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CONTROL OF SWAGING TEMPERATURES

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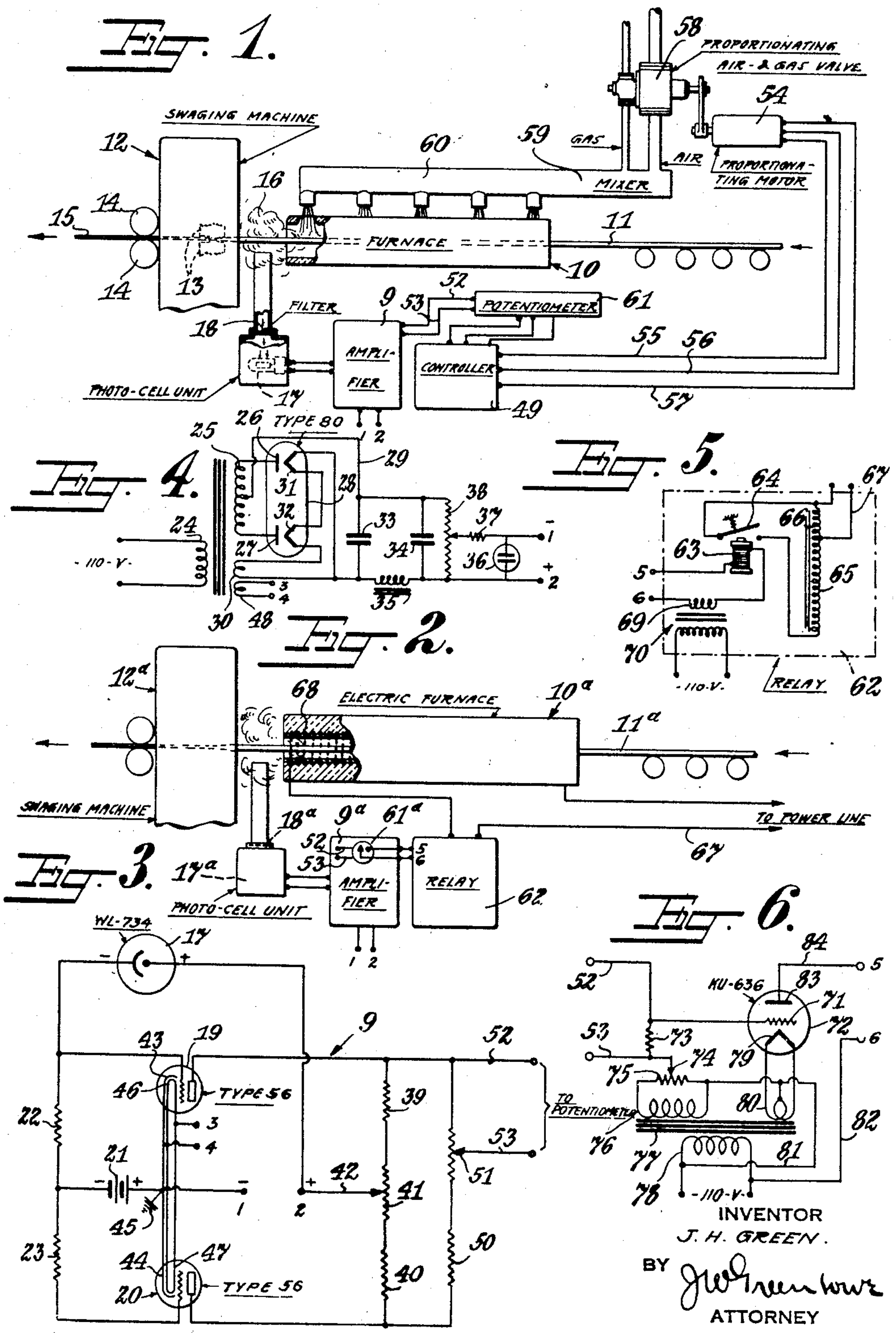

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CONTROL OF SWAGING TEMPERATURES

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6 Claims. (Cl. 236—15)

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This application is a continuation-in-part of my application, Serial No. 195,490, filed March 12, 1938, now abandoned.

This invention relates to the control of swaging temperatures and, more particularly, to the control of the temperature at which rods of refractory metal, such as tungsten or molybdenum, are delivered to a swaging machine for reduction in cross section, as in connection with the manufacture of wire.

The principal object of my invention, generally considered, is the control of the swaging temperature of a rod of refractory metal by means of the radiations from said rod as it emerges from the furnace on its way to the swaging machine.

Another object of my invention is the control of swaging temperatures by means of the infra-red radiations from the rod or wire as it emerges from the heating furnace on its way to the swaging machine.

A further object of my invention is the control of the swaging temperature of refractory metal by means of a photo-electric cell actuated by the radiations from the heated metal, filtered of substantially all but the infra-red portion, thereby using those which are more accurately proportional to the temperature of the metal, and avoiding, to a great extent, loss in transmission due to dust and smoke.

Other objects and advantages of the invention, relating to the particular arrangement and construction of the various parts, will become apparent as the description proceeds.

In the swaging of tungsten and molybdenum rods and wire, as in manufacturing filaments of tungsten and molybdenum, the metal is heated in gas-fired or electrically-powered furnaces before entering the swaging die. Considerable trouble was experienced in the swaging operation. Control of the temperature, as the rod enters the die, is necessary to insure uniformity of product and reduce shrinkage. The high order of shrinkage was traceable directly to inadequate temperature uniformity.

In order to cope with this situation, various means of measuring temperature were experimented with, among them, radiation pyrometers, optical pyrometers and thermocouples. None of these performed satisfactorily, as tungsten or molybdenum metal when heated to incandescence oxidizes with extreme rapidity, giving off dense clouds of vapor which wholly or in part obstruct the vision making it virtually impossible to read or measure temperatures accurately. As a result, controls could not be fitted to any of the above measuring means.

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This, then, indicated that an entirely new approach must be developed which leads to the use of the caesium suboxide photocell. This photocell has an extremely high sensitivity response in the infra-red range, which, when coupled with a filter selected for similar characteristics, gave us a device which would be fairly oblivious to any direct or incidental visible light. By this, I mean to point out that the filter having a visible light transmission of approximately 2% and the photocell itself an exceptionally low response to visible light would combine so as to be practically insensitive to visible radiations.

I therefore use a combination of a photo-electric cell and a filter which absorbs substantially all but the infra-red portion of the spectrum, which is impeded very little by smoke and vapor, so that the cell operates only on such portion, and a minimum loss, due to absorption by dust, vapors, and smoke, results. Such filters are known in the art, as referred to in the article by R. A. Powers, appearing on pages 12 to 15, inclusive, of the April 1937 number of "Electronics" and entitled "Phototube temperature control." A "Woods" filter, that is, one which absorbs undesired radiation, as manufactured by Corning, is suitable for the purpose. The photo-electric cell or tube and filter unit is desirably constructed so that it has great sensitivity in the near infra-red, that is between 7000 and 9000 A. U., and so that it passes only about one percent of the visible radiations.

The above then means that the radiations measured by the cell and filter combination would be that of infra-red only, which is rather definitely known to be absorbed to only a small degree by intervening dust, dirt, oxide fumes, or moisture particles.

The next problem then became one of securing a stable oscillator which would translate the energy from the photocell into usable energy to actuate a device suitably designed to cause off-on control or a proportionating mechanism to hold the furnace temperatures within a predetermined range. This was accomplished by a vacuum tube bridge circuit to incorporate means of compenstion for tube drift or line voltage fluctuations which, are prime necessities in a control function. The addition of a second tube and suitably selected grid resistors combined with an A. C. rectified voltage-regulated power supply corrected all of the above conditions.

I have, therefore, developed a balanced amplifier circuit, including a pair of standard radio tubes in push-pull arrangement, to prevent zero drift, and built-in power supply to correct drift troubles and deliver power at a controlled voltage, regardless of line fluctuation. Temperature control, with tolerances of one percent, is desirably effected by means of a thyratron, a relay, and a reactance operating from the plate circuit of the amplifier, in the case of the electric furnace. In the case of the gas-fired furnace, a proportionating motor-operated valve is used, with the control box directly connected to a similar amplifying circuit.

In the drawings:

Fig. 1 is a diagrammatic plan view of a gas-fired furnace, swaging machine, and furnace control mechanism embodying my invention.

Fig. 2 is a corresponding view of a modification in which an electric furnace is substituted for a gas-fired furnace.

Fig. 3 is a wiring diagram of the amplifier used in the embodiments of Figs. 1 and 2.

Fig. 4 is a wiring diagram of the means for obtaining direct current at a controlled voltage.

Fig. 5 is a wiring diagram of a relay which may be used with the embodiment of my invention shown in Fig. 2.

Fig. 6 is a wiring diagram of the thyratron and circuit, which may be used in connection therewith, between the amplifier of Fig. 3 and the relay of Fig. 5.

Referring to the drawings in detail, like parts being designated by like reference characters, and first considering the embodiment of my invention illustrated in Figs. 1, 3, and 4, there is shown a gas-fired furnace 10 through which is passing a rod or wire 11 of refractory material, such as tungsten or molybdenum, in order to be heated to a desired swaging temperature of from 1400° to 1450° C. (for W. & Mo) prior to being reduced in section by the swaging machine 12, which may be of a type such as disclosed in the Romanelli Patent No. 2,126,923, dated August 16, 1938. The machine 12 includes swaging dies 13 and feed rollers 14, which latter grip the reduced section 15 of the rod or wire 11 and draw it through the swaging dies 13.

As the refractory rod 11 emerges from the furnace 10, it becomes oxidized by the atmosphere and gives off clouds of vapor, indicated at 16. This vapor or smoke absorbs a considerable amount of the visible light emitted from the hot rod, but is not so absorbent to the heat or infra-red rays which are emitted therefrom. Taking advantage of this characteristic, I employ sensitive detecting means, such as a caesium suboxide photoelectric cell 17 responding to the range of radiations passed by the "Woods" filter, which may be one of the type designated "WL-734" and manufactured by the Westinghouse Electric & Manufacturing Company. This is so constructed that it is sensitive to the near infra-red rays. A filter 18 is employed to screen out practically all radiations except those in the infra-red. For this purpose, one such as manufactured by Corning and designated as "Heat Transmitting," Old Glass Code No. 254, New Glass Code No. 2540, may be employed. The cell 17 and associated filter arrangement are sighted on the rod or wire 11, a suitable distance away, as it emerges from the furnace 10.

Referring now to Fig. 3, the amplifier circuit 9 used in connection with the cell 17 is there disclosed. This circuit comprises a pair of radio tubes 19 and 20 which may be of the type designated as "56," that is a "Super-Triode" amplifier detector, 2.5 volts, 1 ampere. These are arranged as illustrated so that tube 20 provides a generally fixed circuit balanced against that provided by tube 19 when the photoelectric cell 17 is dark. For this purpose, the grid circuit of both tubes is energized by the same source of direct current, such as a battery 21, providing a potential of from 3 to 7 volts and acting through duplicate resistances 22 and 23. Control is obtained by measuring the degree of unbalance as the heated rod passes cell and filter assembly 17 and 18, allowing current to oppose the drop through resistance 22.

The plate circuits of both tubes 19 and 20 are energized by a source of potential applied to the points designated as 1 and 2 in Fig. 3. In order to secure close regulation of said potential, as is desired, a circuit such as shown in Fig. 4 may be employed. The primary winding of a transformer for energizing said circuit is indicated at 24, said transformer having a secondary winding 25, the ends of which are connected to the anodes 26 and 27 of a full-wave rectifier 28. A rectifier which may be employed is one of those designated as "80," that is a full-wave rectifier, 5 volts, 2 amperes. The mid-point of the secondary winding 25 is connected to one side of the secondary circuit as indicated at 29, the other side of said circuit being connected to a secondary winding 30 which serves to energize the rectifier cathodes 31 and 32 in series.

In order to stabilize the output of the arrangement, condensers 33 and 34 are connected across the line and between them is inserted an iron core choke 35, as illustrated. The final control of the potential is by a voltage regulating diode 36 connected through a resistance 37 to an adjustable or bleeder resistance 38 across the output line. In this way it is possible with an input potential of, say, 110 volts alternating current to deliver a substantially constant potential of, say, 100 volts direct current to the plate circuits for the tubes 19 and 20.

The plates of both tubes 19 and 20 are connected through fixed resistances 39 and 40 and variable resistance 41, the positive side of the potential supplied at 1 and 2 being connected to an intermediate point on the variable resistance 41 as indicated at 42, the arrow representing a slider movable along the resistance element 41 to vary the proportion at opposite sides. The negative side of the potential 1 and 2 is connected to the mid-point between the indirectly heated cathodes 43 and 44 of the tubes 19 and 20, said point of connection being desirably grounded as indicated at 45. The heater filaments 46 and 47 of the tubes 19 and 20 are desirably energized by a supplemental secondary winding 48 of the same transformer, of which coil 24 is the primary, by connection to points 3 and 4 as shown in Fig. 3.

The output from the circuit illustrated in Fig. 3 is desirably delivered to a recording null potentiometer system of the Leeds & Northrup type, designated as 61 in Fig. 1, which is in turn electrically connected to the controller 49 of a Minneapolis-Honeywell proportionating system as indicated; that is, through fixed resistance 50, variable resistance 51, and connecting leads 52 and 53 from the plates of tubes 19 and 20. The variable resistance 51 provides for adjustment so that the controller 49 acts to the desired extent on the proportionating motor through the wires 55, 56, and 57 to cause said motor to run one way or the other, in accordance with the condition of the amplifier circuits, as determined by the energization of the photoelectric cell 17, so that if the energization of said cell decreases, on account of the temperature of the rod 11 decreasing and the radiation therefrom correspondingly decreasing, the balance of the controller is upset and the proportionating motor operated in one direction, until the increased fuel supply provided through the proportionating valve 58, mixer 59 and manifold 60 increases the temperature of the rod to such an extent that the controller again becomes balanced and the operation of the motor is arrested.

If, on the other hand, the rod 11 becomes too hot, the grid circuit of the tube 19 overbalances that of the tube 20, resulting in an operation of the controller in the opposite manner, causing the proportionating motor to operate in the opposite direction and reduce the fuel supply through the proportionating valve 58, thereby correspondingly reducing the temperature of the furnace and the rod heated thereby.

Referring now to the embodiment of my invention illustrated in Figs. 2 to 5, inclusive, there is shown an electrically heated furnace 10^a through which is passing a rod or wire 11^a of refractory material, such as tungsten or molybdenum, for the purpose of heating the same to a desired temperature, prior to its being reduced in section by a swaging machine 12^a, which may correspond with the machine 12 of the preceding embodiment.

A photo-electric cell 17^a is employed with a filter 18^a, both of which may correspond with the elements designated as 17 and 18 of the preceding embodiment, said cell being sighted on the rod 11^a as it emerges from the furnace 10^a in order that it will receive infra-red rays, which are generated by the hot rod or wire 11^a.

As in the first embodiment, I prefer to use an amplifier 9^a having a circuit which may correspond with the amplifier 9 of the first embodiment as shown in Fig. 3. In the present instance, however, the output from the amplifier circuit is connected to a potentiometer or other direct reading contact device 61^a, which not only shows the temperature of the rod or wire 11^a, but makes a contact to actuate a relay 62, the circuit in which is shown in Fig. 5. When the control circuit becomes unbalanced, as by a reduction in the desired temperature in the rod or wire 11^a, the solenoid or magnet 63 is energized by closing of the contact in 61^a, drawing the armature 64 thereto and closing a circuit through the auto-transformer 65, thereby effectively decreasing the impedance 66 in the power line 67 to the resistance winding 68 in the electric furnace 10^a, and increasing the temperature of said winding, with a corresponding increase in the temperature of the rod or wire 11^a heated thereby.

When the control circuit again becomes balanced, the relay magnet 63 releases, throwing the impedance 66 again into the circuit and allowing the temperature to correspondingly drop. It will be understood that the arrangement is desirably such that the furnace is a little too hot when the impedance 66 is out of the circuit and a little too cool when it is in the circuit, so that throwing it in and out by the relay magnet 63, actuated by the circuit in the amplifier 9^a, and the secondary winding 69 of transformer 70, as required, will keep the temperature to which the rod or wire 11^a is heated substantially constant.

Referring now to the embodiment of my invention illustrated in Figs. 2 to 6, inclusive, there is shown an arrangement exactly like that of Figs. 2 to 5, inclusive, except that the thyratron 72 and circuit of Fig. 6, replaces the potentiometer and contact device 61^a, in the connection between the amplifier circuit of Fig. 3 and the relay 62.

In other words, the relay leads 52 and 53 connect with the correspondingly numbered leads shown in Fig. 6, which in turn connect respectively to the grid 71 of a thyratron 72, which may be of the type designated as "KU-636," as manufactured by the Westinghouse Electric & Manufacturing Company, or similar grid-controlled, half-wave rectifier of the gaseous type. The lead 53 is connected through a resistance 73 to this grid 71, and to the control pointer 74 of a rheostat 75. The rheostat 75 is connected across the terminals of the secondary winding 76 of a transformer 77, the primary winding of which is designated as 78 and is connected across the line. The cathode 79 of the thyratron 72 is energized by suitable secondary winding 80 of the transformer 77, the mid-point of which is connected to the adjacent end of the rheostat 75 and one side of the line which energizes the primary winding 78 by conductor 81. The other side of the line is connected by conductor 82 to terminal 6 of the relay 62, terminal 5 being connected to the plate 83 as by means of conductor 84. With this arrangement, the thyratron 72 merely replaces the contact device 61^a in actuating the relay 62, so that the action of this embodiment is similar to that of the embodiment of Figs. 2 to 5, inclusive.

From the foregoing, it will be seen that I have devised a method and apparatus for controlling the temperature at which rods or wires of refractory metal, such as tungsten or molybdenum, are heated prior to swaging, whereby a greater uniformity of the product is obtainable and shrinkage reduced.

Any one of three systems may be used, as policy demands. The first system shown in Figs. 1, 3 and 4, desirably involves the employment of a recording null potentiometer system, which may be of the Leeds and Northrup type, in conjunction with a Minneapolis-Honeywell or other type of proportionating system which controls or proportions the fuel supply, as by throttling, in accordance with the demand or load. Such a system is disclosed for a glass furnace in the Richardson et al. Patent No. 2,116,450, of May 3, 1938. The second involves the employment of a contact which measures the drop across an amplifier circuit, as indication of the temperature, and has a contact arrangement which may be inserted between the pointer and the zero portion thereof and adjusted over the entire range of the instrument for fixing the point at which a relay operates to regulate the heating of an electric furnace. The third involves the replacement of the contact galvanometer by a thyratron, which when it acts, serves to energize the same relay.

Although preferred embodiments of my invention have been disclosed, it will be understood that modifications may be made within the spirit and scope of the appended claims.

I claim:

1. In combination, a furnace for heating metal, means for supplying heat to said furnace, controlling means for said heat supplying means, a photoelectric cell receiving radiations from said metal as it issues from said furnace, means filtering the visible portion of said radiations so

that substantially nothing but the infra-red portion reaches the photoelectric cell, means connecting said cell to said controlling means through an amplifying circuit for maintaining constant the temperature of said furnace and issuing metal, a pair of tubes in said circuit, each tube containing a thermionic cathode, a grid, and a plate, means electrically connecting said tubes in balanced relation, including a direct connection between the cathodes and a connection between the grids through a resistance, a source of biasing potential impressed between the midpoint of said resistance and said cathode connection, means connecting said plates to said controlling means and also through a variable resistance, said photoelectric cell being connected to the grid of one tube and to an intermediate point on the variable plate resistance, and a voltage-regulating diode with bleeder and series resistances forming a closely-regulated source of potential impressed between said direct cathode connection and the connection from the cell to said intermediate plate-resistance point.

2. In combination, a furnace for heating elongated pieces of metal, means for firing said furnace comprising a mixer for fuel and air, a proportionating valve controlling said mixer, a proportionating motor adapted to run one way or the other, a controller for said motor, a photoelectric cell placed to receive temperature-induced radiations from said metal as it issues from said furnace, a filter disposed between said cell and metal for absorbing practically all but the infra-red radiations from said metal, and amplifying apparatus between said cell and controller for operating the latter to cause the proportionating motor to move the valve toward open position and increase the heat of the furnace if the infra-red radiations reaching the photoelectric cell decrease below a predetermined intensity, and move the valve toward closed position and decrease the heat of the furnace if they increase beyond a predetermined intensity, for maintaining practically constant the temperature of the furnace and issuing metal, said apparatus including a pair of radio tubes, each tube containing a thermionic cathode, a grid and a plate, conductors making a direct connection between the cathodes and a connection between the grids through a resistance, a biasing source of direct current connected between the midpoint of said resistance and the connection between the cathodes, a plate resistance, leads connecting said plates to said controller in parallel with said resistance, leads connecting the cathode of the photoelectric cell to the grid of one tube and the anode to an intermediate point on said plate resistance to allow for variation of the latter on opposite sides of said connection, and a voltage-regulating diode with bleeder and series resistances forming a closely-regulated source of potential connected between said direct cathode connection and the lead from the cell to said intermediate plate resistance point.

3. In combination, an electric furnace for heating elongated pieces of metal, a power circuit to said furnace, a transformer with a winding in said circuit, a relay armature and contact in circuit with said transformer, a solenoid for operating said armature, a switch for said solenoid, a photoelectric cell placed to receive temperature-induced radiations from said metal as it issues from said furnace, a filter disposed between said cell and metal for absorbing practically all but the infra-red radiations from said metal, and

amplifying apparatus between said cell and switch for causing the relay armature to engage its contact, decrease the impedance in the power circuit, and increase the heat of the furnace if the infra-red radiations reaching the photoelectric cell decrease below a predetermined intensity, and disengage its contact, increase the impedance in the power circuit, and decrease the heat of the furnace, if they increase beyond a predetermined intensity, for maintaining constant the temperature of the furnace and issuing metal, said apparatus including a pair of radio tubes, each tube containing a thermionic cathode, a grid and a plate, conductors connecting said tubes in balanced relation including a direct connection between the cathodes and a connection between the grids through a resistance, a biasing source of direct current connected between the midpoint of said resistance and the connection between the cathodes, a plate resistance, leads connecting said plates to said contact device in parallel with said resistance, leads connecting the cathode of the photoelectric cell to the grid of one tube and the anode to an intermediate point on said plate resistance to allow for variation of the latter on opposite sides of said connection, and a voltage-regulating diode with bleeder and series resistances forming a closely-regulated source of potential connected between said direct cathode connection and the lead from the cell to said intermediate plate resistance point.

4. In combination, a furnace for heating rods of refractory metals, such as tungsten and molybdenum, to swaging temperatures of from 1400° to 1450° C., in which heating operation clouds of oxide are evolved making control by visible radiations inaccurate, means for supplying heat to said furnace, controlling means for said heat-supplying means, a caesium suboxide photoelectric cell placed to receive radiations from said rods as they issue from said furnace, a filter of such a character and disposed between the issuing rods and said cell so that substantially nothing but infra-red radiations reach the latter, making the arrangement substantially insensitive to visible light, an amplifying system disposed between and connecting said cell to said controlling means, said system including a pair of tubes each containing a thermionic cathode, a grid, and a plate, means electrically connecting said tubes in balanced relation, including a direct connection between the cathodes and a connection between the grids through a resistance, a source of biasing potential impressed between the midpoint of said resistance and said cathode connection, means connecting said plates through a variable resistance and also to said controlling means, said photoelectric cell being connected to the grid of one tube and to an intermediate point on the variable plate resistance, and a voltage-regulating diode with bleeder and series resistances forming a closely-regulated source of potential impressed between said direct cathode connection and the connection from the cell to said intermediate plate-resistance point, whereby the rods issue at a substantially constant temperature.

5. In combination, a furnace for heating rods of refractory metals, such as tungsten and molybdenum, to swaging temperatures of from 1400° to 1450° C., in which heating operation clouds of oxide are evolved making control by visible radiations inaccurate, means for firing said furnace comprising a mixer for fuel and air, a proportionating valve controlling said mixer, a pro-

portionating motor adapted to run one way or the other, a controller for said motor, a caesium suboxide photoelectric cell placed to receive temperature-induced radiations from said rods as they issue from said furnace, a filter of such a character and disposed between the issuing rods and said cell so that substantially nothing but infra-red radiations reach the latter, making the arrangement substantially insensitive to visible light, and amplifying apparatus between said cell and controller for operating the latter to cause the proportionating motor to move the valve toward open position and increase the heat of the furnace if the infra-red radiations reaching the photoelectric cell decrease below a predetermined intensity, and move the valve toward closed position and decrease the heat of the furnace if they increase beyond a predetermined intensity, said apparatus including a pair of radio tubes, each tube containing a thermionic cathode, a grid and a plate, conductors making a direct connection between the cathodes and a connection between the grids through a pair of fixed equal resistors directly connected, a biasing source of direct current connected directly between said direct connection and the connection between the cathodes, a plate resistance, leads connecting said plates to said controller in parallel with said resistance, leads connecting the cathode of the photoelectric cell to the grid of one tube and the anode to an intermediate point on said plate resistance to allow for variation of the latter on opposite sides of said connection, and means providing a closely-regulated source of potential connected between the direct cathode connection and the lead from the cell to an intermediate plate resistance point, whereby the rods issue at a substantially constant temperature.

6. In combination, an electric furnace for heating rods of refractory metals, such as tungsten and molybdenum, to swaging temperatures of from 1400° to 1450° C., in which heating operation clouds of oxide are evolved making control by visible radiations inaccurate, a power circuit for supplying heat to said furnace, a transformer with a winding in said circuit, a relay armature and contact in circuit with said transformer, a solenoid for operating said armature, a switch for said solenoid, a caesium suboxide photoelectric cell placed to receive temperature-induced radiations from said rods as they issue from said furnace, a filter of such a character and disposed between the issuing rods and said cell so that substantially nothing but infra-red radiations reach the latter, making the arrangement substantially insensitive to visible light, and amplifying apparatus between said cell and switch for causing the relay armature to engage its contact, decrease the impedance in the power circuit, and increase the heating of the furnace if the infra-red radiations reaching the photoelectric cell decrease below a predetermined intensity, and disengage its contact, increase the impedance in the power circuit, and decrease the heat of the furnace if they increase beyond a predetermined intensity, said apparatus including a pair of radio tubes, each containing a thermionic cathode, a grid and a plate, conductors connecting said tubes in balanced relation including a direct connection between the cathodes and a connection between the grids through a resistance, a biasing source of direct current connected between the midpoint of said resistance and the connection between the cathodes, a plate resistance, leads connecting said plates to said contact device in parallel with said resistance, leads connecting the cathode of the photoelectric cell to the grid of one tube and the anode to an intermediate point on said plate resistance to all ow for variation of the latter on opposite sides of said connection, and means providing a closely-regulated source of potential connected between said direct cathode connection and the lead from the cell to said intermediate plate resistance point, whereby the rods issue at a substantially constant temperature.

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