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D. C. PRINCE

1,976,461

CONTROL SYSTEM

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Fig. 1.

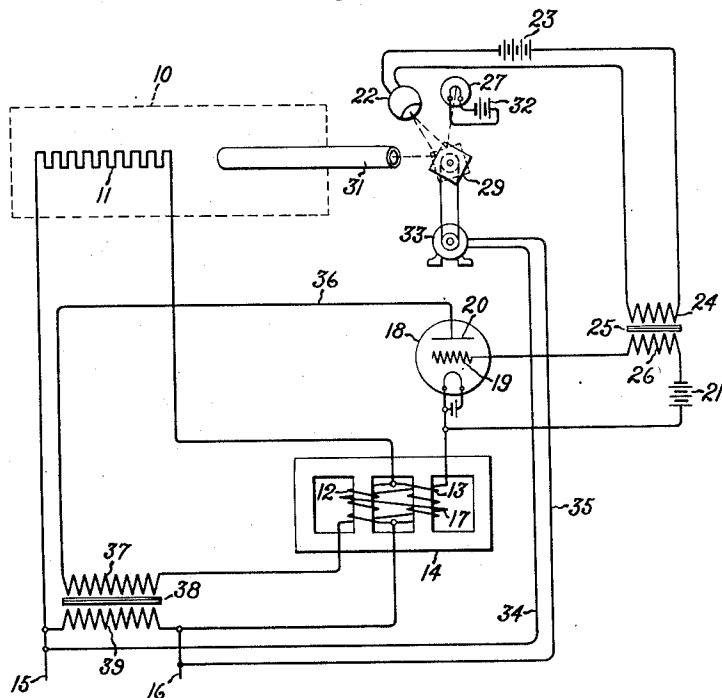
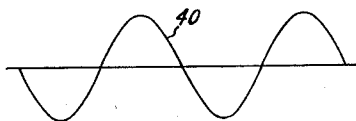
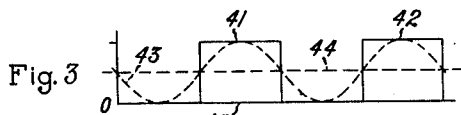
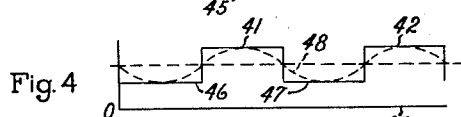
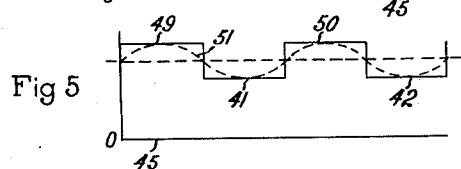


Fig. 2.



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UNITED STATES PATENT OFFICE

1,976,461

CONTROL SYSTEM

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9 Claims. (Cl. 250—41.5)

My invention relates to control systems where-
in a variable source of light is utilized and more
particularly to means for controlling the tem-
perature of electric furnaces and the like, and has
for its object the provision of a simple and re-
liable means for varying the input energy to an
electric furnace to maintain the temperature of
the furnace at a predetermined value.

More particularly my invention relates to tem-
perature control systems employing radiant en-
ergy from the furnace or other heated device to
activate a light sensitive control device, although
it obviously has general application in control sys-
tems where a variable source of light is utilized.

It is an object of my invention to provide a con-
trol system of this type giving uniform and ac-
curate response independently of variations in the
operating characteristics of the light sensitive
device.

In accordance with my invention in one form
thereof, I provide means for controlling the tem-
perature of an electric furnace in response to
the relative intensity of the light radiated from
the furnace and from a standard source of light.

My invention also comprehends a control system
for an electric valve wherein the electric valve is
controlled in response to the relative intensities
of a plurality of light sources, one of which is
variable.

For a more complete understanding of my in-
vention, reference should be had to the accom-
panying drawing, Fig. 1 of which is a diagram-
matic representation of a temperature control
system for a furnace embodying my invention,
while Figs. 2-5, inclusive, illustrate curves ex-
planatory of the operation of my invention.

Referring to the drawing, I have shown my in-
vention in one form as applied to the control of
an electric furnace 10 provided with a heating
resistor 11 which is connected through the coils
12 and 13 of a saturable core reactor 14 to a suit-
able source of alternating current supply as is in-
dicated by the supply lines 15 and 16. The re-
actor 14 is also provided with a coil 17 connected
in the output circuit of an electric valve 18, pre-
ferably of the type having an inert gas, such as
mercury vapor within its envelope and sometimes
termed a grid controlled arc rectifier. It will be
understood that when the grid 19 is made suffi-
ciently positive when its anode 20 is positive the
valve or rectifier 18 becomes conductive. As
shown a battery 21 is connected in the grid cir-
cuit so as to maintain the grid 19 sufficiently
negative normally to prevent the passage of cur-
rent through the valves. In order to render the

valve 18 conductive under certain conditions of
operation, a light sensitive device 22 is connected
through a battery 23 to the primary winding 24
of a transformer 25, the secondary 26 of which is
connected in the grid circuit of the rectifier.

The temperature of the furnace is controlled
by comparing the amount of intensity of light
from the furnace with the amount of intensity
of the light of a standard source of radiation 27.
As shown, the comparison is made by means of a
rotatably mounted mirror 29 provided with four
reflecting surfaces arranged at right angles with
each other to form a cube.

With the mirror 29 occupying the full line po-
sition one of its reflecting surfaces serves to di-
rect light from a tube 31 extending within the
furnace 10 to the light sensitive device 22. This
tube 31 may be directed to a point on the wall of
the furnace and as will be understood by those
skilled in the art, the intensity of the light con-
ducted through the tube 31 to the mirror 29 will
vary with the temperature of the furnace.

If the mirror occupies the position illustrated
by the broken lines, light will be directed from
the standard 27 to the light sensitive device 22.
By rotating the mirror 29 at a speed such that the
radiation from the standard 27 is thrown on the
light sensitive device 22 while the anode voltage
of the rectifier 18 is positive and the radiation
from the standard 27 is directed to the device 22
while the anode is negative, the valve or rectifier
19 may be controlled in a manner to govern the
temperature of the furnace 10. A synchronous
motor 33 is therefore employed to drive the mir-
ror 29. The motor 33 is connected by conductors
34 and 35 across the anode supply lines 15 and 16.
The anode or plate 20 is connected by a conductor
36 to the secondary 37 of a transformer 38, the
primary 39 of which is connected to the supply
lines 15 and 16.

With the above understanding of the elements
and their organization with respect to each other
in the system, the operation of the system itself
and the manner in which the light sensitive de-
vice 22 accurately controls the temperature of the
furnace 10 due to the difference in the intensity
of the light rays from the furnace with the light
rays from the standard will be readily understood
from the description which follows:

It will be assumed that the supply lines 15 and
16 are suitably energized from an alternating cur-
rent source of supply (not shown) and that the
standard light source 27 has been adjusted by
means of the battery 32 to produce radiant energy
having an intensity the same as the radiant en-

ergy directed by the tube 31 on the light sensitive device 22 when the temperature of the furnace has reached a predetermined value. As I have stated, the motor 33 drives synchronously the mirror 29 with respect to the anode voltage so that the light from the standard 27 is directed to the light sensitive device 22 during one half of a cycle of anode voltage while light from the furnace 10 is directed to the device 22 during the other half cycle of anode voltage.

Referring now to Fig. 2, the anode voltage is represented by the curve 40, while in Fig. 3 the condition is represented when the furnace is cold and consequently no light rays from the furnace are directed to the light sensitive device 22 during the negative half cycle of anode voltage. However, during the positive half of the cycle, the light rays from the standard are directed on the device 22 to cause a response from the photo-electric cell which, for the sake of clarity of description, is represented by the straight lines 41 and 42. The resulting voltage wave obtained at the terminals of the secondary winding 26 of the transformer 25 may therefore be represented by drawing a sinusoidal like curve 43 with the zero axis represented by the broken line 44 half way between the line 41 and the line 45 representing the zero axis.

It will be observed that the positive half of the cycle occurs while the anode is positive. The transformer 25 is therefore connected so that the grid 19 of the rectifier 18 is caused to be positive when the anode 20 is positive. The rectifier 18 therefore becomes conductive and saturating current flows through the coil 17 of the reactor 14. Consequently the reactor permits current to flow through its coils 12 and 13 to the heating resistance 11.

As soon as the temperature of the furnace 10 increases radiant energy is produced which is directed on the device 22. This condition is represented in Fig. 4. During the negative half of the cycle of anode voltage the light rays from the furnace are directed on the device 22 to cause the light sensitive device 22 to respond as indicated by the lines 46 and 47. The response of the device 22 due to the radiation from the standard 27 remains the same as before and is again represented by the lines 41 and 42.

The resulting wave form 48 of secondary voltage has the same phase relation with respect to the anode voltage as before but its amplitude has been decreased due to the response of the device 22 to the radiations from the furnace.

As soon as the temperature of the furnace increases so that its radiation as directed on the light sensitive device 22 is greater than that of the standard 27, the phase of the grid voltage reverses and control of the electric valve 18 is thereby obtained. This condition is represented in Fig. 5, the lines 41 and 42 again representing the response of the device 22 to the standard, while the lines 49 and 50 represent the response from the furnace radiation. In this case it will be observed that the peak of the voltage wave 51 of the secondary voltage occurs during the negative half cycle of anode voltage while in the previous cases (Figs. 3 and 4) the peak occurred during the positive half cycle of anode voltage. The result is a reversal in the phase of the grid voltage with respect to its anode voltage, which reversal renders the valve or rectifier 18 non-conductive. Consequently the saturation of the reactor 14 disappears thereby substantially preventing current flow through the heating resistance 11.

The control of the heating current or the rate of heat generation therefore depends on the relative intensities of the light rays from the standard 22 and the furnace 10. The effect of any variations in the response of the light sensitive device 22 as well as any variations of voltage of the battery 23 do not affect the temperature control of the furnace because it is the relative light radiation that effectuates the temperature control of the furnace. In other words the response of the light sensitive device to the two sources of light will vary by equal amounts and result in the same grid control voltage for a given relative intensity of the two light sources, regardless of the sensitivity of the device 22.

It will be observed that the amount of light received by the device 22 is not constant over a half cycle of anode voltage. In the positions shown, the maximum amounts of light are directed to the light sensitive device 22. For instance, considering the full line position of the mirror it will be seen that the intensity gradually decreases as the mirror is rotated until no light from the furnace is directed to the device 22. In the same manner, the light directed by the mirror 29 from the standard 27 gradually increases to a maximum and then decreases to zero.

While I have described what I at present consider the preferred embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In a control system, an electric valve provided with input and output circuits, a source of alternating current supply for said output circuit, a standard source of light, a variable source of light, and means including a light sensitive member and a member for directing light thereto alternately from said standard source and from said variable source for impressing an alternating voltage on the input circuit of said valve varying in phase relation with respect to the voltage of said alternating current supply in accordance with the relative intensities of the light from said standard source and from said variable source.

2. In a control system, a grid controlled electric valve provided with input and output circuits, a source of alternating current supply for said output circuits, a light sensitive device, a standard source of light, a variable source of light, a light directing device synchronized with said source of alternating current for successively directing light from said sources to said light sensitive device, and means responsive to said light sensitive device for impressing on said input circuit a voltage varying in phase relation with respect to the voltage of said source of alternating current in accordance with the relative intensities of the light from said standard source and from said variable source.

3. In combination, a furnace, a heating resistor therefor, a grid controlled electric valve the conductivity of which is arranged to be controlled by variation of the phase relation between the grid and anode voltages, means responsive to said valve for controlling the energization of said resistor, a standard source of light rays, a light sensitive device, means for alternately directing light rays from said furnace and from

said standard source to said light sensitive device, and means responsive to said light sensitive device for varying the phase relation between the grid and anode voltage of said valve.

5 4. A temperature control system comprising a furnace, a heating resistor therefor, a reactor for controlling the heating current of said resistor, a grid controlled rectifier for controlling the degree of saturation of said reactor, a source
10 of alternating current for the anode of said rectifier, a standard source of light and means including a light sensitive device responsive to radiations from said furnace and from said standard
15 for controlling the phase relation between said grid and anode voltages whereby the saturation of said reactor is controlled so as to maintain a substantially constant temperature within said furnace.

5. In combination, a furnace, a heating resistor therefor, a standard light source, a light
20 sensitive device, means for alternately directing radiations from said furnace and said standard source to said light sensitive device, a grid controlled rectifier arranged to control the energiza-
25 tion of said resistor, means for electrically connecting said light sensitive device in the grid circuit of said rectifier so that said grid is positive with respect to the anode so long as the
30 light rays from one of said sources of radiation of said rectifier has a greater intensity than the other of said sources.

6. In combination, a furnace having light emitting characteristics varying with its temperature, a heating resistor for said furnace, a light sensitive device, an arc rectifier having an anode and
35 having input and output circuits for controlling the energization of said resistor, connections for connecting said light sensitive device to said input circuit, a source of alternating current supply for said output circuit providing a voltage on
40 said anode, a standard source of light, a reflecting device having a plurality of movable reflecting surfaces, means for moving said surfaces in synchronism with said anode voltage to reflect
45 light to said light sensitive device alternately from said furnace and from said standard, and means responsive to said light sensitive device for impressing on the input circuit of said rectifier a voltage varying in phase relation with respect
50 to said anode voltage in accordance with the relative intensities of the light from said sources.

7. In combination, a furnace having light emitting characteristics varying with its temperature, heating means for said furnace, an arc sec-
55 tifier having input and output circuits for con-

trolling said heating means, a light sensitive device, connections for connecting said light sensitive device to said input circuit, a standard source of light, a source of alternating current
80 for said output circuit, a reflecting device having a plurality of reflecting surfaces mounted for rotation to bring said surfaces into positions alternately to reflect light to said light sensitive device from said furnace and from said standard,
85 means for rotating said reflecting device in synchronism with said output voltage so that when the anode of said rectifier is positive, light is reflected from said standard to said light sensitive device, and when said anode is negative, light is reflected from said furnace to said light
90 sensitive device.

8. In combination, a furnace having light emitting characteristics varying with its temperature, a heating resistor for said furnace, a saturable
95 core reactor for controlling the energization of said resistor, an arc rectifier having grid and anode circuits for controlling the saturation of said reactor, a source of alternating current supply for said anode circuit, a light sensitive device
100 connected to said grid circuit, a standard light source, a rotatably mounted reflecting device having a plurality of reflecting surfaces movable to interrupt light alternately from said furnace and said standard and to reflect it on said light
105 sensitive device, a motor connected to said supply source for driving said reflecting device in synchronism with said supply source so that said light sensitive device alternately receives light from said standard and said source, and a trans-
110 former connected to said light sensitive device and said grid circuit for impressing on said grid circuit a voltage varying in phase relation with respect to said anode circuit in accordance with the relative intensities of the light from said light
115 sources.

9. The method of controlling a tube having input and output circuits by a light sensitive device, a standard source of light and a variable
120 source of light, which consists in alternately directing light from said standard source and from said variable source on said device, causing said device to generate a voltage varying in phase relation with respect to said output circuit in accordance with the relative response of said device to said sources, and causing said voltage to be
125 impressed on said input circuit so as to render said tube conductive when one of said sources has a greater light intensity than the other of said sources.

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