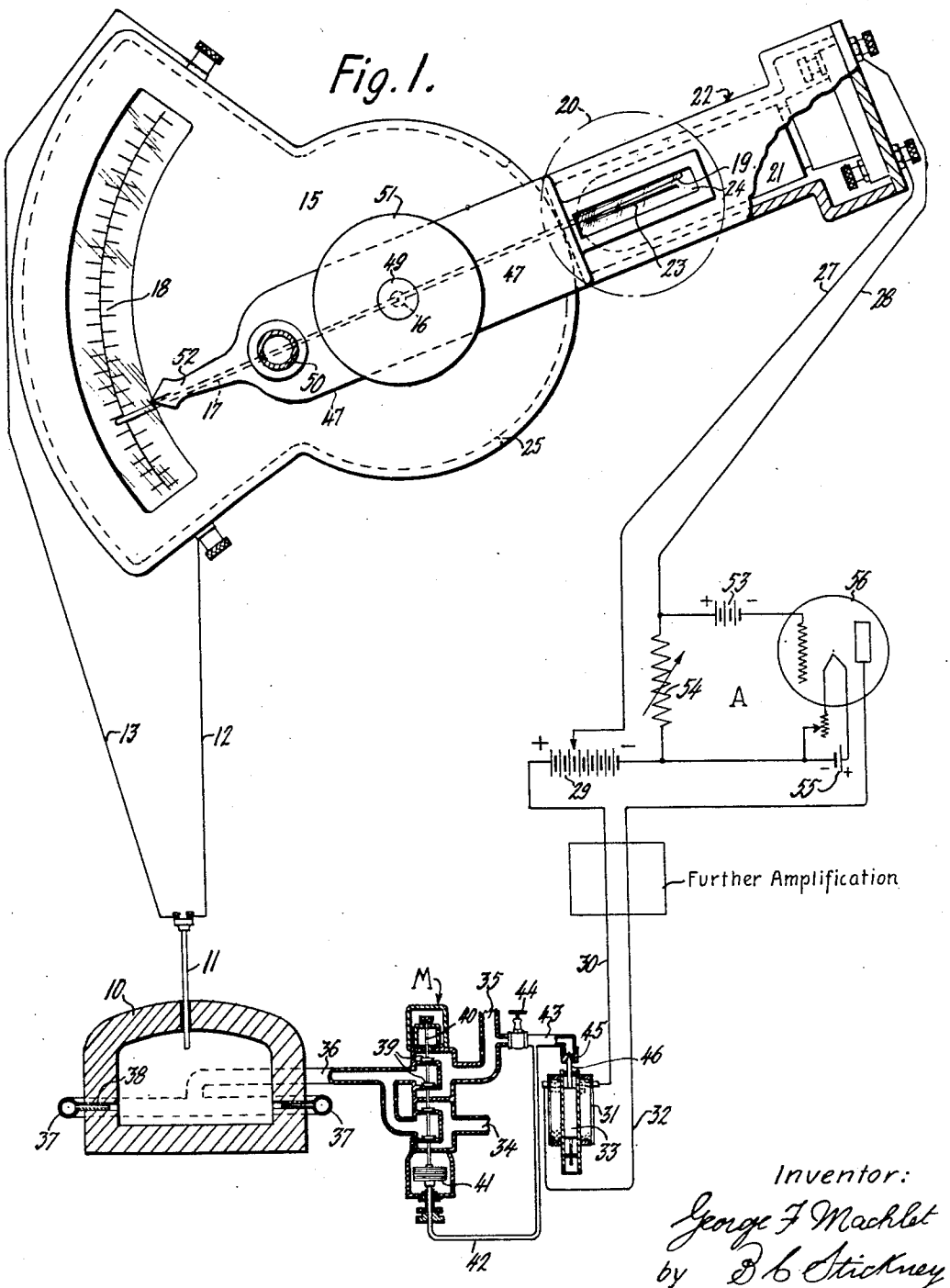
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May 13, 1930. G. F. MACHLET 1,758,450

REGULATOR

Filed June 18, 1926 2 Sheets-Sheet 1

Fig. 1.



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250-201

CROSS REFERENCE

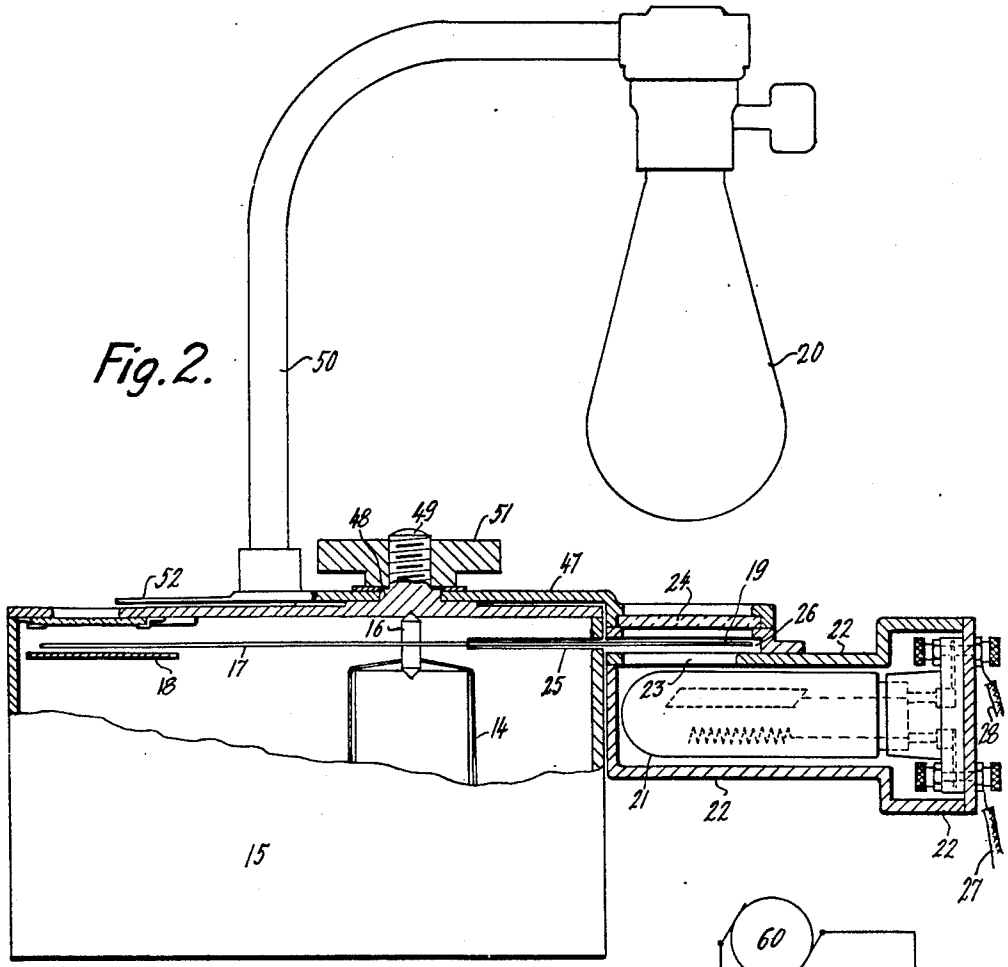
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REGULATOR

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Fig. 2.



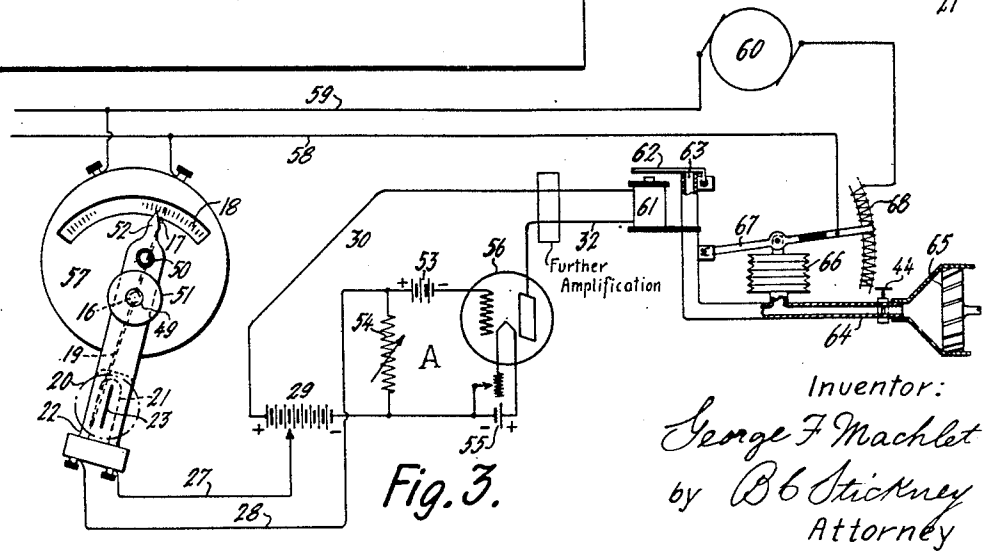


Fig. 3.

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1,758,450

UNITED STATES PATENT OFFICE

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REGULATOR

Application filed June 18, 1926. Serial No. 116,801.

This invention relates to means for regulating the heat of furnaces, such as shown, for example, in my Patents No. 1,068,065, of July 22, 1913; No. 1,099,658, of June 9, 1914, and No. 1,306,015, of June 10, 1919, and for regulating power and other apparatus, as, for example, electric circuits, and for other purposes, especially where delicate action is involved.

In heat regulators, there has usually been employed a galvanometer, which is affected by variations in the heat of a furnace. In other cases regulation has been effected by variations in the strength of the electric current which is to be controlled, or by variations in the output of power.. The galvanometer, voltmeter or other electric measuring device usually includes a delicate needle, whereby it has been sought to secure a very close regulation, as, for example, it has been the practice to maintain a furnace at say 2000 degrees, without a variation of more than five or ten degrees of heat.

In certain of said patents, and in my Patent No. 1,227,921, of May 29, 1917, mechanically-operating devices have been made to co-operate with the galvanometer or voltmeter needle, in such a manner that the needle would act as a mechanical interponent in the mechanism. A feature of the present invention is that the movement of the needle is absolutely unobstructed, and the necessity for intricate mechanism is avoided, while the regulation is rendered very fine, even under extreme heat or other extreme conditions. The device is inexpensive, and is readily connected to the voltmeter, galvanometer or other needle device, as well as to the furnace or other apparatus to be regulated.

To secure these and other ends, a selenium tube or bulb, or a photo-electric cell, or light-sensitive cell, is exposed to light from any suitable source, this light-sensitive cell being included in an electric circuit, in which the power of the electric current is dependent upon the effect of the light upon the sensitive cell, as is understood. The light of the lamp, which may be an electric bulb is concentrated preferably by the means of a convex oblong lens, and directed through a slit onto the sensitive cell. The needle of the galvanometer advances to and over this slit as the heat of the furnace rises, or as a fluctuation occurs in an electric power system or other apparatus. Thus the light is diminished or shut off from the sensitive cell, and hence there is weakening of the current in the circuit which includes said cell.

This fluctuation in the circuit of the light-sensitive cell is utilized to vary the supply of fuel to the furnace, or to vary the strength of the electric current in a system which is to be controlled, or to effect such other regulation or change as may be required.

Preferably the regulation is effected in proportion to the fluctuation of heat and during such fluctuation. The regulator preferably does not turn the fuel supply wholly on or wholly off, but rather affects the rate of fuel supply in proportion to the intensity of the light falling upon the sensitive cell. The invention has in its preferred form the advantage of reducing or increasing the rate of supply of fuel in proportion to the requirements of the furnace, the flow of fuel being uninterrupted, but being diminished or augmented. The temperature of the furnace advances slowly, the shutter slowly diminishes the light effect upon the sensitive cell, the galvanometer comes to rest at a point where the light is only partially obscured by the shutter, and the supply of fuel is slowly and evenly reduced. There may thus be brought about a balance, the supply of fuel being automatically held at a point where the furnace heat will neither decrease nor increase.

Preferably a special resistance amplifier, such as is commonly used, for example, with photo-electrical cells, is introduced in the light-sensitive cell circuit, and there may be connected in the same circuit a solenoid, which is energized by the aid of said amplifier, and is able to control the opening and closing of valves or ports which govern the quantity of fuel supplied to the furnace. As many amplifiers may be used as required.

The light-sensitive cell may be enclosed in a light-excluding housing or sheathing having said slit, and the housing frame may be mounted upon the boxing of the galvanometer

in a way to permit rotative adjustment of the cell and frame about the axis of movement of the galvanometer needle, so that the regulation of the furnace may be set to take place at any desired point. The electric lamp may be mounted upon the same frame, so as to be adjusted together with the cell. The shutter portion of the needle may radiate from the galvanometer pivot, and may extend oppositely from the needle itself; and it may be of a width to cut off the light from the sensitive cell long enough for increasing the heat of the furnace to be checked, and in case it is rapidly increasing at any time.

Other features and advantages will hereinafter appear.

In the accompanying diagrams.

Figure 1 is a galvanometer with an adjustable selenium or light-sensitive cell frame, this view showing also a furnace which is included in the circuit of the galvanometer needle and which has a fuel supply which is included in the circuit of the light-sensitive cell, there being also included in the selenium circuit an amplifier.

Figure 2 is an elevation, partly in section, of the galvanometer and the light-sensitive cell and its housing adjustable thereon, showing also the electric light bulb.

Figure 3 shows a voltmeter forming part of an electric current regulator.

Into the flame-chamber of a furnace 10, whose heat is to be regulated, extends a fire end 11, connected by wires 12, 13, to a rotative coil or element 14 of a galvanometer 15 as usual, the element 14 being pivoted as indicated at 16, and having a needle 17 extending over the usual scale 18, whereby may be ascertained the heat of the furnace 10.

According to the present invention, the element 14, by its rotation, is also utilized to control the heat of the furnace. For this purpose a shutter-arm 19 radiates from said pivot 16, preferably in the opposite direction from the needle 17, and preferably formed in one piece with said needle. The use of this shutter-arm is to intercept all or part of the light, which is caused to fall from an electric lamp 20 upon a selenium, photo-electric, or other light-sensitive cell, tube, or bulb 21. This light-sensitive cell 21 is within a dark housing 22, having along its top a narrow slit 23, permitting light to enter from the lamp 20. An oblong lens or light-focusing device 24 above said slit serves to concentrate the light from the lamp 20 and increase the efficiency of the apparatus. The shutter 19 may swing freely in the space between the lens and the slit 23, the boxwork of the wall of the galvanometer 15 having a horizontal slot 25 to permit this motion, and an open or clear space being left at 26 above the housing 22, for the same purpose. While the furnace is heating up and the needle 17 and the shutter 19 are swinging, the light from the lamp 20 shines freely upon the light-sensitive cell 21 until the heat reaches the desired point, at which time the shutter 19 swings over the slit 23 in the housing of the light-sensitive cell, and may partially cover said slit, thereby diminishing the strength of the current in the circuit of which said cell 21 forms a part, and consequently reducing the supply of fuel to the furnace.

To perform these functions, the light-sensitive cell 21 is included in an electric circuit having conductors 27, 28. Included in the same circuit is a battery or source of power 29 and an amplifier, which is generally designated as A; the amplifier being of a construction usual in radio-receiving sets and in other arts, being usually in the form of the well-known tube. From the battery 29 a conductor 30 of said circuit extends to a solenoid 31, and from the latter there extends a return conductor 32 to the amplifier A, the effect of the amplifier being to augment the power of the solenoid 31. By the rising and falling of the core 33 of said solenoid, the supply of fuel to the furnace 10 is regulated.

The fuel usually consists of gas from a main 34 and compressed air from a main 35, which enter a mixer, designated as M, from which the mixed fuel is delivered through a pipe 36 to a manifold 37, from which extend burners 38 into the frame-chamber of the furnace 10. In the mixer are various ports which are opened and closed by means of poppet-valves 39 mounted upon a common stem 40, the lower end of which is joined to a bellows-like drum 41, which is in the form of a thin-walled copper cylindrical box having peripheral corrugations or pleats which permit the drum to lengthen and shorten according to the variation in air pressure therein, the air entering from a tube 42. Increase of pressure causes the drum or "diaphragm" 41 to expand and thereby lift the stem 40 and the poppet-valves, while a decrease in pressure has the opposite effect, closing the ports.

From the compressed air main 35 extends a nozzle 43 into which opens the end of the diaphragm tube 42; and a needle or other valve 44 may be provided in said nozzle between the tube 42 and the main 35, to control manually the pressure of air in the tube 42 and in the diaphragm 41. The nozzle is also provided with an outlet 45, forming a continuing leak, which is reducible by a stem or closure 46 extending up from the solenoid core 33.

From the foregoing it will be understood that when the shutter 19 of the galvanometer partially closes the slit 23 and thereby partly shuts off the light-sensitive cell 21 from receiving light, the electric current in the circuit of said cell is weakened accordingly, and hence the power of the solenoid 31 is reduced, and the core 33 drops more or less.

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thereby opening more or less the leak 45 and permitting waste of compressed air from the nozzle 43, whereby the pressure in the tube 42 is reduced, as well as in the drum or diaphragm 41, which contracts, so that its stem 40 descends, together with all of the poppet-valves 39, and the supply of fuel to the furnace is reduced or cut off. Upon the heat of the furnace falling, the galvanometer is affected accordingly, and the shutter 19 rotates, thereby uncovering more of the slit 23, and affecting the light-sensitive cell circuit accordingly, and increasing the power of the solenoid 31, whereby the core 33 is lifted and the leakage at 45 is reduced, and the pressure in the tube 42 and diaphragm 41 is raised accordingly, and the valves 39 hence are opened and the supply of fuel to the furnace is increased.

It will be noted that there is entire absence of any obstruction or opposition to the movement of the needle 17 or shutter 19, so that the same may be extremely sensitive in operation and yet positively control the heating of the furnace in a simple manner. The control is quickly effected, and a furnace may be maintained at heat of thousands of degrees with negligible fluctuation. The shutter by only partially closing the slit 23 may effect sufficient weakening of the current in the selenium cell circuit as to barely open the leak 45, and permit an almost imperceptible constant or continuous waste of air from the nozzle 43, but still sufficient to keep the air pressure in 42 and 41 at the exact point for supplying just enough fuel to maintain the heat of the furnace at that point substantially without any variation; the entire apparatus being very sensitive, while at the same time efficient to control the furnace.

For using the device at different degrees of heat, an adjustment is provided. A bracket or frame 47 is pivoted upon a shoulder 48 of a stud 49, rising from the top of the casing of the galvanometer 15, said bracket carrying at one end a bent arm 50 supporting the electric-light bulb 20, and carrying at its other end the housing 22 of the selenium cell, whereby the bracket, the housing and the light may be adjusted as a unit concentrically with the rotary element 14 of the galvanometer, a thumb-nut 51 being threaded upon the stud 49 to secure the parts where adjusted. The adjustment may be aided by means of an index 52 carried upon the bracket and co-operative with the usual scale 18 of the galvanometer.

The amplifier unit is of well-known construction, and may include an 18-volt battery 53, a grid leak 54, a 6-volt battery 55 and the usual tube 56. The invention is not limited to the use of an amplifier in the same circuit with the light-sensitive cell and the solenoid, for the invention includes broadly any means which enables the light-sensitive cell to control the supply of fuel to the furnace, as, for example, the use of a relay placed in a simple circuit of the light-sensitive cell and controlling a stronger current in another circuit which is inclusive of the solenoid.

While there is illustrated a galvanometer shutter for controlling the supply of fuel to the furnace whose heat affects the galvanometer, still it will be understood that the control of the light-sensitive cell by a galvanometer may be utilized in regulating other apparatuses or elements than furnaces.

At Figure 3 a voltmeter 57 is connected to the power mains 58, 59, leading from a dynamo 60. The voltmeter is provided with the shutter-arm 19, to cover a light slit 23 over a light-sensitive cell 21, as in the other views, the circuit of the sensitive cell including wires 27, 28, amplifier A, battery 29 and wires 30, 32, the latter leading to and from a magnet 61. By means of this magnet and its pivoted armature 62, there is kept closed or nearly closed a jet 63, similar to 43, from which compressed air leaks; this jet or nozzle leading from a pipe 64, in which air is kept under pressure by a pump or blower 65. Also connected to pipe 64 is a large expansible drum 66, corresponding with 41, which is maintained in expanded condition by the compressed air therein. To the top of the drum is pivoted a switch-arm 67, operating upon rheostat 68 included in said main circuit 58, 59. When the current in the dynamo circuit is below normal, the light slit 23 remains open, and a strong current is maintained in the sensitive-cell circuit, and the magnet 61 keeps the leak 63 practically closed, so that there is high air pressure in the drum or diaphragm 66, and the switch-arm 67 is kept at its upper position, cutting out much of the resistance 68. When the current in the dynamo circuit increases to the desired point, the slit 23 is wholly or partially covered by the shutter 19, and through the described train the air pressure in the drum 66 is weakened, and it collapses to a certain extent, lowering the switch-arm 67 and thereby cutting more resistance into the dynamo circuit.

Variations may be resorted to within the scope of the invention, and portions of the improvements may be used without others.

Having thus described my invention, I claim:

1. The combination with an element or apparatus subject to fluctuations, of means including a galvanometer or the like including a shutter movable by fluctuations in the galvanometer circuit, a light-sensitive cell, a housing therefor having a light-receiving slit closable by said shutter, and means controlled by said light-sensitive cell for regulating said element or apparatus, said regulating means including a coil in circuit with

said light-sensitive cell, an amplifier in the same circuit with said coil and cell, and a regulating device having an independent source of power and including a controller for said power operated by said coil.

2. The combination with an element or apparatus subject to fluctuations, of means including a galvanometer or the like including a shutter movable by fluctations in the galvanometer circuit, a light-sensitive cell, a housing therefor having a light-receiving slit closable by said shutter, a coil in circuit with said cell, and means controlled by said light-sensitive cell through said coil for regulating said element or apparatus, said cell-circuit including a step-up device whereby weak variations in current caused by the effect of the galvanometer shutter upon the light-sensitive cell effect strong variations in current in said coil, an independent source of power under control of said coil, and means to enable said source of power to regulate said apparatus.

3. In combination, a galvanometer having a movable shutter-arm, a photo-electric cell, a housing therefor having a slit, a lamp mounted to shine through said slit upon said cell, said slit closable by said shutter-arm, the advancing shutter covering or obscuring the slit in proportion to its advance, and diminishing the conductivity of the photo-electric cell in proportion as the light is obscured by said shutter-arm, an amplifying device in circuit with said cell, and an independent source of power through which said cell-circuit is connected to operate a regulator for heat, power or electricity, said independent source of power being controlled by a device in said cell-circuit.

4. In combination, a galvanometer having a movable shutter-arm, a photo-electric cell, a housing therefor having a slit, a lamp mounted to shine through said slit upon said cell, said slit closable by said shutter-arm, the advancing shutter covering or obscuring the slit in proportion to its advance, and diminishing the conductivity of the photo-electric cell in proportion as the light is obscured by said shutter-arm, an amplifying device in circuit with said cell, said amplifier being included in the same circuit with said photo-electric cell, and an electrically-operated regulator controlled by said circuit and having means to regulate heat, power or electricity.

5. In combination, a galvanometer having a movable shutter-arm, a photo-electric cell, a housing therefor having a slit, and a lamp mounted to shine through said slit upon said cell, said slit closable by said shutter-arm, said housing and cell carried upon a frame which is adjustably mounted to permit said shutter-arm to effect regulation at different selected points in the movement of the galvanometer shutter-arm.

6. In combination, a galvanometer having a movable shutter-arm, a photo-electric cell, a housing therefor having a slit, a lamp mounted to shine through said slit upon said cell, said slit closable by said shutter-arm, said housing and cell carried upon a frame which is adjustably mounted to permit said shutter-arm to effect regulation at different selected points in the movement of the galvanometer shutter-arm, said galvanometer having a scale, and an index to co-operate therewith in setting the adjustable device.

7. In combination, a galvanometer having a movable shutter-arm, a photo-electric cell, a housing therefor having a slit, a lamp mounted to shine through said slit upon said cell, said slit closable by said shutter-arm, said housing and cell carried upon a frame which is adjustably mounted to permit said shutter-arm to effect regulation at different selected points in the movement of the galvanometer shutter-arm, said galvanometer having a scale, an index to co-operate therewith in setting the adjustable device, and a lamp mounted upon said adjustable frame to shine through said slit upon said cell.

8. The combination of a galvanometer circuit including a part affected by the condition of a generator to be regulated, and which sets up a current in said circuit, said galvanometer having a movable shutter affected by the strength of the current, a light-sensitive cell, a housing therefor having an opening for the reception of light, said shutter mounted to be capable of closing said opening, a lamp to shine through said opening upon said cell, said light-sensitive cell being included in a circuit having a battery or other source of power and also having an amplifier inclusive of an amplifier tube, a coil, included in the same circuit with said amplifier and said cell, and a generator-regulating device controlled by said coil.

9. The combination of a galvanometer circuit including a part affected by the condition of a generator to be regulated, and which sets up a current in said circuit, said galvanometer having a movable shutter affected by the strength of the current, a light-sensitive cell, a housing therefor having an opening for the reception of light, said shutter mounted to be capable of closing said opening, a lamp to shine through said opening upon said cell, said light-sensitive cell being included in a circuit having a battery or other source of power and also having an amplifier inclusive of an amplifier tube, a coil included in the same circuit with said amplifier and said cell, a generator-regulating device controlled by said coil, said generator in the form of a furnace, means for supplying fuel to said furnace, and means controlled by said regulating coil for varying the supply of fuel to the furnace.

10. Heat-regulating means for a furnace, including an expansible drum or diaphragm

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operable by compressed air and controlling the supply of fuel to said furnace, and a galvanometer circuit having a thermotic element affected by the fluctuations in the heat of the furnace, a shutter element operated by said galvanometer, a light-sensitive cell, a housing therefor having a slit which may be opened and closed by said galvanometer shutter, means for permitting the pressure of air in said drum or diaphragm to leak, and means controlled by said sensitive cell to close and open said leak.

11. The combination with an element or apparatus subject to fluctuations, of means including a galvanometer or the like including a shutter movable by fluctuations in the galvanometer circuit, a light-sensitive cell, a housing therefor having a light-receiving slit closable by said shutter, means controlled by said light-sensitive cell for regulating said element or apparatus, said galvanometer having an adjustable frame or bracket pivoted thereon concentrically with the rotative device of the galvanometer, said sensitive cell carried upon said frame for adjustment, a light bulb upon said frame, and an index to co-operate with said frame in adjusting the same.

12. A heat-controlling means for a furnace, said controlling means including a galvanometer circuit having a thermotic element affected by the fluctuations in the heat of the furnace, a shutter-element operated more or less by said galvanometer, according to fluctuations in the galvanometer circuit. an electrical controller including both a light-sensitive cell and a housing therefor having a slit which may be opened and closed by said galvanometer-shutter, the fluctuations of said electrical controller being dependent upon variations in the current in the light-sensitive cell-circuit effected by said shutter, and means governed by said electrical controller for determining the supply of fuel.

13. In a fuel-supply-regulating means for a gas furnace having a set of air and gas mixing valves and also having a galvanometer circuit including a thermotic element affected by the fluctuations in the heat of the furnace, the combination of a shutter operated by said galvanometer, a light-sensitive cell, a housing therefor having a light-opening closable by said shutter, a source of light to shine through said opening upon said cell, said light-sensitive cell being included in a second circuit having a source of power and also having an amplifier inclusive of an amplifier tube, a coil being also included in said second circuit, a drum having a controlling stem joined to said valves, said drum formed of flexible metal and having circumferentially plated sides and expansible by air pressure, a connection from said drum to the supply of compressed air to said mixing valves, and means controlled by said coil to vary the pressure of air in said drum.

14. The combination with a furnace having a supply of gas and a supply of compressed air and a set of mixing and controlling valves, and also having a galvanometer circuit including a thermotic element affected by the fluctuations of heat in the furnace, of a shutter-element controlled by said galvanometer, a light-sensitive cell, a source of light, a housing for said cell having a slit which may be opened and closed by said shutter, a solenoid in a circuit controlled by said cell, a drum connected to operate said valves and having a connection from its interior to said supply of compressed air, said drum formed of flexible sheet-metal and having sides formed of bellows pleats, and being longitudinally expansible and contractible, and means controlled by said solenoid to vary the pressure of air in said drum and thereby control its elongation or contraction for operating the valves.

15. The combination with a furnace having a supply of gas and a supply of compressed air and a set of mixing and controlling valves, and also having a galvanometer circuit including a thermotic element affected by fluctuations of heat in the furnace, of a light-sensitive cell, a shutter-element operated by said thermotic element and controlling the lighting of said cell, a solenoid in a circuit controlled by said cell, an expansible drum connected to operate said valves and having a manually regulatable connection from its interior to said supply of compressed air, and means controlled by said solenoid to vary the pressure of air in said drum and thereby control its expansion and contraction, for operating the valves.

16. The combination with a furnace having a supply of gas and a supply of compressed air and a set of mixing and controlling valves, and also having a galvanometer circuit including a thermotic element affected by fluctuations of heat in the furnace, of a light-sensitive cell, a shutter-element operated by said thermotic element and controlling the lighting of said cell, a solenoid in a circuit controlled by said cell, an expansible drum connected to operate said valves and having a connection from its interior to said supply of compressed air, said drum provided with a leak, and a closure for said leak controlled by said solenoid to vary the pressure of air in said drum and thereby control its expansion and contraction, for operating the valves.

17. The combination with a furnace having a supply of gas and a supply of compressed air and a set of mixing and controlling valves, and also having a galvanometer circuit including a thermotic element affected by fluctuations of heat in the furnace, of a light-sensitive cell, a shutter-element operated by said thermotic element and controlling the lighting of said cell, a solenoid in a

circuit controlled by said cell, an expansible drum connected to operate said valves and having a connection from its interior to said supply of compressed air, said drum provided with a leak, a closure for said leak controlled by said solenoid to vary the pressure of air in said drum and thereby control its expansion and contraction, for operating the valves, and a manually regulatable valve between said drum and said compressed air supply.

18. The combination with a furnace having a supply of gas and a supply of compressed air and a set of mixing and controlling valves, and also having a galvanometer circuit including a thermotic element affected by fluctuations of heat in the furnace, of a light-sensitive cell, a shutter-element operated by said thermotic element and controlling the lighting of said cell, a solenoid in a circuit controlled by said cell, a drum formed of thin flexible sheet-metal and having sides formed of bellows pleats, and being longitudinally expansible and contractible to control said valves, a separate connection between the interior of the drum and the compressed air supply, and a nozzle extending from said compressed air supply, said nozzle having a leak, and said solenoid having a closure for said leak.

19. The combination of a heating apparatus to be regulated, a galvanometer controllable by said apparatus and affected by the heat thereof, and having a movable shutter, a light-sensitive cell dominated by said shutter, an electric circuit including said cell, a pneumatic device having a leak, magnetic means being included in said cell circuit for controlling said leak, and a regulator for said heating apparatus controlled by said pneumatic device.

20. In combination, with an apparatus to be regulated, a galvanometer circuit, the needle of which has a delicate shutter form and is sensitively movable by reason of fluctuations in the current, a light-sensitive cell dominated by said shutter, said shutter having a substantially great range of idle movement without dominating said cell, permitting the regulated apparatus to reach approximately the desired stage of efficiency before regulation begins, and a regulating circuit including said cell; whereby delicate regulation of the apparatus is secured in a short range of movement of the shutter around the point of desired efficiency of the apparatus.

21. In combination, with an apparatus to be regulated, a galvanometer circuit, the needle of which has a delicate shutter form and is sensitively movable by reason of fluctuations in the current, a light-sensitive cell dominated by said shutter, said shutter having a substantially great range of idle movement without dominating said cell, permitting the regulated apparatus to reach approximately the desired stage of efficiency before regulation begins, and a regulating circuit including said cell; said shutter and cell being mounted for relative adjustment, to predetermine the stage at which regulation shall begin.

22. The combination with a member to be regulated, of a pneumatic regulator having a continuously operating leak, an electric circuit having means for delicately varying the rate of flow of air through said leak and thereby controlling said regulator, and means for automatically varying the flow of current through said circuit.

23. The combination with a member to be regulated, of a pneumatic regulator having a continuously operating leak, an electric circuit having a light-sensitive cell and also having means for delicately varying the rate of flow of air through said leak, and means for automatically controlling the supply of light to said cell.

24. The combination with a member to be regulated, of a pneumatic regulator having a continuously operating leak, an electric circuit having a light-sensitive cell and also having means for delicately varying the rate of flow of air through said leak, and a master electric circuit having a sensitively moving shutter dominating said cell.

25. The combination with a member to be regulated, of a pneumatic regulator having a continuously operating leak, an electric circuit having a light-sensitive cell and also having means for delicately varying the flow of air through said leak, and a master electric circuit having a sensitively moving shutter dominating said cell; means being provided for affording a preadjustment between said shutter and said cell.

26. The combination with a regulatable apparatus subject to fluctuations, of a light-sensitive cell, an enclosure therefor having an opening for the admission of light thereto, a shutter for said opening, said shutter sensitive to the fluctuations of said apparatus, an electric circuit including said light-sensitive cell, a pneumatic device including a diaphragm or pneumatic member having a continuously operating air leak, magnetic means in said circuit for delicately varying the rate of flow of said air leak and thereby controlling the movement of said diaphragm, and means under the control of said diaphragm for effecting regulation of said apparatus.

27. The combination with a regulatable apparatus subject to fluctuations, of a light-sensitive cell, an enclosure therefor having an opening for the admission of light thereto, a shutter for said opening, said shutter sensitive to the fluctuations of said apparatus, an electric circuit including said light-sensitive cell, a pneumatic device including a diaphragm or pneumatic member having a

continuously operating air leak, magnetic means in said circuit for delicately varying the rate of flow of said air leak and thereby controlling the movement of said diaphragm, and means under the control of said diaphragm for effecting regulation of said apparatus; means being provided for affording relative preadjustment between said opening and said shutter, for predetermining the point at which regulation of said apparatus shall take place.

28. The combination with a regulatable apparatus subject to fluctuations, of an instrument whose movements are sensitively controlled by said fluctuations, a pneumatic device capable of effecting regulation of said apparatus, said pneumatic device having a continuously operating air leak, and means under the control of said sensitive instrument for delicately varying the rate of escape of air through said leak and thereby controlling the movements of said pneumatic device.

29. The combination with a regulatable apparatus subject to fluctuations, of an instrument whose movements are sensitively controlled by said fluctuations, a penumatic device capable of effecting regulation of said apparatus, said pneumatic device having a continuously operating air leak, and means under the control of said sensitive instrument for delicately varying the rate of escape of air through said leak and thereby controlling the movements of said pneumatic device, said leak-regulating means including a light-sensitive cell whose light supply is controlled by said sensitive instrument, and an electric circuit including said light-sensitive cell and a magnetic valve for said leak.

30. The combination with a regulatable apparatus subject to fluctuations, of an instrument whose movements are sensitively controlled by said fluctuations, a pneumatic device capable of effecting regulation of said apparatus, said pneumatic device having a continuously operating air leak, and means under the control of said sensitive instrument for delicately varying the rate of escape of air through said leak and thereby controlling the movements of said pneumatic device, said leak-regulating means including a light-sensitive cell whose light supply is controlled by said sensitive instrument, and an electric circuit including said light-sensitive cell and a magnetic valve for said leak, said sensitive instrument mounted for oscillation, and said cell being mounted for adjustment around the center of said oscillation, to predetermine the point at which regulation shall take place.

31. The combination with an apparatus to be regulated, of an electric circuit including a needle whose movements are sensitively affected by fluctuations in said apparatus, a light-sensitive cell, said needle having a part moving therewith to control the supply of light to said cell, an electric circuit including said cell and also including a magnetically movable valve, and a pneumatic device having means to control said apparatus and also having a continuously operating leak through which the flow of air is delicately varied by said valve.

32. The combination of a heating apparatus, an electric circuit including a shutter sensitively affected by fluctuations in the heat of said apparatus, a light-sensitive cell dominated by said shutter, an electric circuit including said cell and a magnetic valve, and an air-pressure device controlling the heat of said apparatus and having a continuously operating leak through which the passage of air is delicately varied by said valve.

33. Heat regulating means for a furnace having a fuel-controlling means, said regulating means including a galvanometer circuit including a thermotic element affected by the fluctuations in the heat of the furnace, a shutter element controlled by said galvanometer, a light-sensitive cell, a housing therefor having a slit which may be opened and closed by said shutter, a solenoid in a circuit controlled by said cell, and means to enable said solenoid to control the operation of said fuel-controlling means.

34. The combination of a galvanometer having a moving element, a circuit including said galvanometer, a shutter movable by the current in said circuit, a light-sensitive cell dominated by said shutter, an adjustable mount for said cell upon said galvanometer affording adjustment of the cell along the path of the moving element of the galvanometer, an electric circuit including said cell, and a regulating device controlled by said electric circuit.

GEORGE F. MACHLET.