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CONTROL OF HARDENING OF STEEL

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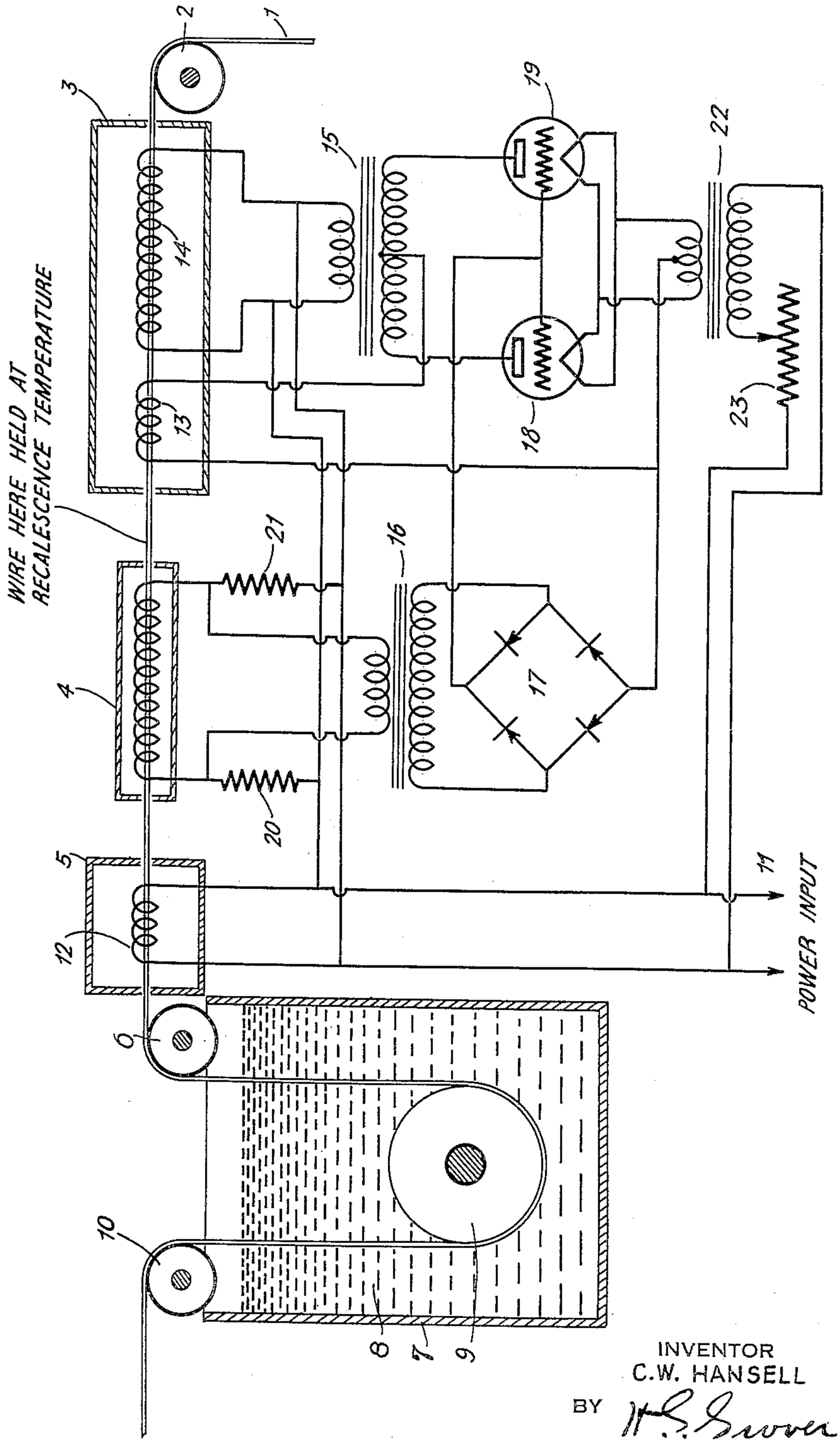


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## CONTROL OF HARDENING OF STEEL

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7 Claims. (Cl. 219—11)

This invention relates to an improved method of hardening of steel, and is particularly adapted to the hardening of steel wire.

An object of this invention is to simplify and improve the method of controlling the hardening of steel wire by keeping the temperature of the wire to be hardened substantially constant.

Another object of this invention is to produce a steel wire which is tempered extremely uniform throughout its entire length, which results in a more uniform product. The hardening of steel wire is well known in the art, there being numerous methods and processes. However, there is not known any simple method or system of which applicant is aware, that will produce a wire which is uniformly tempered throughout its entire length.

In the hardening process of steel wire according to this invention, the wire is hardened at a uniform temperature by a simple method of accurately controlling the temperature of the steel wire just before it is chilled. The underlying principle of this invention is an electrical system comprising electron discharge devices and associated inductance coils through which the wire passes. The wire when passing through the inductance coils acts as a core to vary the inductance, the change of the inductance in the coils being due to the permeability of the wire changing with the fluctuations in temperature which is used to control the temperature and maintain it uniform just before quenching in the cooling bath. The invention makes use of the change in permeability of the wire at the recalescence temperature to vary the inductance coil as it passes through its center.

The invention will be more clearly understood by referring to the accompanying drawing in which the wire 1 to be tempered passes over a roller 2 into a primary heating oven 3 and then through the center of a reactance coil 4 where it is then led into the secondary heating oven 5 from which the wire passes over a roller 6 and into the cooling tank 7 which contains the desired cooling or quenching liquid 8, such as oil, water, mercury, or any other suitable liquid. The wire passes through the cooling tank and under the submerged roller 9, and then over the roller 10 from which it is then wound upon any desired form of spool.

Referring now in detail to the drawing, the temperature of the wire to be hardened is raised and then maintained constant by means of an electrical power input 11 which supplies energy to the electric heaters 12, 13 and 14.

The functions of the three heaters are as follows: Heater 14 is of large size and considerable length. Its purpose is to raise the wire temperature to a point a little below the recalescence temperature. Its temperature and the temperature to which it raises the wire may be manually adjusted. Heater 13 is smaller and shorter than heater 14, and is provided with automatically controlled temperature for holding the wire just before going through the reactance coil very accurately at the recalescence temperature. Heater 12 is designed to raise the wire temperature slightly above its normal recalescence temperature than when it passed through the reactance coil in order to obtain just the right desired temperature for quenching. Due to the need of a very accurate control of the ingoing wire temperature, heater 12 may if desired be manually adjusted by any suitable resistance means, not shown. Associated with the heaters are transformers 15 and 16, and a rectifier 17 which is connected in a bridge-like arrangement. The output of the secondary of the transformer 15 is connected to the plates of a pair of electronic discharge tubes or thyratrons 18 and 19 which consist of evacuated containers enclosing the cathodes, grids, anodes, and an inert gas. A thyratron of this construction has such properties that if the grid is maintained sufficiently negative, an anode current will not flow unless a critical value of positive potential on the anode electrode is exceeded. However, if the anode electrode is positively charged beyond the critical point determined by the grid bias potential, current will commence to flow, and having once started to flow, will continue flowing until the positive polarization or charge is removed from the anode electrode. As the anode becomes positive on each alternate half cycle of the applied alternating current anode voltage the time on the potential wave at which current starts to flow is determined by the grid potential. Therefore the total or average flow of current may be readily controlled by variations in the grid potential. After once starting the arc the flow or continuation thereof cannot be affected by the grid. However, it can be stopped by the removal or reversal of the anode voltage which occurs once each cycle of the impressed alternating current anode voltage. Thus it will be seen that such a type of tube operates as an intermittent arc discharge device whose average current flow is controlled by its grid.

Further reference to the operation of a thyratron type of electron discharge device may be

obtained by referring to an article by A. W. Hull, appearing on page 390 of the General Electric Review for July, 1929 (vol. 32, No. 7).

The cathodes of both electron discharge tubes are heated by the secondary of transformer 22, and the voltage of the primary is controlled by a rheostat 23. The input voltage 11 supplied to the reactance controlling coil 4 is applied through the resistances 20 and 21.

In the operation of this invention the wire 1 which is to be hardened, passes over the roller 2 into the primary heating oven 3, and is heated by means of the large heating unit 14. It then passes through the automatically controlled small heater 13 whose heating current consists of the direct current or rectified component of current through the tubes 18 and 19. The heated wire which has been heated to the recalescence temperature, then passes through the reactance or heat control coil 4; the wire so passing acts as the core for the reactance coil. As the temperature of the wire changes, the reactance of the inductance coil 4 increases as the wire temperature drops below the recalescence temperature and decreases when the temperature rises above the recalescence temperature. The variation in reactance varies the voltage drop across the reactance coil. This voltage is rectified by rectifier 17 which is preferably of the oxide type, and used to control the grid bias potential on the thyratrons 17 and 18.

If the wire passing through the reactance coil has a temperature slightly below the recalescence temperature, it will have a relatively high magnetic permeability and give the coil a large reactance. This increases the voltage drop across the coil and, through the rectifiers, drives the thyratron grids positive. This in turn increases the power applied to heater 13 and raises the wire temperature.

If the wire temperature is too high the wire loses its magnetic permeability, the coil reactance diminishes, the thyratron grids become less positive, and the power input to heater 13 is diminished. Thus the temperature of the wire through the reactance coil is held very accurately at a point where the magnetic permeability vanishes and reappears. This is known in the art as the recalescence temperature.

The figure shows only one very simple arrangement for practicing my invention. Obviously many additional features may be added in accordance with arts well known in the electrical and metallurgical fields. As examples of modifications the following may be noted:—

(*a*) Electrical regulating devices and measuring instruments may be added to the circuits.

(*b*) The heating of the wire may be done in reducing atmospheres, such as hydrogen, for preventing deterioration or oxidation of the wire heaters, reactance coil, etc.

(*c*) All or a portion of the heating may be done in atmospheres containing carbon or other elements for case hardening the wire or for modifying the properties of the surface in any other way.

(*d*) The rollers shown in the cooling tank may be eliminated or altered to prevent undesirable bending of the wire by arranging the assembly vertically instead of horizontally as shown.

(*e*) A part or all of the heating may be done by other means than electricity. For example, gas heating, electrically controlled by the thyratron current may be used.

(*f*) The thyratrons may be replaced with high vacuum tubes, relays, or any other suitable electrical control device.

(*g*) In some cases the cooling bath may be such materials as molten lead, tin, zinc, cadmium, or metal alloys and mixtures. If the finished product is to be coated with zinc, for example, the use of a zinc cooling bath will automatically result in the production of a coating roughly equivalent to galvanizing or shearardizing.

(*h*) Automatic tensioning, measuring and speed control devices may be added to the equipment.

(*i*) The reactance which is varied by the variation in magnetic permeability of the wire around its recalescence temperature need not be a coil about the wire, but may be any arrangement in which a portion of the wire forms a part of a magnetic circuit interlinking a coil.

(*j*) In addition to controlling the heat by means of the variable reactance coil the speed with which the wire is drawn through the hardening apparatus may be varied automatically by automatically varying the power input to the pulling apparatus as well as to the heater.

(*k*) Between the controlled heater and the variable reactance there may be a space over which the wire temperature is dropping. This permits the wire to be heated considerably above the recalescence temperature, cooled down to the recalescence temperature for accurate control, reheated somewhat above the recalescence temperature and then quenched. This corresponds to the heat treatment required for desired results in some steel wire products.

While this invention has been described as being used for controlling the temperature of steel wire, it is to be understood that its limitations are to be only those imposed by the appended claims.

What is claimed is:

1. In a system wherein a steel wire is heated prior to being hardened, comprising means for moving said wire, means for heating and controlling the temperature to maintain a constant value of heat on said wire, said means comprising a first heater, a second heater, and a reactance coil, all of which surround said wire, a source of alternating current connected to said first heater, means for connecting said alternating current to said reactance coil, means for obtaining a voltage drop across said reactance coil as the wire moves through said coil in accordance with the permeability of the wire as influenced by the temperature thereof, a rectifier having its input coupled to said reactance coil to rectify said voltage drop, an electron discharge device having an anode, grid and cathode, means for maintaining said cathode in an electron emitting condition, means for keeping the temperature of said wire at a desired constant temperature as it passes through said second heater, said means comprising a circuit connection from the output of said rectifier to the grid circuit of said electron discharge device, and a circuit connection from the anode circuit of said electron discharge device to said second heater whereby the grid bias potential of said electron discharge device is altered by variations in the permeability of the steel wire as it passes through said reactance coil to thereby control the temperature of said second heater.

2. In a system wherein a steel wire is heated prior to being hardened comprising means for

moving said wire, means for heating and controlling the temperature to maintain a constant value of heat on said wire, said means comprising a first heater, a second heater, and a reactance coil, all of which surround said wire, a source of alternating current connected to said first heater, means for connecting said alternating current to said reactance coil, means for obtaining a voltage drop across said reactance coil as the wire moves through said coil in accordance with the permeability of the wire as influenced by the temperature thereof, a rectifier having its input coupled to said reactance coil to rectify said voltage drop, a pair of electron discharge devices each having an anode, grid and cathode, means for maintaining said cathodes in an electron emitting condition, means for keeping the temperature of said wire at a desired constant temperature as it passes through said second heater, said means comprising a circuit connection from the output of said rectifier to the grid circuit of said electron discharge devices, and a circuit connection from the anode circuit of said electron discharge devices to said second heater whereby the grid bias potential of said electron discharge devices is altered by variations in the permeability of the steel wire as it passes through said reactance coil to thereby control the temperature of said second heater.

3. In a system wherein a steel wire is heated prior to being hardened comprising means for moving said wire, means for heating and controlling the temperature to maintain a constant value of heat on said wire, said means comprising a first heater, a second heater, and a reactance coil, all of which surround said wire, a source of alternating current connected to said first heater, means for connecting said alternating current to said reactance coil, means for obtaining a voltage drop across said reactance coil as the wire moves through said coil in accordance with the permeability of the wire as influenced by the temperature thereof, a rectifier having its input coupled to said reactance coil by a transformer to rectify said voltage drop, an electron discharge device having an anode, grid and cathode, means for maintaining said cathode in an electron emitting condition, means for keeping the temperature of said wire at a desired constant temperature as it passes through said second heater, said means comprising a circuit connection from the output of said rectifier to the grid circuit of said electron discharge device, and a circuit connection from the anode circuit of said electron discharge device to said second heater whereby the grid bias potential of said electron discharge device is altered by variations in the permeability of the steel wire as it passes through said reactance coil to thereby control the temperature of said second heater.

4. In a system wherein a steel wire is heated prior to being hardened comprising means for moving said wire, means for heating and controlling the temperature to maintain a constant value of heat on said wire, said means comprising a first heater, a second heater, and a reactance coil, all of which surround said wire, a source of alternating current connected to said first heater, means for connecting said alternating current to said reactance coil, means for obtaining a voltage drop across said reactance coil as the wire moves through said coil in accordance with the permeability of the wire as influenced by the temperature thereof, a rectifier comprising a plurality of rectifier units being connected in a bridge-like arrangement, said rectifier having its input coupled to said reactance coil by a transformer to rectify said voltage drop, an electron discharge device having an anode, grid and cathode, means for maintaining said cathode in an electron emitting condition, means for keeping the temperature of said wire at a desired constant temperature as it passes through said second heater, said means comprising a circuit connection from the output of said rectifier to the grid circuit of said electron discharge device, and a circuit connection from the anode circuit of said electron discharge device to said second heater whereby the grid bias potential of said electron discharge device is altered by variations in the permeability of the steel wire as it passes through said reactance coil to thereby control the temperature of said second heater.

5. In a system wherein a steel wire is heated prior to being hardened comprising means for moving said wire, means for heating and controlling the temperature to maintain a constant value of heat on said wire, said means comprising a first heater, a second heater, and a reactance coil, all of which surround said wire, a source of alternating current connected to said first heater, means for connecting said alternating current to said reactance coil, means for obtaining a voltage drop across said reactance coil as the wire moves through said coil in accordance with the permeability of the wire as influenced by the temperature thereof, a rectifier having its input coupled to said reactance coil to rectify said voltage drop, an electron discharge device having an anode, grid and cathode, means for maintaining said cathode in an electron emitting condition, means for keeping the temperature of said wire at a desired constant temperature as it passes through said second heater, said means comprising a circuit connection from the output of said rectifier to the grid circuit of said electron discharge device, a circuit connection from the anode circuit of said electron discharge device to said second heater whereby the grid bias potential of said electron discharge device is altered by variations in the permeability of the steel wire as it passes through said reactance coil to thereby control the temperature of said second heater, and a third heater surrounding said wire, said third heater being connected to said alternating current to slightly raise the temperature of said wire to a desired constant value prior to quenching.

6. In a system wherein a steel wire is heated prior to being hardened comprising means for moving said wire, means for heating and controlling the temperature to maintain a constant value of heat on said wire, said means comprising primary and secondary heating ovens, said primary heating oven having contained therein a first heating coil of considerable length and a second heating coil shorter in length than said first heating coil, a reactance coil located between said primary and secondary heating ovens, all of said coils surrounding said wire, a source of alternating current connected to said first heating coil, means for connecting said alternating current to said reactance coil, means for obtaining a voltage drop across said reactance coil as the wire moves through said coil in accordance with the permeability of the wire as influenced by the temperature thereof, a rectifier having its input coupled to said reactance coil to rectify said voltage drop, an electron dis-

charge device having an anode, grid and cathode, means for maintaining said cathode in an electron emitting condition, means for keeping the temperature of said wire at a desired constant temperature as it passes through said second heating coil, said means comprising a circuit connection from the output of said rectifier to the grid circuit of said electron discharge device, a circuit connection from the anode circuit of said electron discharge device to said heating coil whereby the grid bias potential of said electron discharge device is altered by variations in the permeability of the steel wire as it passes through said reactance coil to thereby control the temperature of said second heating coil, and a third heating coil surrounding said wire and located in said secondary oven, said third heating coil connected to the alternating current to slightly raise the temperature of the wire to a desired constant value prior to quenching.

7. In a system wherein steel strip material of substantially continuous length is heated prior to being hardened comprising means for moving said strip, means for heating and controlling the temperature to maintain a constant value of the heat on said strip, said means comprising a first heater, a second heater, and a reactance coil, all of which surround said strip, a source of alternating current connected to said first heater, means for connecting said alternating current to said reactance coil, means for obtaining a voltage drop across said reactance coil as the strip moves through said coil in accordance with the permeability of the strip as influenced by the temperature thereof, a rectifier having its input coupled to said reactance coil to rectify said voltage drop, an electron discharge device having an anode, grid and cathode, means for maintaining said cathode in an electron emitting condition, means for keeping the temperature of said strip at a desired constant temperature as it passes through said second heater, said means comprising a circuit connection from the output of said rectifier to the grid circuit of said electron discharge device, and a circuit connection from the anode circuit of said electron discharge device to said second heater whereby the grid bias of said electron discharge device is altered by variations in the permeability of said steel strip as it passes through said reactance coil to thereby control the temperature of said second heater.

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