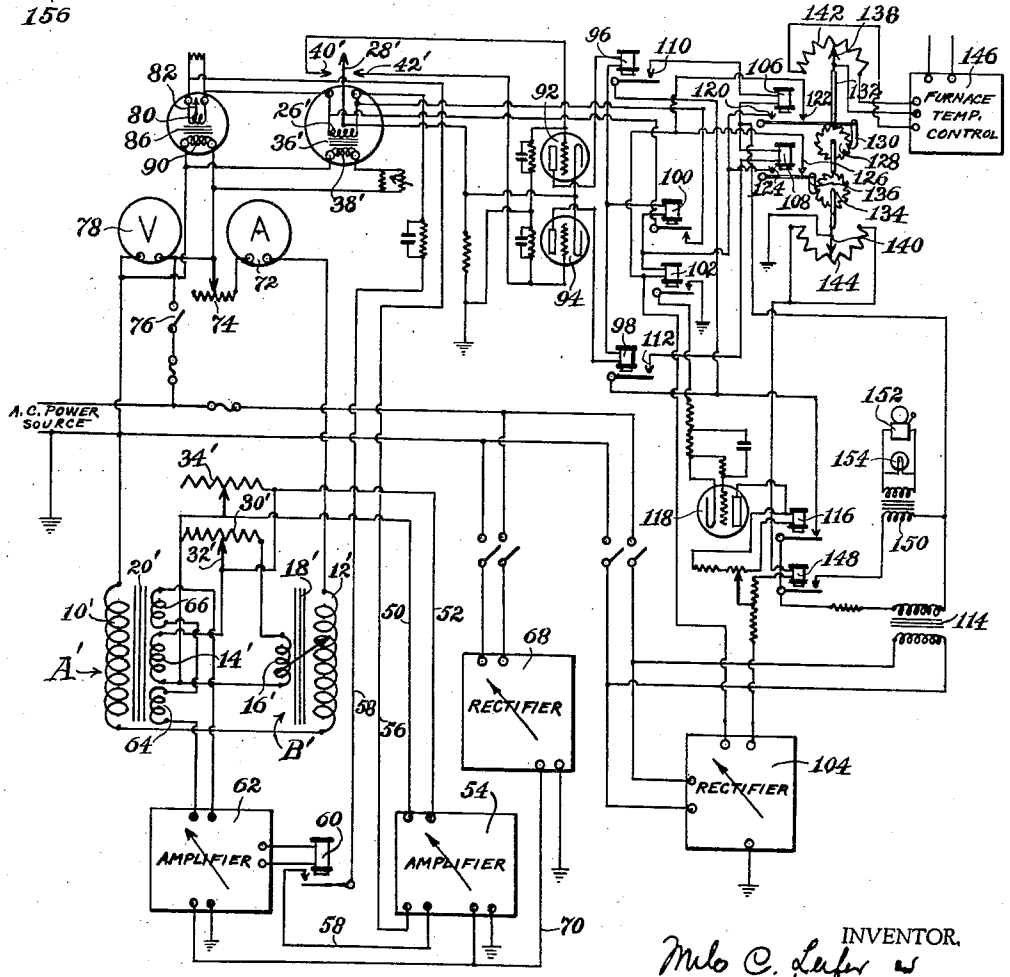


Fig. 3

Fig. 2



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MAGNETIC HARDNESS CONTROL DEVICE

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6 Claims. (Cl. 266—2)

This invention relates to the heat treatment of steel and in particular it relates to an arrangement for so controlling such heat treatment as to result in a product that is of a uniform predetermined standard of hardness.

While our invention has been disclosed in connection with the heat treatment of steel it will be understood that as to certain phases thereof it may have other applications.

It has been discovered that the hardness of steel bears a definite relation to its magnetic permeability. In general the harder the steel the lower will be its permeability. If therefore two pieces of steel having the same composition and characteristics are compared as to permeability and it is found that they have the same permeability, it will be found that they also have the same hardness.

Our invention is based on the comparison of the permeability of two pieces of steel, one of which is the product of treatment in a hardening furnace and the other of which is a standard sample, and the consequent adjustment of the temperature of the hardening furnace in accordance with this comparison whereby the heat treatment in the furnace will result in a permeability of the product substantially identical with that of the standard sample, and our invention contemplates making such adjustment of the hardening furnace entirely automatic. Instead of comparing the product directly with the standard sample we have found it convenient to use what may be termed a "secondary standard," that is, a standard that is first set by or compared with the standard sample and is thereafter used for purposes of comparison with the product.

It is among the general objects of our invention to provide apparatus for the automatic control of the temperature of a hardening furnace whereby the hardness of steel treated therein is automatically controlled and to provide apparatus for this purpose that is effective in operation, simple in construction and low in cost.

For the attainment of these objects and such other objects as will hereinafter appear or be pointed out we have illustrated several embodiments of apparatus for the practice of our invention in the drawing, in which:

Figure 1 is a diagrammatic view showing a simple form of apparatus for the practice of our invention and intended to make clear the underlying principles thereof;

Figure 2 is a diagrammatic view showing another form of apparatus; and

Figure 3 is a sectional view through one of the transformers used in our apparatus.

As already indicated, our invention contemplates the comparison of the permeability of a standard sample, which possesses the characteristics desired in the material to be treated, with an adjustable standard, which may be termed a secondary standard, and adjusting the latter so that it bears a definite relation to the standard sample and thereafter substituting for the standard sample a portion of the product of heat treatment in a heat treating device such as a hardening furnace and adjusting the conditions in the latter until the product emerging therefrom when compared with the secondary standard is identical in permeability with said secondary standard.

The apparatus according to our invention for accomplishing this comprises in general two transformers, one having the primary and secondary thereof magnetically coupled by using the standard sample or the product to be controlled as the core thereof, while the coupling of the primary and secondary of the other transformer is made adjustable. The coupling of the first transformer is obviously dependent on the permeability of the material inserted thereinto.

The secondary or output sides of the transformers are so connected that they are opposed to each other and the resultant of their outputs is used to adjust the conditions in the heat treating furnace.

Since the output of the transformers depends on the coupling between their primaries and secondaries it will be obvious that if the adjustable transformer is first balanced against the standard sample in the other transformer and the standard sample is then replaced by the product, that a balance will exist in the latter case only if the permeability of the product is the same as that of the standard sample, and our invention contemplates that where such balance does not exist adjustment of the furnace is effected until the product thereof has the same permeability as the standard sample.

We have disclosed our invention in connection with a continuous process in which the steel to be treated is in the form of an elongated strip. As the strip advances through the hardening furnace in which the hardening treatment takes place the portion thereof that emerges from the furnace is passed through the transformer and is advanced correspondingly. Since this portion represents the result of the hardening treatment undergone thereby a short time previously, it is

clear that control of the furnace in accordance with tests on this portion will result in a uniform treatment for the succeeding portions of the strip. However, it is to be understood that our invention is not limited to a continuous process.

On referring to Figure 1 it will be observed that our invention comprises first of all a pair of transformers designated respectively by A and B. The transformer B has its primary 12 coupled to its secondary 16 by the core 18 and the coupling is indicated as being adjustable. The other transformer A also has its primary 10 coupled to its secondary 14 magnetically, the coupling in this case being effected by a core that may be either a standard sample to which it is desired to conform the material to be treated or may be the treated material itself.

In Figure 1 the magnetic coupling in transformer A is shown as formed by a portion 20 of a strip or roll of material that is in process in our apparatus, the portion 20 being a portion of the strip that has just emerged from the hardening furnace, which is shown diagrammatically in Figure 1 at 24, and which may be of any well known type in which the temperature may be controlled by automatic means. The condition of permeability of the portion 20 may therefore be taken to represent the result or effect of the hardening treatment that the following portion of the strip is undergoing in the hardening furnace 24, while the advance portion of the strip is positioned in the transformer A and is being tested. By correcting the conditions in the hardening furnace shown to be necessary by the testing of the said portion 20, the remaining portions of the strip will be assured of the desired heat treatment.

The untreated portion 22 of the material in process is shown in coil form. It will be observed that our apparatus is peculiarly adapted for continuous operation and this we have found to be of particular advantage in the manufacture of safety razor blades, the starting point in the manufacture of which is a continuous strip of material which is subjected to the hardening process before being separated into individual blades.

It will be observed by referring to Figure 1 that the primaries 10 and 12 of the transformers A and B are connected in series across an alternating current power source and that the secondaries 14 and 16 of these transformers are also connected in series.

A potentiometer 30 is connected across the terminals of secondary 16 while its movable contact 32 is connected to that terminal of secondary 14 that is not connected to the secondary 16. It will be observed that when the current in the potentiometer 30 resulting from the action of the secondary 16 of transformer B flows away from terminal 33 of the potentiometer, the current in the potentiometer resulting from the action of the secondary 14 of transformer A flows toward the terminal 33 of the potentiometer, since in relation to the point 33, the voltage and currents in these respective secondaries are opposite in phase. It follows that the current flowing between the movable contact 32 and the terminal 33, which is the resultant of the currents flowing in the respective transformers, is equal numerically to the difference in their currents, and where these currents are of equal magnitude, the resultant will be zero. If one current is stronger than the other the resultant current will flow either toward or away from the terminal 33.

A movably mounted coil 26 carrying a pointer 28 is connected across the terminal 33, which is the meeting point of the secondary terminals and the movable contact 32, and since this coil 26 is shunted across the potentiometer at movable contact 32 and the terminal 33 it follows that the direction of the currents therein will be similar to those in the potentiometer between the movable contact 32 and the terminal 33. A variable resistance 34 is shown connected across the terminals of coil 26 whereby its sensitiveness may be adjusted.

It will now be clear that a condition of zero current in the coil 26 may be effected by variation of the magnetic coupling in the transformers A and B respectively and also by shifting the movable contact 32 of the potentiometer so as to control the resistance of the two legs thereof, and in the practice of our invention this condition is first attained with the standard sample in place in transformer A. If now the test strip is substituted for the standard sample, it is clear that if there is no current in coil 26 the test strip has the same permeability as the standard, while if there is current in coil 26 it is necessary to adjust the furnace in order to again obtain a zero current.

The movable coil 26 is shown as coupled through a magnetic core 36 to a fixed coil 38 that is thrown across the power source and therefore carries a substantially uniform current. The pointer 28 moves with the coil 26 in accordance with the current passing through the coil and is shown as controlling auxiliary circuits comprising contacts 40 and 42, a battery 44, and temperature control means 46 and 48 by which the temperature in the hardening furnace may be controlled. When there is no current in coil 26 the pointer is in its middle or inactive position, but when current flows through it, it moves to one side or the other, depending on the direction of the current flow and will then move against one of the contacts. When the pointer 28 contacts with 40 it activates the temperature increase device 46, while when it contacts with 42 it activates the temperature decrease device, whereby the furnace temperature is respectively raised or lowered.

We have not illustrated the details of the temperature control means inasmuch as such devices form no part of our invention, and any of the known types in which the control of the heat generating medium is effected electrically may be used.

In the operation of the device a standard sample of the desired degree of hardness is first inserted into the transformer A, and the coupling of the transformer B and the variable potentiometer 30 are adjusted until a balance is obtained, which is indicated by the fact that the pointer 28 assumes a mid position, with no current flowing in the coil 26. The standard sample is now removed and that portion of the strip that has just been passed through the hardening furnace and been subjected to its action is inserted into the transformer A in place thereof. If the permeability of this treated portion is the same as that of the test sample, the equilibrium of pointer 28 is not disturbed. If however the permeability is less or greater than that of the standard sample, the equilibrium is disturbed and the voltage of one secondary or the other will predominate and will cause current to flow through the coil 26 in one direction or the other, and consequently the pointer will move to one side or the other and either increase or decrease

the hardening furnace temperature until it is such that the hardness of the steel passing therethrough is the same as that of the standard sample.

It will be understood of course that the standard sample must be of the same material and should have the same dimensions as that portion of the strip of material undergoing heat treatment that is positioned within the transformer, as otherwise the degree of coupling will be dependent on other factors than the permeability.

It will be observed that the heat treatment of the strip of material 22 is continuous and entirely automatic.

In the embodiment of my invention disclosed in Figure 2, while the basic principles outlined in connection with Figure 1 have been retained, many refinements have been added which greatly increase the practical utility of the device.

Among these the use of electronic amplification, by which the sensitiveness of the device is enormously increased, and the addition of an alarm system for indicating an exceeding of the limits of the apparatus may be mentioned.

In the showing of Figure 2 many accessories to the electronic circuits have been included which it has been deemed unnecessary to describe since they are customary with such circuits. Among these may be mentioned resistances and by-pass condensers. Other customary details such as switches and fuses have also not been described. The filament connections for the electronic tubes have not been shown in full, but it will be understood that said filaments are connected in the well-known manner either to the rectifiers indicated in the figure or to any other suitable source of electric current.

In Figure 2 the main transformers are indicated by the letters A' and B', their primaries being respectively 10' and 12' and their secondaries 14' and 16'. The primaries 10' and 12' are connected in series with each other and the secondaries 14' and 16' ars also connected in series with each other. The magnetic coupling of transformer B' is indicated at 18' and the test strip is indicated at 20'. A potentiometer 30' having a movable contact 32' is similarly connected and has identical functions with that of the potentiometer 30 and its movable contact 32 of Figure 1 and the resultant current from the transformer secondaries 14' and 16' passes through the leads 50 and 52 into the amplifier 54 and into the adjustable resistance 34' (corresponding to 34) shunted thereacross. The output of amplifier 54 passes into the movable coil 26' corresponding in function to the coil 26 through leads 56 and 58. The variable resistance 34' is shunted across the amplifier 54 for purposes of adjusting the sensitiveness of coil 26'. The lead 58 is shown as having inserted therein a switch controlled by a relay 60 energized from the amplifier 62 which receives current from a pair of auxiliary secondary coils 64 and 66 inductively coupled to the primary 10' of transformer A'.

When the primary 10' is coupled to the coils 64 and 66 through iron, as when the standard sample or the test strip are positioned within the transformer A', the amplifier 62 and consequently the relay 60 will be energized and the lead 58 will be unbroken. When however the iron coupling in the transformer A' is removed, as when there is no standard sample and no test strip within the transformer A', then the amplifier 62 receives either no current, or insufficient current, to energize the relay 60, and the lead 58 is broken by the relay so that the coil 26' becomes inoperative.

In order to provide the necessary current for the amplifiers 54 and 62 where they are of the electronic type we have shown a rectifier 68 of any suitable or preferred type, such as the customary electronic type, and this may furnish the plate current to the amplifiers 54 and 62 through the lead 70 and may also provide the filament current for the electron tubes of these amplifiers, although we have not shown connections for accomplishing this in detail. It will be observed that the amplifier 62 as well as the other amplifiers and rectifier are also adjustable as has been indicated in the drawing.

The primaries 10' and 12' of the transformers A' and B' are shown, as in Figure 1, connected in series and thrown across an alternating current power source, and an ammeter 72 and the variable resistance 74 and a switch 76 are also shown in series with the primaries 10' and 12'. A voltmeter 78 is shown connected in the conventional manner so as to indicate the line voltage.

In series with the movable coil 26' is shown a second movable coil 80 which carries the pointer 82. The pointer 82 moves in synchronism with the pointer 28' carried by the movable coil 26', the function of which is identical with that of the pointer 28 of Figure 1, and the purpose of pointer 82 is to visualize to an attendant the movement of the pointer 28'. The coils 26' and 80 are magnetically coupled, as indicated at 36' and 86, to fixed coils 38' and 90 respectively, these being connected across the power source so as to take the line voltage.

The contacts 40' and 42', corresponding respectively to the contacts 40 and 42 of Figure 1 are shown as connected respectively to the grids of a pair of electronic tubes 92 and 94, the plate circuit of which includes the relays 96 and 98 which are in parallel with each other and in series with a relay 100 and a relay 102, through which they are connected to a rectifier 104 energized from the power source and serving to supply plate current to tubes 92 and 94 and also, if desired, to supply them with filament current, although no connection for this purpose has been shown.

It will be observed that when the pointer 28' touches contact 40' that the grid of tube 92 will be biased so as to affect the plate current of tube 92 to energize the relay 96 while when the pointer 28' contacts with 42' the tube 94 similarly energizes the relay 98. When either relay 96 or 98 is energized both relays 100 and 102 are also energized.

When the relay 100 is energized it short circuits the coil 26' which thereupon returns to its no current position and the pointer 28' returns to its midposition, breaking the contact thereof with either 40' or 42' and consequently deenergizing the electronic circuits associated therewith.

The relay 96 when energized serves to close a circuit comprising a relay 106, and the relay 98 similarly serves when energized, through contact 112 to close a circuit comprising the relay 108. The circuits including relays 108 and 106 are energized from the secondary of a booster transformer 114 that is shown as having its primary connected across the main alternating current power source. The circuit including the relays 106 and 108 and connected across the secondary of transformer 114 may be broken by a relay 116 that is connected into the plate circuit of an electronic tube 118, which is rendered operative by the closing of relay 102.

When the relay 106 becomes energized it closes a circuit comprising the contacts 120 and 122 and the effect of this is to short circuit the relay 102 which thereupon disconnects the tube 118 and breaks the circuit connecting relays 108 and 106 to the transformer 114 because of the operation of relay 116. The function of relay 102 is to delay the interruption of the transformer circuit 114 so that the relay 106 will perform its function of advancing a ratchet 128, to be subsequently described, and for this purpose it may, if desired, be of the retarded type, particularly one in which the opening is retarded.

A similar effect is obtained when the pointer 28' touches the contact 42' and energizes the tube 96, which causes the operation of relay 98; in that case the relay 108 is energized and through contacts 124 and 126 it also short circuits the relay 102.

Whenever the relay 106 operates it actuates a ratchet wheel 128 through a pawl 130. This ratchet wheel is mounted on a shaft 132 which also carries a second ratchet wheel 134 that is actuated by the pawl 136 whenever the relay 106 operates. It will be observed that the ratchets 128 and 134 have their teeth arranged oppositely, so that the effect, as viewed in Figure 2, when the relay 106 operates, is to turn the shaft 132 counterclockwise while when the relay 108 is operated the shaft 132 is turned clockwise. Also mounted on shaft 132 are the movable contacts 138 and 140 of potentiometers 142 and 144 respectively, and as the shaft 132 turns the setting of these potentiometers is changed. The setting of potentiometer 142 effects the furnace temperature control 146 to increase or decrease the temperature in the hardening furnace.

The details of this furnace control device have not been shown as already mentioned heretofore since any of the many well known devices for this purpose may be used. When the contact 138 moves in one direction the control device 146 will be set to lower the temperature of the furnace while when it moves in the other direction the control device will be set to raise the temperature of the furnace.

The potentiometer 144 has a different function. Its contact 140 moves in synchronism with the shaft 132 but its active functioning is limited to the end positions of its movable contact 140 at either end, which corresponds to positions of no, or practically no, resistance between said movable contact and the fixed contacts, which are connected in parallel in a circuit comprising a relay 148 energized from the rectifier 104. When the contact 140 is in one of its aforementioned end positions the relay 148 will close the primary circuit of a transformer 150 which is energized from the secondary of transformer 114, and this will result in the ringing of bell 152 and the lighting of an incandescent lamp 154, so that an attendant is warned, both audibly and visibly, that the limits of the control device are about to be exceeded. When this occurs suitable adjustments may be undertaken by the attendant to remedy this condition.

It will be observed that the coil 26' is shown as operating intermittently instead of continuously. This, besides enabling the requisite stepwise operation of the pawls and ratchets, is found to be of advantage in that the contacts of the coil 26', which it will be recalled is movable, are thereby kept clean, due to the frequent wipings to which they are subjected.

It may be mentioned here that we have found that a hardening furnace in which the heating is followed by a quenching is highly convenient for the practice of our invention. We do not intend however thereby to exclude other types of furnaces such as a type for instance, in which no quenching takes place, and the heating is in the nature of a tempering operation.

As already mentioned, we have found our apparatus of great utility in connection with the manufacture of safety razor blades, which are made from flat steel strips. In attempting to introduce such a strip into the core space of a transformer having cylindrical primary and secondary coils we have found that because of the difference in crosssectional configuration between the steel strip and the coils, the large air spaces make the change in coupling effect when the steel is introduced into the transformer so small as to reduce the utility of the device. We therefore propose to use a transformer having a cross-section as indicated in Figure 3 in which 156 indicates a "spool" or "bobbin" in the form of a tube of any suitable or preferred non-magnetic material and split longitudinally to prevent eddy currents, where the tube is made of electrically conducting material, such as brass (which we have found very satisfactory for this purpose). The secondary 14 is wound on this spool and the primary 10 is wound over the secondary. The space within tube 156 conforms closely to the steel production strip.

While we have herein disclosed several illustrative embodiments of our invention and one manner of practicing the same it will be understood that the same may be embodied in many other forms and practiced in many other ways without departing from the spirit thereof as will be obvious to those skilled in the art and that the disclosure herein is by way of illustration only and is not to be construed in a limiting sense and that we do not limit ourselves other than as called for by the prior art.

Having thus described our invention and illustrated its use, what we claim as new and desire to secure by Letters Patent, is:

1. Means for controlling the temperature of a hardening furnace in response to variations in the product thereof, said means comprising a control device movable from a normal position into either of two positions in accordance with predetermined departures of said product from a predetermined standard, a circuit adapted to be energized by said control device when it is in one of its said positions for adjusting the temperature of the furnace in one direction and a second circuit adapted to be energized by said control device when it is in its other position for adjusting the temperature of the furnace in the other direction, each of said circuits comprising means for changing the setting of said furnace a predetermined amount each time the circuit is energized, means for deenergizing each of said circuits a brief interval of time after it is energized and means for rendering said control device ineffective after it is energized, and means for automatically rendering said control device inoperative when the product is not associated with said temperature control means, said last named means comprising electromagnetic means inductively coupled to said control means and a circuit breaking device held in its closed position by current from said electromagnetic means when the product is associated with said control means and said circuit breaking device being permitted to open so as to render said control device in-

operative when the product is no longer associated with said control device.

2. Means for controlling the hardness of steel under treatment, said means comprising two transformers into one of which a piece of steel that has undergone treatment may be inserted as a core, and the other transformer comprising a secondary adjustably coupled to its primary, means for indicating a state of balance between the outputs of said transformers, and means effective when said steel is removed from said first transformer to disconnect said indicating device, said last named means comprising an electromagnetic coil inductively coupled to the primary of the first transformer and a circuit breaking device held in its closed position by current from said coil when the steel is in said first transformer and adapted to open so as to disconnect said indicating device when said steel is removed from said first transformer.

3. Means for controlling the hardness of steel under treatment, said means comprising two transformers into one of which a piece of steel that has undergone treatment may be inserted as a core, and the other transformer comprising a secondary adjustably coupled to its primary, means responsive to a state of unbalance between the outputs of said transformers to vary the operating conditions and means effective when said steel is removed from said first transformer to disconnect said condition-varying device, said last named means comprising an electromagnetic coil inductively coupled to the primary of the first transformer and a circuit breaking device held in its closed position by current from said coil when the steel is in said first transformer and adapted to open so as to disconnect said condition-varying device when said steel is removed from said first transformer.

4. In apparatus for testing steel, a transformer adapted to receive alternately a standard steel sample or a portion of a steel strip under treatment as a core, a second transformer having its primary adjustably coupled to its secondary, the secondaries of said transformers being connected in parallel opposition to each other through a potentiometer, a control device having a movably mounted coil adapted to be moved by the resultant current from said transformer secondaries, a contact carried by said coil, a pair of electrical circuits adapted to be closed alternately by said contact as it moves in one direction or the other, means adapted to short circuit said movably mounted coil when one of said circuits is closed, means associated with one of said circuits adapted, when the circuit is closed, to change the setting of a temperature control device for a hardening furnace by a limited predetermined amount so as to increase the temperature of the furnace, means associated with the other of said circuits adapted, when the circuit is closed, to change the setting of a temperature control device for a hardening furnace by a limited predetermined amount so as to decrease the temperature of the furnace, and means associated with both of said circuits adapted to cause a delayed opening of said circuit a brief interval of time after it is closed.

5. In a device for comparing the permeability of magnetic materials, a pair of transformers having their primaries connected in series, a potentiometer having two fixed terminals and a movable terminal, and said transformers having one terminal of each of their secondaries connected to each other and to one of the fixed terminals of said potentiometer, the other terminal of the secondary of one transformer being connected to the other fixed terminal of said potentiometer, and the other terminal of the sceondary of the other transformer being connected to the movable terminal of said potentiometer, and a control device connected between the first mentioned fixed terminal and the adjustable terminal of the potentiometer.

6. In a control device for a furnace, a rotatable member, means for rotating said member in one direction, means for rotating said member in the opposite direction, a potentiometer having two end terminals and an intermediate adjustable contact, said contact being connected for movement by said member, the three terminals of said potentiometer being connected to a furnace regulating device in such a manner that when the adjustable potentiometer contact is in an intermediate neutral position said regulating device will be inactive, while when said adjustable potentiometer contact is moved to one side of its neutral position said regulating device will cause the furnace temperature to increase, while when said adjustable contact is moved in the other direction said regulating device will cause the furnace temperature to decrease, a second potentiometer having two end terminals and an intermediate adjustable contact, said contact being connected for movement by said member, and said two end terminals being connected to one side of a power circuit, and said movable contact being connected to the other side of said power circuit, an alarm device connected intermediate one of the legs of said power circuit and its hereinabove described connection to said potentiometer, and the resistance of said second potentiometer being such that when said adjustable contact of said second potentiometer is in its middle positions, said alarm device will remain inactive, while when said contact moves a predetermined distance to either side of the middle said alarm device will become active.

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