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March 29, 1949.

G. A. FREEMAN ET AL

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AUTOMATIC CARBONIZATION OF FILAMENTS

Filed June 22, 1943

5 Sheets-Sheet 1

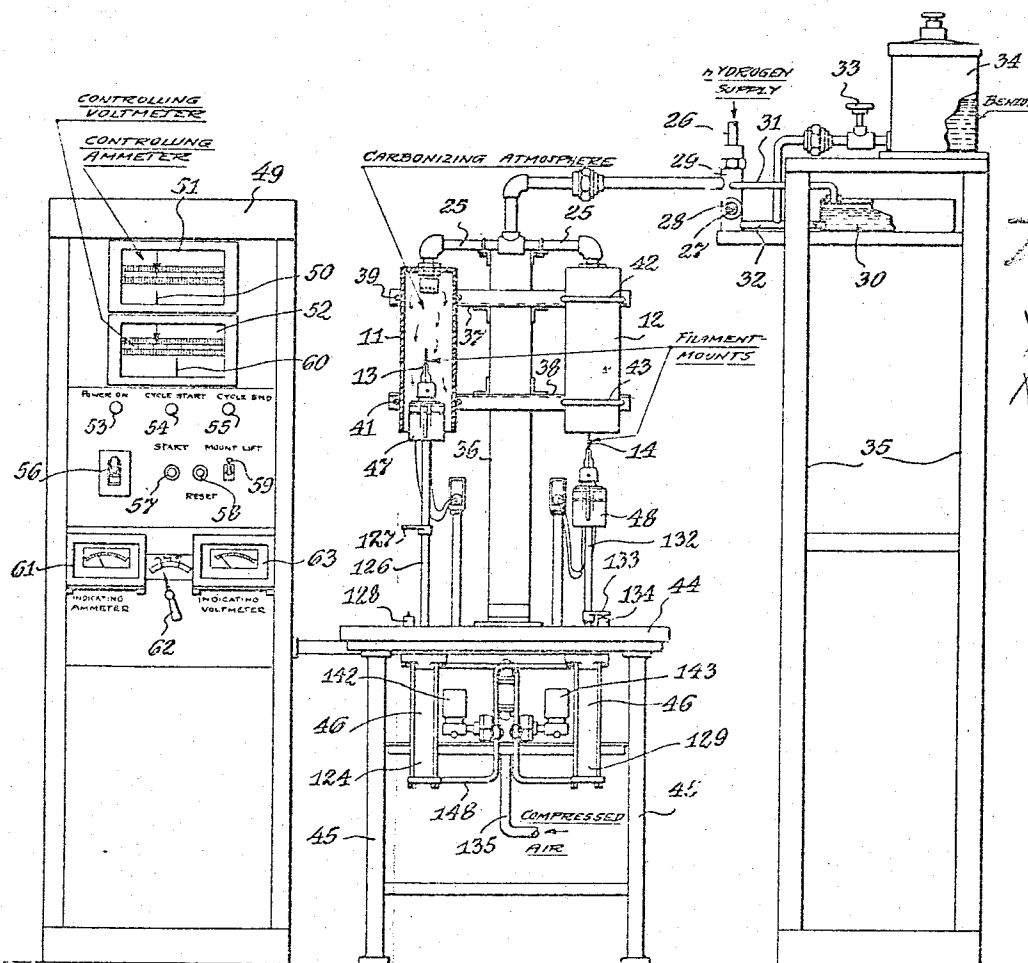


Fig. 1.

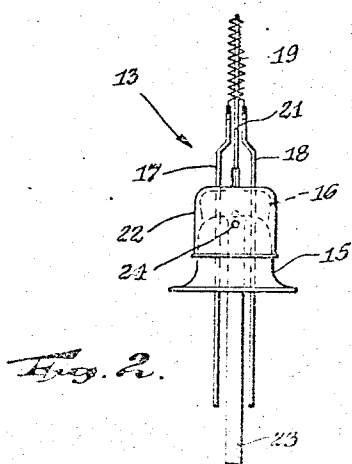


Fig. 2.

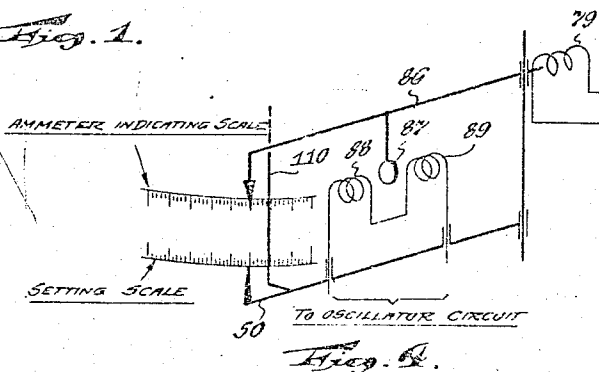


Fig. 3.

INVENTORS
G. A. FREEMAN
J. H. GREEN.
BY *J. H. Green*
ATTORNEY

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March 29, 1949.

G. A. FREEMAN ET AL

2,465,864

AUTOMATIC CARBONIZATION OF FILAMENTS

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5 Sheets-Sheet 2

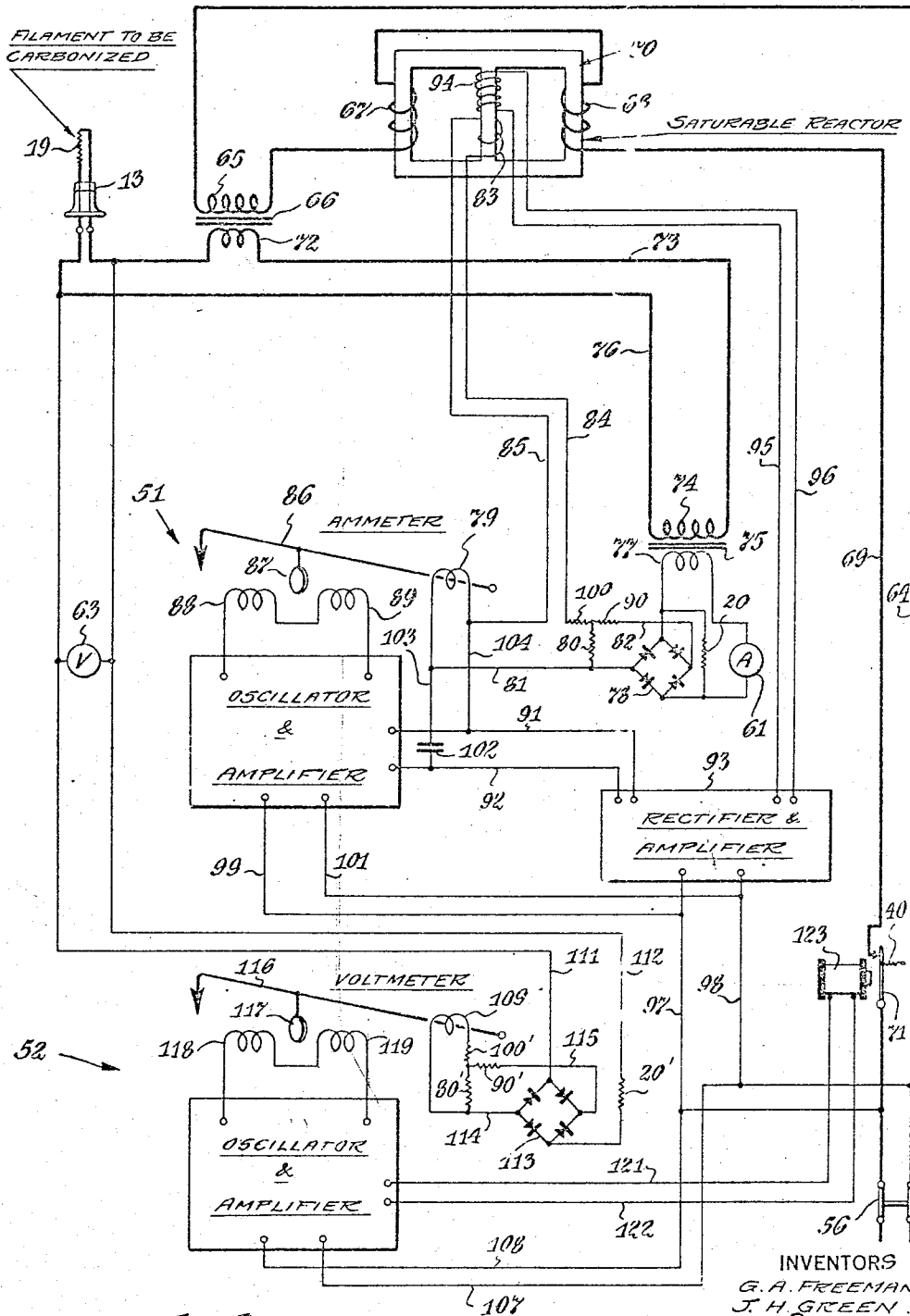


Fig. 3.

INVENTORS
G. A. FREEMAN
J. H. GREEN.
BY *J. H. Green*
ATTORNEY

March 29, 1949.

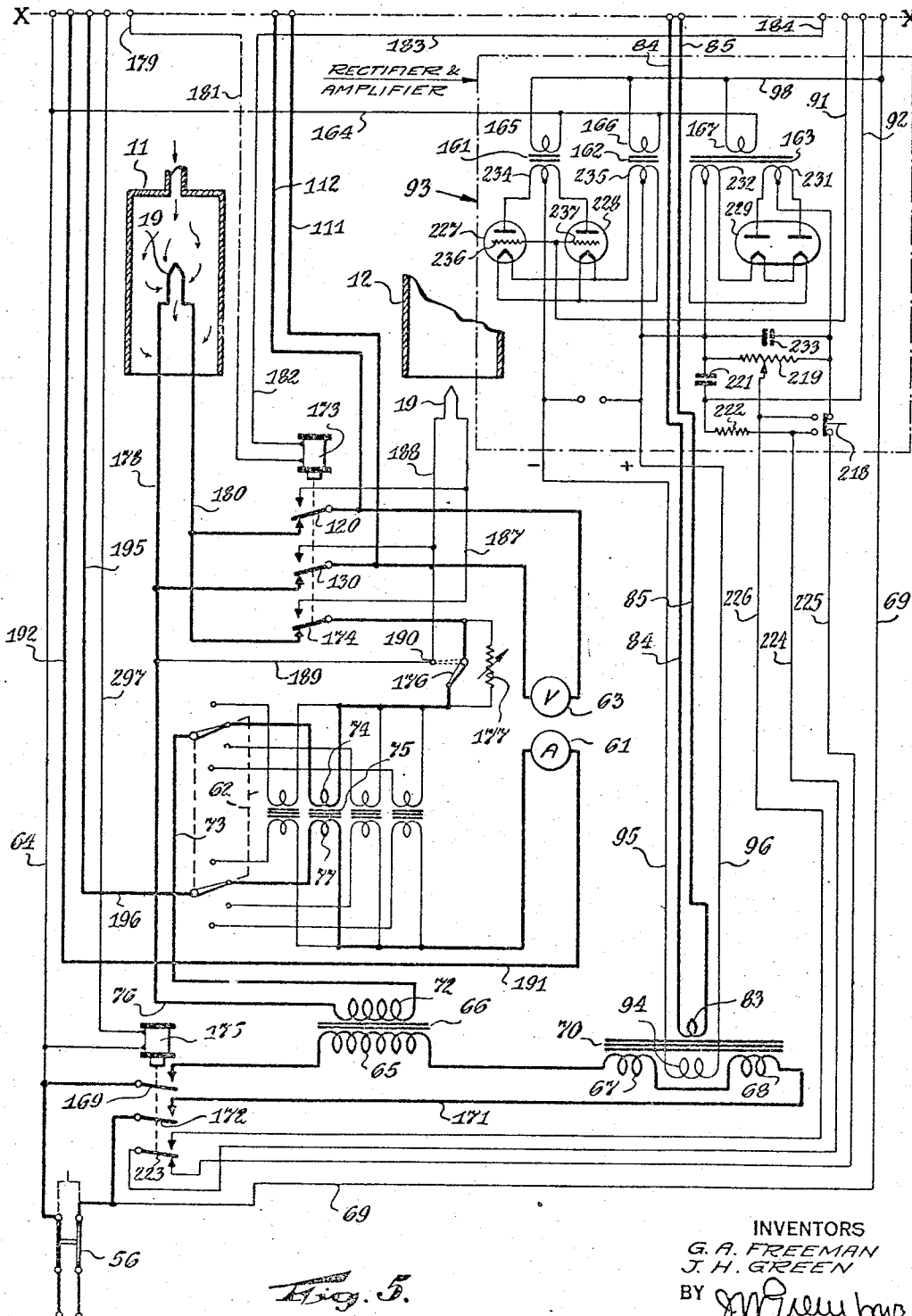
G. A. FREEMAN ET AL

2,465,864

AUTOMATIC CARBONIZATION OF FILAMENTS

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5 Sheets-Sheet 3



INVENTORS
G. A. FREEMAN
J. H. GREEN
BY *J. M. Green*
ATTORNEY

March 29, 1949.

G. A. FREEMAN ET AL

2,465,864

AUTOMATIC CARBONIZATION OF FILAMENTS

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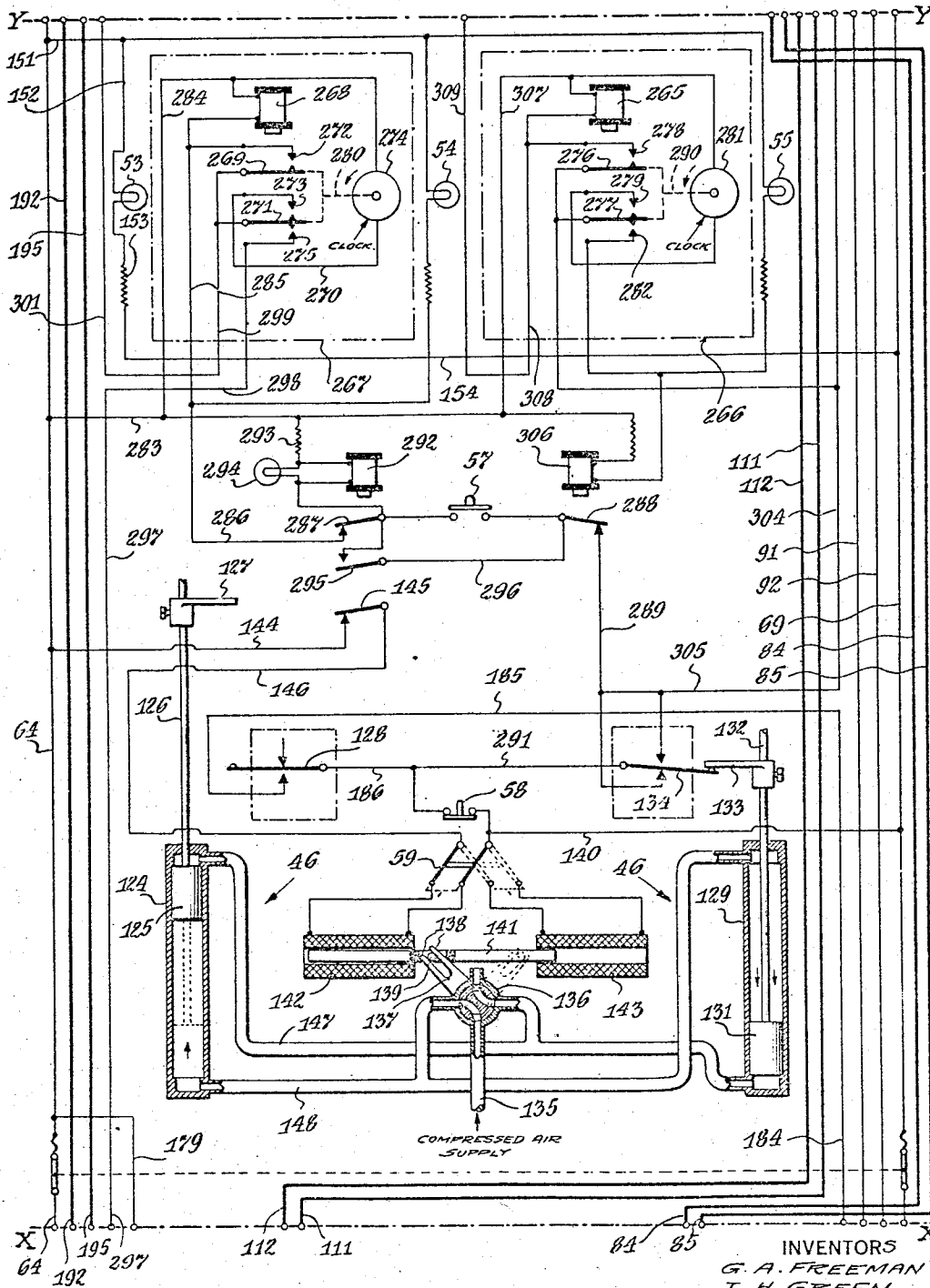


Fig. 6.

INVENTORS
G. A. FREEMAN
J. H. GREEN
BY *J. H. Green*
ATTORNEY

March 29, 1949.

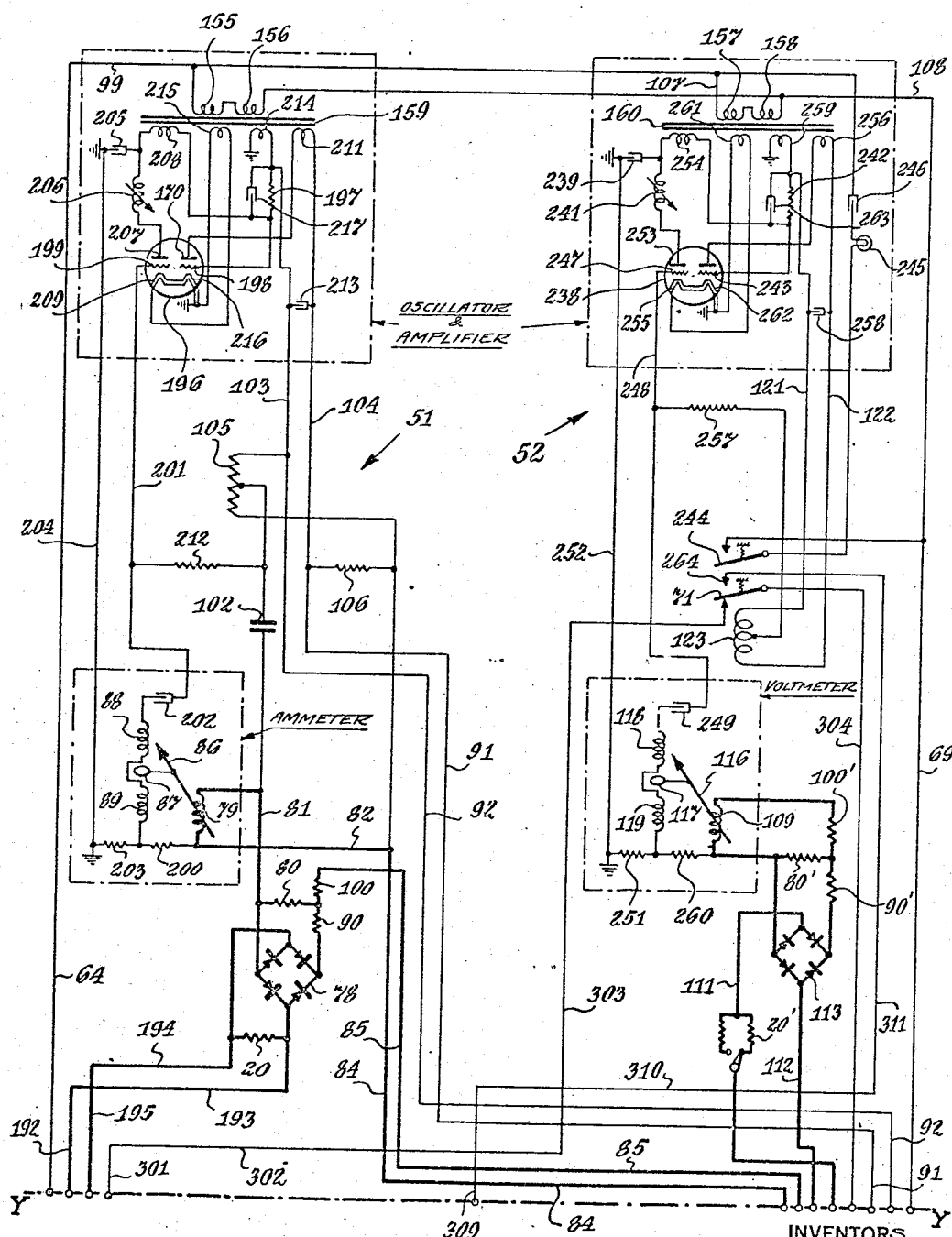
G. A. FREEMAN ET AL

2,465,864

AUTOMATIC CARBONIZATION OF FILAMENTS

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5 Sheets-Sheet 5.



INVENTORS
G. A. FREEMAN
J. H. GREEN.
BY *J. H. Green*
ATTORNEY

Patented Mar. 29, 1949

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UNITED STATES PATENT OFFICE

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AUTOMATIC CARBONIZATION OF
FILAMENTS

George A. Freeman, East Orange, and James H. Green, West Orange, N. J., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application June 22, 1943, Serial No. 461,780

15 Claims. (Cl. 148—13.1)

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This invention relates to automatic means for treating filamentary material, and more particularly to such means for carbonizing filaments which may be used for radio tubes.

A primary object of our invention, generally considered, is to provide means which give uniform carbonization of filaments, for such devices as radio tubes, upon the mere pushing of a button.

Another object of our invention is to provide automatic means for heating filaments to carbonize them to a predetermined resistance, and then automatically shutting off the heating current.

A further object of our invention is to provide means for automatically damping the current controller to prevent "hunting" when the moving pointer reaches an oscillator coil set at a desired point.

An added object of our invention is to provide means to delay the application of power, to the filament to be carbonized, while the treating bottle is being purged.

A still further object of our invention is to provide means to delay lowering of the filament-carrying mount for a short cooling period after carbonization to prevent oxidation of the parts.

An additional object of our invention is to provide means to disable the control buttons during carbonization, so that accidental lowering of the mount during such operation cannot happen.

Another object of our invention is to prevent starting of the carbonization cycle with the wrong mount in position.

An additional object is to form uniformly carbonized thoriated tungsten filaments.

A further object of our invention is to provide means for maintaining a substantially constant level of the carbonizing liquid in the carbureting device.

A still further object of our invention is to provide automatic means for carbonizing filaments by uniform current and then automatically shutting off said current when the voltage producing it reaches a predetermined value.

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.

Referring to the drawing:

Fig. 1 is a front elevational view of apparatus embodying our invention.

Fig. 2 is an elevational view of a mount carrying a filament to be carbonized.

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Fig. 3 is a schematic diagram showing the general principles of the invention in order to make it easier to understand the detailed description.

Fig. 4 is a diagrammatic showing of the arrangement which we prefer to use in the control ammeter.

Fig. 5 is a portion of the complete wiring diagram of apparatus which we may use in the practice of our invention.

Fig. 6 is an adjoining portion of the wiring diagram of Fig. 5.

Fig. 7 is an adjoining portion of the wiring diagram of Fig. 6.

Before describing the apparatus and operation thereof, it might be well to point out that we propose to accomplish carbonization, as for "activation," by surrounding the filament with a reducing atmosphere, such as hydrogen, carbureted with benzol or other suitable hydrogen vapor, while heating said filament as by means of electric current maintained at a critical value. The degree of filament carbonization is accurately controlled by closely regulating the current until the filament resistance increases, due to its increasing carbonization, to a predetermined point. As the current is held constant, the voltage across the filament is proportional to its resistance. As soon as the resistance-determined voltage rises to a predetermined value, the current is automatically shut off.

The invention involves means to accomplish the above operations automatically, in order to obtain uniformity of the product, as well as speed of production. A simplified diagram, as well as the entire commercial apparatus, will be described. The latter may be separated into the following parts, in addition to the benzol vapor supply:

1. The mount raising and lowering mechanism.
2. The power supply.
3. The filament carbonizing circuits.
4. The control ammeter and voltmeter circuits.
5. The direct current supply.
6. The stabilization of the filament carbonizing current.
7. The termination of the current flow upon a predetermined rise in voltage, and
8. The time delay relays.

GENERAL DESCRIPTION

The hydrogen picks up a reasonably constant percentage of hydrocarbon vapor, as by passing from a jet approximately one inch above the level

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of the liquid benzol. Evaporation causes the liquid level to fall, but at a very slow rate in view of the reserve in the leveling tank.

The current regulator and voltage shut-off circuits make use of instruments each of which contains an oscillator, the output of which varies with the passing of a vane or flag, fastened to the pointer, through a coil in the oscillator circuit. An amplifier converts the oscillator output to an inversely proportional D. C. voltage. The voltage shut-off circuit uses the amplified oscillator output to operate a relay to cut off the power when the voltage on the filament being carbonized reaches a predetermined value. The current controlling instrument, however, makes use of the continuous, but rapid, change in the oscillator output voltage as the instrument pointer vane moves within the oscillator coil. The current regulator output controls the amount of direct current in a saturable reactor, and in this way exerts its effect upon the load current.

Due to inertia effects of the current controlling instrument pointer, and the magnetic field of the saturable reactor, there is a tendency for violent "hunting" on oscillation of the current about the desired value. This is eliminated by the use of differentiating circuits which "damp" the "hunting" oscillations. The damping is proportional to the speed of the pointer movement and, therefore, is proportional to the "first derivative" of the current. It exists only when the pointer is moving in the control range, and thus acts as a narrow "trap" to hold the pointer at the desired spot on the scale. Any tendency for the pointer to go up is opposed by a voltage in the instrument to push it back. As the pointer starts to drop it is opposed by a voltage opposite in polarity which holds it up. The position of the pointer is definitely fixed thereby and holds the load current likewise fixed.

With the apparatus used, two means simultaneously act as proportional to the "first derivative" of the current. One is a connected winding of one of two turns around the D. C. winding of the saturable reactor and in series with the current instrument coil. The voltage induced in this extra winding is proportional to the rate of change of the magnetic flux through the D. C. leg of the saturable reactor, which is in turn proportional to the rate of change of the oscillator output voltage.

The other "first derivative" voltage is obtained by starting with the oscillator output voltage itself and applying it through a fixed condenser directly to the ammeter operating coil. The direct current voltage, of course, does not pass the condenser, but any variation in it changes the charge on the condenser, at a rate proportional to the rate of change of the D. C. voltage. The condenser charging current which is proportional to the rate of change of the D. C. voltage is made to pass through the operating coil of the ammeter.

It is desirable to use together both methods of obtaining the "first derivative" control, since each ties back to one of the inertia components. Any movement of the pointer results in a current pulse direct to its coil to damp it. Likewise any change in the saturation of the reactor results in a current pulse to the meter pointer to damp the change.

The current control exists when the moving pointer reaches the oscillator coil which can be moved to a desired control point. An index pointer shows where the oscillator coil is. To

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prevent a current surge immediately after power is turned on, it is desirable for the pointer to move up to the oscillator coil index pointer as quickly as possible. A stop below the index pointer, is provided for the moving pointer to keep the distance of travel short. In the direct current power supply, a time delay circuit is provided to prevent a sudden change in the C bias and hence the saturation current. This gives the pointer time to move before the current rises too high.

Automatic control is effected by employing a number of relays which delay the turning on of the power while purging the treating bottle, delay the lowering of the mount for a short cooling period after carbonization is complete, completely disable the control buttons during carbonization so that accidental lowering of the mount cannot occur during carbonization, and prevent the starting of the carbonization cycle with the wrong mount in position.

GENERAL DESCRIPTION OF FIG. 1 AND THE CARBONIZING VAPOR SUPPLY

Referring to the drawing in detail, and first considering the general view shown in Fig. 1, we have the carbonizing bottles 11 and 12, which may be constructed of any desired material such as steel, and alternately receive filament mounts 13 and 14, one of which is shown in detail in Fig. 2. Each mount, for example, may comprise a flare tube 15 having a press 16 through which lead-in conductors 17 and 18 extend to a filament 19, the central portion of which is supported on an arbor 21. The press and adjacent portion of the flare are shown protected, as by a metal shield 22 which fits thereover. The flare tube 15 is, as usual provided with an exhaust tube 23, opening at its upper end therethrough and through the protector, as indicated at 24.

Each treating bottle has a pipe connection 25 from a supply of carbureted gas, which in the present instance is intended to be hydrogen carrying benzol vapor. For this purpose hydrogen is admitted through the pipe 26 above the level of a supply of benzol 27, which may be viewed through the glass window 28 in the carbureter chamber 29. The level is maintained substantially constant by having the chamber 29 communicating with a larger chamber 30, as by means of pipes 31 and 32, so that the level drops very slowly. When considered desirable, the benzol is replenished by opening the valve 33 and admitting more through the pipe 32 from the large supply tank 34. This carbureted gas supply apparatus is supported in any desired manner, as by means of framework 35.

The treating bottles 11 and 12 and their connecting pipes are supported on a standard 36 having cross arms 37 and 38, which hold said bottles, as by encircling bands 39, 41, 42 and 43. The standard 36 projects from a table or bench 44 having legs 45, and below the top of which is disposed apparatus 46 for alternately raising and lowering the mount-supporting means 47 and 48 for the carbonizing cycles.

To the left of the carbonizing bottles, as viewed in Fig. 1, is mechanism 49 consisting of a control ammeter, oscillator and amplifier 51, a control voltmeter, oscillator and amplifier 52, and a series of indicator lamps, that is, a green lamp 53, a red lamp 54, and a yellow lamp 55, to respectively show when the power is on, when the carbonizing cycle is on, and when the carbonized filament may be removed. Below the indicator lamps are the main switch 56, the starting button 57, the reset

button 58, and the mount lift lever 59. Below these devices are the indicating ammeter 61, the manual current regulator or transformer selector 62 (which simultaneously selects both primary and secondary coils, as shown in Fig. 5) and the indicating voltmeter 63. The indicating instruments are used in addition to the control ammeter and voltmeter in order to obtain accurate readings when desired.

DESCRIPTION OF SCHEMATIC DIAGRAM OF FIG. 3,
WITH REFERENCE TO FIGS. 1 AND 4

Referring now to the diagram of Fig. 3, we have the mount 13 carrying filament 19 being carbonized. For heating the filament for carbonization purposes, we have the power supply through main switch 56, suitable protective devices or circuit breakers (not shown), power line 64, primary winding 65 of filament transformer 66, and then alternating current coils 67 and 68, of what we choose to call a "saturable reactor" 70, which is really a reactance device adapted to be automatically varied in value for the purpose of controlling the current through the filament being carbonized. From the coil 68 current passes back to the main switch along power line 69 through normally closed contactor or switch 71, adapted to open upon release of normally energized relay coil 123 by action of any suitable means, such as return spring 40.

The power supply for carbonizing the filament is from the secondary winding 72 of the transformer 66, and the current therefrom is controlled by passing through line 73 to the primary winding 74 of a control or current transformer 75, and from thence back through line 76 to the filament. Current from the secondary winding 77 of the transformer 75 goes through the indicating ammeter 61 to a copper oxide rectifying network 78, from which rectified current emerges to pass to the actuating coil 79 of the control ammeter 51, through lines 81 and 82, in series with a direct current coil 83 of few turns on the saturable reactor 70 through lines 84 and 85. Resistances 20, 80, 90, 100 are used to load the circuit and adjust the range of the instrument.

The ammeter indicating needle or pointer 86 carries a vane or flag 87, which is normally external to (or below, insofar as scale reading is concerned) the field of the control coils 88 and 89 of an oscillator triode circuit (shown in detail in Fig. 7) for controlling the flow of carbonizing current and preventing "hunting" of the ammeter needle 86. The coils 88 and 89 are carried by and movable with a setting hand or pointer 50, which also carries a stop 110 to limit return movement of the pointer 86 (see Figs. 1 and 4). The output of the oscillator is amplified and fed back through lines 91 and 92 to rectifier and amplifier 93, the D. C. output from which is fed back to direct current coil 94 on reactor 70 through lines 95 and 96. Power for the rectifier and amplifier 93 is received from the power lines through lines 97 and 98, and for the ammeter, oscillator and amplifier 51 through lines 99 and 101.

It will readily be seen that we have two means which act simultaneously and proportionately to the speed of movement of the ammeter pointer 86 to stabilize the carbonizing current. One is the D. C. coil 83 on the reactor 70, which is directly connected in the actuating circuit of the ammeter through lines 84 and 85. The other is by the oscillator output feed-back voltage, which is applied through differentiating condenser 102, and leads 103 and 104, to the actuating coil 79.

The direct current component of the feed-back through lines 91 and 92, of course, does not pass the condenser, but variations in it causes a condenser charging current which is proportional to the rate of variation, thereby serving as an additional stabilizer.

The control voltmeter, oscillator and amplifier 52 is supplied with power through lines 107 and 108, and is generally similar to the ammeter, oscillator and amplifier 51 in construction, except as will now be explained. The voltmeter actuating coil 109 is connected across the carbonizing current line through lines 111 and 112, rectifying network 113, lines 114 and 115. Resistances 20', 80', 90', 100' serve to load the circuit and adjust the range of the instrument. The voltmeter needle or pointer 116, like that of the ammeter, carries a vane or flag 117 which is normally external to (or below, insofar as scale reading is concerned) the field of the control coils 118 and 119 of an oscillator triode circuit (shown in detail in Fig. 7) for finally shutting off the flow of carbonizing current when the voltage necessary to cause said current increases beyond a predetermined value. The output of the oscillator is amplified to operate a small relay 123 through lines 121 and 122. When the voltage of the carbonizing circuit rises sufficiently, said relay 123 is substantially de-energized and releases the contactor or switch 71, allowing it to open and de-energize the carbonizing circuit through the filament 19, ending the carbonizing cycle.

OPERATION IN ACCORDANCE WITH SCHEMATIC DIAGRAM OF FIG. 3, AND WITH REFERENCE TO FIGS. 1 AND 4

In brief the operation of the apparatus previously described is as follows:

Upon setting the selector handle 62 (see Fig. 1) in accordance with the filament to be carbonized, and the ammeter and voltmeter setting hands 50 and 60 at the desired control points on the respective scales, operating the mount lift switch or lever 59 to place the desired filament in position for carbonizing, and closing the main switch 56, visually indicated by energization of a green light designated 53, the power lines become energized, after which the carbonizing cycle may be started. The push button 57 (not shown in Fig. 3) used in the actual circuit, then also has to be depressed. The depressing of said push button, establishes a holding circuit and the red pilot light 54 is energized to indicate the beginning of a cycle. Then after a predetermined time delay (measured by a timer provided in more detailed apparatus to be subsequently described) a relay closes the circuit to start the energization and carbonization of the positioned filament 19. The energization of the carbonizing circuit also energizes the voltmeter and ammeter control circuits, the feed-back circuits between ammeter coil 79 and the reactor 70 effectively smoothing out and stabilizing the current through said filament 19 by controlling the residual voltage applied to the primary winding 65 of the filament transformer 66. The carbonizing circuit through the filament 19 is maintained until the voltage, as measured by the output circuit from the voltmeter oscillator, reaches a sufficient value to cause de-energization of the relay 123 and opening of the switch 71.

It will, therefore, be seen that the time of carbonizing the filament is measured, not in minutes, but in accordance with the resistance of the fila-

ment as determined by the degree of carbonization. In other words, the resistance rises as the carbonization progresses and the carbonizing current is shut off when said carbonizing has progressed to a predetermined point.

In the more detailed apparatus to be subsequently described, a timer is provided to make it impossible to actuate the mount lift device 59 to withdraw the filament until the same has cooled sufficiently. At the end of this timing cycle, the yellow lamp 55 (see Fig. 1) is energized. After the filament has been withdrawn from the treating bottle conditions are restored to initial position for the beginning of a new carbonizing cycle.

DETAILED DESCRIPTION WITH REFERENCE TO FIGS. 1, 4, 5, 6 AND 7

1. The mount raising and lowering mechanism

The mount raising and lowering mechanism 46, shown generally in Fig. 1, is also represented diagrammatically in Fig. 6. In said latter figure, is shown at the left an air cylinder 124 in which reciprocates a piston 125, the rod 126 of which has mount-supporting means 47 (see Fig. 1) and an adjustable switch-operating arm 127 adapted to open and close an associated single-acting switch 128 as the rod moves one way or the other. The mount-actuating mechanism is approximately duplicated on the right, as indicated by the cylinder 129, piston 131, rod 132, mount-supporting means 48 (see Fig. 1), switch actuating arm 133 and double-acting switch 134. Both cylinders are connected to a compressed air supply line 135 through control valve 136, the handle 137 of which terminates in prongs 138, between which a projection 139 on an armature 141, reciprocable between solenoids 142 and 143, is provided.

These solenoids are alternatively energized by the mount-lift switch 59, which in the position shown in full lines has taken power from line 64, through line 144, normally closed relay-controlled switch 145, line 146, left element of mount-lift switch 59, left solenoid 142, right element of mount-lift switch 59, and on through line 140 to power line 69. This, as illustrated, has drawn the armature 141 into the solenoid 142 and admitted compressed air through line 148 below the piston 125 to push it to the upper end of the cylinder 124 while exhausting air from above said piston through line 147. This raises the mount supporting means 47 and its mount 13 into the carbonizing bottle 11, while at the same time lowering the mount 14 from its carbonizing bottle 12, releasing the switch 128 to allow it to open, and moving the switch 134 from engagement with its upper contact to engagement with its lower contact.

This latter operation is performed by means of the member 133 on the piston rod 132, by admitting compressed air against the upper end of the piston 131 through line 148 and exhausting air from below it through pipe line 147. This raising and lowering operation may be repeated after each mount-carried filament has been carbonized and replaced by another one, so that first a filament at the left and then one at the right is carbonized, and so on alternately.

2. The power supply

The power supply in the present instance, as represented in the embodiment of our invention of Figs. 5, 6 and 7, involves the use of 220 volt lines 64 and 69. Power passes from power line 64 through lines 151 and 152, to energize the

green lamp 53 through resistance 153, and line 154 to power line 69, as an indication that the power is on, as shown in Fig. 6.

The current and voltage control apparatus of Fig. 7 receive power, for the primary coils 155, 156, 157 and 158 of their transformers 159 and 160, from the power line 64 through line 99, coils 155 and 156, and line 108 to power line 69; and from the power line 64 through lines 99 and 107, coils 157 and 158, and line 108 to power line 69.

The primary coils of the rectifier and amplifier transformers 161, 162 and 163, shown in Fig. 5, receive power from the line 64 through line 164, which from there passes in parallel through 15 primary coils 165, 166 and 167 and line 98 to line 69.

The power of the primary winding 65 of the filament transformer 66, shown in Fig. 5, is drawn from the power line 64 through normally-open relay-controlled switch 169, also passing through the coils 67 and 68 of the saturable reactor 70 and line 171, on to the power line 69 through normally-open relay-controlled switch 172.

3. The filament-carbonizing circuits

The preferably thoriated tungsten filaments 19 to be carbonized receive their electric current from the secondary winding 72 of the transformer 66. When said filaments are in the positions illustrated in Fig. 5, the switch 128 (see Fig. 6) is open so that no power is received by the relay 173 and the relay-controlled switch 174 remains in engagement with its lower contact, thereby allowing current to pass from the secondary coil 72 (on closure of the switch 169 upon energization of the relay 175) through line 73, selector switch 62, primary coil 74 of selected instrument transformer 75, through switch 176 (or adjustable testing resistance 177 when the switch is thrown to other position), relay-controlled switch 174, line 180, left hand filament 19, and back to the secondary coil 72 through lines 178 and 75.

When the mount lift switch 59 is moved to the position shown in dotted lines in Fig. 6, the left hand filament 19 is withdrawn from the bottle 11 and the right hand filament 19 moved up into the bottle 12. This causes the arm 127 to close the switch 128 and current to pass from power line 64 through lines 179 and 181 (see Fig. 5), relay 173, lines 182, 183, 184 (see Fig. 6) and 185, switch 128, line 186, switch 58, and line 149 to power line 69.

The energized relay 173 (Fig. 5) draws the switch 174 to engage its upper contact (as well as making a corresponding change in the connections to voltmeter 63, by moving switches 120 and 130) and breaks the circuit through its lower contact, thereby de-energizing the left hand filament 19 and energizing the right hand filament 19, as viewed in Fig. 5. The energization circuit is generally the same, except that the power does not pass through line 180, but instead passes from switch 174 to line 187, through right hand filament 19, then through lines 188, 189, and 76, back to the secondary winding 72.

4. The control ammeter and voltmeter circuits

The control of the carbonizing current is by a circuit built around the dual triode tube 196, type 53 (see Fig. 7). This is an indirect-heater type of tube. The left hand triode section, is used as a high frequency oscillator with a self-tuned grid tank circuit. Alternating current is supplied from the transformer 159 to the tube 196. Rectified plate current goes through a load

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resistor 197, the drop across which is used to bias the grid 198 of the right-hand or amplifier section of the tube 196.

The amplified output connects through lines 91 and 92 to the rectifier and amplifier 93 (see Fig. 5) from which a rectified output circuit passes through line 95 to coil 94 of reactor 70, and back through line 93 to rectifier and amplifier 93. The variations in the current passing through the coil 94, through this connection, control the current through the filament being carbonized by affecting the magnetization of the core of reactor 70.

Reverting now to the details of the ammeter control instrument circuit 51 (see Fig. 7) we find that the oscillator grid 199 is connected through line 201 and condenser 202 to coil 88, from whence the circuit passes through it and on through coil 89, resistance 203, and back through line 204, air condenser 205, and adjustable inductance 206, to plate 207 of said oscillator section. Energy is supplied to the plate circuit by means of secondary winding 208 of transformer 159. This energy is alternating current and the plate element 207, in conjunction with its cathode 209, acts as a self-tuned oscillator.

The plate circuit of the amplifier or right hand section of the tube 196 is energized from secondary winding 211 of the transformer 159, so that it also acts as a self-rectified triode. The drop across this amplifier is used, in turn, to bias the grid 199 of the oscillator section through resistances 105 and 212. A condenser 213 is placed across the output lines 103 and 104, from the grounded winding 214 to the winding 211, to smooth out the energy peaks of the amplified plate current during the negative portion of the rectified cycle. Secondary winding 214 is used as additional bias to fix the plate energy levels upon proper operating points of the triode graph. The winding 215, of course, supplies the power to heat the cathodes 209 and 216 of the tube 196. A leak resistance 200 is provided between the coils 79 and 89 to dissipate static electricity.

By virtue of this circuit arrangement, the oscillator triode section normally operates at full radio-frequency excitation, with the plate current normally low. The drop across the bias resistor 197, in parallel with condenser 217, is low so that grid bias on the triode amplifier section is low. This results in high amplifier plate current.

Upon the approach of the control flag 87 to the field of the coils 88 and 89, the grid tank circuit through condenser 205 and inductance 206 becomes detuned, with a consequent rise in the plate current of the oscillator, or left hand, section of the tube 196. The bias across the resistor 197 therefore rises, increasing the negative bias on the grid 198 of the right hand or amplifier section, thereby lowering the control plate current. As this plate current drops, the consequent voltage, which is used to bias the grid 199 of the oscillator section, decreases. This reduces the negative bias of said grid 199 which, in turn, due to increase of the plate current of the oscillator, increases the bias across resistance 197, further increasing the negative bias of the amplifier section grid. The net result of this transfer action is to produce a sharp drop in the plate current to approximately the cut-off point of the amplifier section of tube.

The plate current of the amplifier section will therefore alternate between a high value, as fixed by the components in the circuit when the flag

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87 is outside of the coils 88 and 89, and cut-off, when the flag 87 is between said coils. These sharp swings are important, as upon the flag 87 leaving the control coils 88 and 89 reverse action takes place and the amplifier plate current sharply rises. The plate current swings as a result of the pointer passing through the coils 88 and 89 are, therefore, sharp, abrupt and rapid, resulting, through the action of the circuit through the differentiating condenser 102, in a strong control on the movement of pointer 86 and a corresponding control of the current through the filament being carbonized.

The constants of ammeter and oscillator circuits 51 are preferably so chosen that the amplifier plate current swing through the relay 123 from flag positions entirely out of the coils, to flag position one-quarter within the coils is between about 20 milliamperes and 2 milliamperes. This current swing may be made any value up to the saturation limit of the amplifier triode section. Saturation value of the zero grid bias point in said section is approximately 40 milliamperes. Since the maximum plate current drawn at any time is 18 milliamperes and the filament is operated at 80% of its regular voltage, the tube 196 has a long life expectancy. The output from the amplifier section of the tube 196 passes from the plate 170 out through coil 211 and lines 104 and 91, and back through lines 92 and 103, to and from the bias-supply and input connections, respectively, of the rectifier and amplifier 93.

5. The direct current supply

A push button 218 (see Fig. 5) is provided to short the bias voltage provided by the dual rectifier tube 229, supplied with plate current by the secondary coils 231 and 232, and with cathode heating power by the coil 232, of transformer 163, and smoothed out by condenser 233. The voltage-divider resistance 219 is for the variable control of said bias. The condenser 221 and resistance 222 provides a time-delay circuit to prevent the current over-shooting, and also forms the filter circuit for the bias supply.

The normal output voltage supplied by oscillator in the control ammeter 51 and its associated amplifier is about 70 volts. The voltage of the rectifier and amplifier 93 is adjusted by divider 219 to overcome this voltage for proper bias on the grid-controlled rectifier network built around the tubes 227 and 228. The condenser 221 is charged through resistance 222, switch 223 and lines 224 and 225. When in operation the switch 223 is raised, by energization of the relay 175, the charge in the condenser 221 tends to hold conditions normal, but discharge thereof gradually lowers the bias and plate current starts from the connected amplifier and rectifier tubes 227 and 228 supplied with power by the secondary coils 234 and 235 of the transformer 161 and 162. Increased plate current increases the magnetization of the core of the reactor 70 which allows more current to flow through the filament being carbonized. When the pointer 86 (see Fig. 7) of the control ammeter 51 reaches the control target, the output voltage drops and stabilizes at some value lower than the normal output potential, of 70 volts. Movement of the pointer a few thousandths of an inch causes oscillator output voltage change which is reflected in the D. C. supply to the saturable reactor. By the connection through line 92 (Fig. 5) to the grids 236 and 237 of the tubes 227 and 228, ampli-

fied current is fed to the coil 94 of the reactor 70 thereby causing corresponding variation in its impedance for controlling the flow of carbonizing current.

6. The stabilization of the filament carbonizing current

Two circuits are used for stabilizing the filament carbonizing current. One is a direct connection from the operating coil 79 of the ammeter 51 (Fig. 7) through lines 82 and 84 to coil 83 (one or two turns around the D. C. coil 94) of the reactor 70 (Fig. 5) and the line 85 in series with the supply from the copper oxide rectifier network 78 (Fig. 7) and back to the coil 79. The actuating current to the coil 79 is from the secondary coil 77 (Fig. 5) (selected by the switch 62) of the transformer 75, through ammeter 61, lines 191, 192 and 193 (Fig. 7), rectifier network 78, on through the circuit just traced through the coil 83, to the coil 79, and back through line 81, rectifier network 78, lines 195 and 196, and through switch 62 (Fig. 5) back to coil 77.

It will thus be seen that any variation in the D. C. current which passes through the coil 94 will have a corresponding effect on the induced voltage in coil 83 of the saturable reactor 70. In other words, the voltage induced in the extra winding 83 is proportional to the rate of change of the magnetic flux in the "direct" magnetic circuit of the reactor 70, which is in turn proportional to the rate of change of the output from the rectifier 93 and so serves to feed back a damping or stabilizing current to the coil 79.

The other stabilizing circuit is from the tube 196 (Fig. 7) output line 103 through resistance 105 and differentiating condenser 102 to the actuating coil 79 of ammeter 51. The other side of the coil 79 is connected to the other output line 104 through line 82 and resistance 106.

7. The termination of current flow upon a predetermined rise in voltage

The control of the length of time the carbonizing current flows is by a circuit built around the dual triode tube 238. This is similar to the tube 196. The left hand section, as viewed in Fig. 7, is used as a high frequency oscillator with self-tuned grid tank circuit consisting of an air condenser 239 and appropriate adjustable inductance 241. Alternating current is supplied from the transformer 160 to the tube 238. Rectified plate current goes through a load resistor 242, the drop across which is used to bias the grid 243 of the right hand or amplifier section of the tube 238. A condenser 263 is in parallel with this resistor.

The amplifier output lines 121 and 122 of the tube 238 are connected to the normally energized relay 123 in order to open the switch 71 to de-energize relay 175 (Fig. 5) and terminate the flow of carbonizing current when the voltage of the filament being carbonized has reached a predetermined point. De-energization of the relay 123 also allows the switch 244 to close, energizing the indicator 245 connected between lines 64 and 69 in series with condenser 246 to show that the carbonizing cycle has been completed.

Reverting now to the details of the network of the voltmeter control 52, we find that the circuit is almost identical with that of the ammeter control network. It normally operates with the oscillator current low and the corresponding amplifier plate current high, so that

the relay 123 normally receives enough current to hold the switch 71 against its lower contact and the switch 244 open. This of course means that the flag 117 is at the beginning of the carbonizing cycle disposed below the coils 118 and 119.

When the voltage rises to the predetermined point, this flag passes between the coils 118 and 119, detuning the oscillator circuit, thereby effecting an increase in the oscillator plate current and a corresponding large decrease in the amplifier plate current, that is, sufficient to de-energize the relay 123 and allow the switch 71 to open and terminate the flow of carbonizing current. Opening of the switch 71 causes an engagement thereof with the upper contact 264, thereby energizing the relay 265 (Fig. 6) to operate the timing clock 281 to start timing of the cooling period.

Showing the similarity of the voltmeter control circuit with the ammeter control circuit, it is pointed out that the oscillator grid 247 is connected through line 248 and condenser 249 to coil 118, from whence it passes through it and on through coil 119, resistance 251, and back through line 252, condenser 239 and variable inductance coil 241, to plate 253 of said oscillator section. Energy is supplied to the plate circuit by means of secondary winding 254 of transformer 160. This energy is alternating current and the plate element 253, in conjunction with its cathode 255, acts as a self-tuned oscillator. The rectified plate current therefore goes through load resistor 242, the drop across which acts as a bias for the grid 243 of the right hand or amplifier section of the tube 238.

The plate circuit of the amplifier, or right hand section of the tube 238, is energized from secondary winding 256 of the transformer 160, so that it also acts as a self-rectified triode. The drop across this amplifier is used, in turn, to bias the grid 247 of the oscillator section through part of the coil of relay 123 and resistance 257. A condenser 258 is placed across the output lines 121 and 122 to smooth out energy peaks during the negative portion of the rectified cycle. Secondary winding 259 is used as additional bias to fix the plate energy levels upon proper operating points of the triode graph. The winding 261, of course, supplies the power to heat the cathodes 255 and 262 of the tube 238. As in the ammeter control circuit, a leak resistance 260 is provided between the coils 109 and 119.

8. The time delay relays

In order to prevent energization of the filament for carbonizing purposes prior to complete flushing of the treating bottle, 11 or 12 as the case may be, and an explosion of a mixture of carburated hydrogen with air, a timing device 267 is provided with a relay 268 (see Fig. 6) which, upon energization, closes switches 269 and 271 against upper contacts 272 and 273, thereby starting operation of a clock or timing element 274. After the lapse of a time for which the clock has been set, downward movement of its arm 280 opens the switch 269, by withdrawing it from its contact 272, and pulls the switch 271 from engagement with upper contact 272 into engagement with lower contact 275. The interval of adjustment of the timer 267 may be up to two minutes, although ten or fifteen seconds are usually sufficient as a setting.

The other timer 266 is similar in construction, in that its relay 265, upon energization as when

the carbonization current has been cut off, closes switches 276 and 277 against upper contacts 278 and 279, thereby starting operation of the clock or timing element 281 until a length of time, of say ten or fifteen seconds in accordance with a predetermined setting, has elapsed. The switch 276 is then opened, and the switch 277 pulled down from engagement with its upper contact 279, into engagement with lower contact 282, by downward movement of the clock's arm 290, to thereby energize yellow signal lamp 55 to show the operator that the carbonizing cycle is complete, including the cooling period, and that the filament can be removed from the bottle and its support, by actuating the mount lift switch 59, which automatically removes the carbonized filament and, at the same time, feeds a new uncarbonized filament into the other treating bottle.

The timing clocks are automatically reset as power to the timers is interrupted. This releases the electrical interlock formed by one contact in the relay part of timer.

9. Detailed operation of the apparatus illustrated in Figs. 5, 6 and 7

Prior to the actual carbonization of a mounted filament the apparatus is adjusted and tested for the type of filament to be carbonized. For this purpose the switch 62 (see Fig. 5) is set on the proper contact to select the proper transformer, in this case 75, to agree with the scale of the indicating ammeter 61. The resistor 177 is set to a figure agreeing with that of the filament to be carbonized, and switch 176 moved to its left hand contact 190, thereby shorting the connection to the filament 19 and placing the adjusted resistor 177 in the circuit usually employed for carbonization.

After closing the main switch 56, which energizes the green lamp 53 (see Fig. 6), the push button 57 is depressed, closing the circuit through the relay coil 268 of timer 267, initiating the flush-time cycle, and energizing the red lamp 54. Of course, in the testing, the flush-time cycle has no function, but in order to determine that it is operating satisfactorily, the timing thereof should be noted. This establishes a holding circuit by the operation of the relay 292, after a time-lag, and the mount-lifting circuit is de-energized, unnecessarily in the present instance because there is no actual carbonizing of a filament.

When the timer 267 finishes, it starts current through the testing resistor 177 (Fig. 5) and the indicating ammeter 61, indicating voltmeter 63, control ammeter and associated circuits 51 and control voltmeter and associated circuits 52. The controlling ammeter 51 is then set to give the desired current for carbonizing, as indicated on the ammeter 61, and the adjustable resistor 177 is set to give the desired voltage reading on the indicating voltmeter 63. Voltmeter 52 is then adjusted so that the power circuit opens when the voltage increases to the desired extent, as at the end of the carbonizing period.

After complete setting and testing a mount for carbonization is placed, say on the left mount support member 47 and the mount lift switch 59 operated to cause it to be moved into the treating bottle 11, as illustrated in Fig. 1. The hydrogen supply is admitted to the pipe 26 so that it starts flowing into the carbureting chamber 29 and out of the pipe 25 into the treating bottles 11 and 12. The main switch 56 is closed energizing the green lamp 53, and the push button 57

depressed, which energizes the red lamp 54 to indicate the beginning of a cycle, and causes a flow of current from the power line 64 through lines 283, 284 (Fig. 6), relay 268, lines 285, 286, normally closed switch 287, push button 57, normally closed switch 288, line 289, switch 134, depressed when the left hand mold holding member is up, as assumed, line 291, resetting button 58, and line 140 to power line 69.

In order to avoid the necessity of holding the push button depressed for any long period of time, second timer means is provided establishing a holding circuit through lines 296 by operation through resistance 293 of the relay 292, after a time interval predetermined by time delay member 294, closing the switch 295. This of course means that the timing period for flushing the bottle 11, prior to the initiation of the carbonizing treatment, has been initiated. The operation of the relay 292 also de-energizes the circuit through the solenoid 142 by opening the switch 145, thereby making it impossible to withdraw the left mount-supported filament 19 from the treating bottle while the carbonizing cycle is in progress.

After the termination of the flushing time, as indicated by the clock 274 opening the switch 269 and moving the switch 271 from engagement with its upper contact to engagement with its lower contact 275, the relay 175 (Fig. 5) is energized from power line 64 through lines 297 and 298, switch 271, lines 299, 301 (Fig. 7), 302 and 303, normally closed switch 71, lines 304 and 305, switch 134, line 291, button 58, and line 140 to power line 69, to close the switch 169 and start the flow of carbonizing current through the filament 19. The lowering of switch 271 of timer 267 (see Fig. 6) from engagement with its contact 273 breaks the power circuit through line 270 to, and stops the clock 274.

The energization of the carbonizing circuit also energizes the circuits of the indicating ammeter 61 and voltmeter 63 (Fig. 5), the control ammeter apparatus 51 and the control voltmeter apparatus 52 (Fig. 7). The feed-back circuit between the amplifier side of the tube 198 through lines 91 and 92 and reactor coil 94, as well as the direct connection between the ammeter coil 79 and the coil 83, assist one another in smoothing out and stabilizing the current through the filament being carbonized, as will be understood.

The carbonizing circuit through the filament 19 is maintained until the voltage on the filament 19 in the output circuit from the voltmeter control apparatus 52 is sufficient to cause the normal flow of current through the relay 123 to substantially terminate to allow the switch 71 to open, and thereby de-energize the relay 175 (Fig. 5) to allow the switches 169 and 172 to open and de-energize the filament-transformer 66.

De-energization of the relay 123 also allows the switch 71 to engage its upper contact 264, which starts the timer 265 and prevents withdrawal of the filament until it has cooled for a predetermined period. The operating circuit is from power lines 64, through lines 283 and 307, relay 265, lines 308, 309, 310, 311, contact 264, switch 71, lines 304 and 305, switch 134, line 291, button 58, and line 140 to power line 69. Closing of the switch 244 shows completion of the carbonizing cycle by energizing the indicator 245. At the end of the predetermined cooling time the switch 277 is moved to engage its lower contact 282, energizing the yellow lamp 55 showing the end of the

cycle. The engagement of the switch 277 with its lower contact 282 also energizes the relay 306 to open switch 288 and return the circuit to initial position. The apparatus is then ready for movement of the mount lift switch 59 to its other position, after the application of a mount-carried filament 19 to the mount supporting device 48, to lower the left hand filament and raise the right hand filament, prior to beginning a new carbonizing cycle, this time in the treating bottle 12 instead of the bottle 11.

In brief, the operation of the apparatus will therefore be seen to be as follows:

1. Hydrogen supply turned on.
2. Main switch closed, energizing green lamp.
3. Set the switch 176 to engage its contact 190, reference being had to Fig. 5, so that testing resistor is in the power circuit from the transformer secondary 12.
4. The push button 57 is depressed for a testing of the operation of the relay coil 268 of timer 267, as initiating a flush time cycle, with energization of the red lamp 54.
5. A holding circuit should be established by the operation of relay 292, after a desired time lag, and the mount-lifting solenoid circuit should be de-energized, making it impossible to secure any movement if the switch 59 is operated.
6. When the timer 267 finishes its operation, current should flow through the testing resistor 177.
7. The energization of the testing circuit also energizes the indicating ammeter and voltmeter, and the control ammeter and voltmeter.
8. The current controlling ammeter is set so that current, equivalent to the desired carbonizing current, is indicated.
9. The resistor 177 should be set to give the desired voltage.
10. The controlling voltmeter should be set so that the power circuit opens at the desired voltage, as when the resistor 177 is adjusted upwardly until the power is automatically shut off.
11. The timer 266 then starts automatically to prevent the operation of the mount lifter apparatus for a predetermined period.
12. At the end of said predetermined period the timer 266 energizes relay coil 306, which breaks the circuit to restore conditions to initial position and causes the yellow lamp 55 to glow. Switch 176 put in "full" position.
13. Mount placed. (This will take place during carbonizing cycle of previous lamp after starting machine.)
14. Mount lift switch operated, de-energizing relay coil 306 and yellow lamp 55.
15. Push button 57 depressed, closing the circuit through the relay coil 268 of timer 267, initiating flush-time cycle and energizing red lamp 54.
16. A holding circuit is established by the operation of relay 292, after a time lag, and the mount-lifting solenoid circuit is de-energized.
17. When timer 267 finishes, it closes circuit to energize filament for carbonizing.
18. The initiation of the carbonizing circuit also causes current to flow to indicating ammeter and voltmeter, and closing of the control ammeter and voltmeter circuits.
19. During carbonization, the current through the filament is maintained constant.
20. The carbonizing circuit is maintained until the voltage thereof rises to a predetermined point, when it is broken by the control voltmeter.

21. Timer 266 is then started to prevent withdrawal of the filament until cooled sufficiently.

22. At the end of the predetermined period, timer 266 energizes relay coil 306 which breaks circuit to restore conditions to initial position, and causes the yellow lamp 55 to glow.

23. The operator then begins again with step No. 14 and repeats.

24. If, during the operation of the apparatus, it is desired to reset the parts to initial position, the push button 58 is depressed to break the circuit to the power lines.

From the foregoing disclosure it will be seen that we have provided a method and apparatus whereby filaments which may be used for radio tubes or any desired purpose are, after mounting, positioned in a treating bottle and automatically carbonized to a desired extent, safeguards being provided for preventing the application of carbonizing current prior to complete flushing of the treating bottle and withdrawing the carbonized filament until it and parts of its mount have cooled sufficiently to avoid undesired oxidation. Although we have shown a special form of mount and filament, it will be understood that we are not limited to this showing, as "birdcage" and all other forms of filaments, mounted or unmounted, may be treated.

It will also be understood that the main purpose of showing Fig. 3 is to enable the reader to more clearly understand Figs. 5, 6 and 7. The saturable reactor, illustrated diagrammatically in Fig. 5, is like that shown in Fig. 3 in that the direct current coils 83 and 93 are on the center or directly-magnetized leg of the saturable reactor core, as distinguished from the end or "alternating current" legs of said core.

Although a preferred embodiment of our invention has been disclosed, it will be understood that modifications may be made within the spirit and scope of the appended claims.

We claim:

1. The method of carbonizing a filament comprising heating to a carbonizing temperature by passing a uniformly maintained current through it in a carbureted reducing atmosphere until its resistance, as indicated by a predetermined rise in the voltage of said current, reaches a predetermined value, and then terminating the flow of said current.

2. The method of carbonizing a filament comprising introducing a mount holding such a filament into a treating bottle, supplying a carbureted reducing gas to said bottle, passing a uniformly-maintained current through said filament to heat it to a carbonizing temperature, and stopping the flow of said current when the voltage causing it rises to a predetermined value.

3. The method of carbonizing a filament comprising heating it in a carbureted reducing atmosphere to a carbonizing temperature by uniformly-maintained current passing therethrough until its resistance, as indicated by the voltage causing said current, reaches a predetermined value, automatically terminating the flow of said current, and automatically delaying the withdrawal of said filament from the treating bottle for a predetermined period of time.

4. The method of carbonizing a filament comprising lifting a mount holding said filament into a treating bottle containing carbureted gas, passing uniformly maintained carbonizing current through the filament and thereby heating it to a carbonizing temperature only until the voltage thereof rises to a predetermined value, holding

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the carbonized filament in position after termination of the carbonizing current until it has cooled to a predetermined extent, and finally withdrawing said carbonized filament from the treating bottle.

5. Apparatus for carbonizing a filament comprising a compartment, means for introducing carbureted reducing gas thereinto, means for holding said filament therein and surrounded by said gas, means for supplying stabilized carbonizing current to said filament, and means for automatically terminating the flow of said current after the voltage necessary to cause the same rises above a predetermined value.

6. Apparatus for carbonizing a filament comprising a compartment, means for introducing carbureted reducing gas thereinto, means for holding a filament therein while surrounded by said gas, means for maintaining a uniform carbonizing current through said filament, and means for automatically terminating the flow of said current when the voltage producing the carbonizing current through said filament reaches a predetermined value.

7. Apparatus for carbonizing a filament comprising a treating bottle, means for introducing carbureted reducing gas thereinto, means for holding said filament therein and surrounded by said gas, and means for supplying a uniformly-maintained carbonizing current to said filament, after a predetermined delay allowing for flushing of said bottle, and means for automatically terminating the flow of said current after the voltage necessary to cause the same rises above a predetermined value.

8. Apparatus for carbonizing a filament when held on a mount comprising a treating bottle, means for introducing a carbonizing atmosphere thereinto, means for holding said mount in said bottle and surrounded by said atmosphere, means for passing substantially constant carbonizing current, closely controlled as to strength, through said filament, means for automatically stopping the flow of said current when the voltage causing it rises to a predetermined value, and means making it impossible to remove said filament from said bottle until after a predetermined cooling period.

9. Apparatus for carbonizing a filament when held on a mount comprising a treating bottle, means for introducing a carbonizing atmosphere thereinto, means for holding said mount in said bottle and surrounded by said atmosphere, means for passing uniformly maintained current through said filament to heat it to a carbonizing temperature, means for automatically stopping the flow of said current when the voltage causing it rises to a predetermined value, and means making it impossible to remove said filament from said bottle until after a predetermined cooling period.

10. Apparatus for carbonizing a filament when on a mount comprising a treating bottle, means for introducing carbonizing atmosphere thereinto, means for holding a mount and operating it so that it may be moved into said treating bottle or withdrawn, a switch for controlling circuits for causing such mount movement, a push button for initiating a cycle during which the treating bottle is filled with carbonizing gas prior to the application of carbonizing current to a filament, a timer for controlling the length of said cycle, means for establishing a holding circuit around the push button and effecting de-energization of the mount-lifting circuit to avoid

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withdrawal of a mount until carbonization is complete, a timing device for closing the carbonizing circuit to the filament when a predetermined time after pushing the button has elapsed, an ammeter in the carbonizing circuit for closely controlling the strength of the carbonizing current, a control voltmeter for shutting off the current through the filament when the voltage of said current reaches to a predetermined value, and a timing device in the circuit to prevent withdrawal of the filament after termination of the carbonizing current until a sufficient cooling period has transpired.

11. Apparatus for carbonizing a filament when on a mount comprising a plurality of treating bottles, means for introducing carbonizing atmosphere thereinto, means for holding a pair of mounts and operating them so that when one is moved into one treating bottle the other is withdrawn from the other treating bottle, a switch for controlling circuits for causing such mount movement, a push button for initiating a cycle during which the treating bottles are filled with carbonizing gas prior to the application of carbonizing current to a filament, a timer for controlling the length of said cycle, means for establishing a holding circuit around the push button and effecting de-energization of the mount-lifting circuit to avoid withdrawal of a mount until carbonization is complete, a timing device for closing the carbonizing circuit to the filament when a predetermined time after pushing the button has elapsed, an ammeter in the carbonizing circuit for maintaining the carbonizing current substantially constant during filament treatment, a control voltmeter for shutting off the current through the filament when the voltage of said current reaches to a predetermined value, a timing device in the circuit to prevent withdrawal of the filament after termination of the carbonizing current until a sufficient cooling period has transpired, and signal means for showing when the cooling period has elapsed and the filament may be withdrawn upon the termination of the set cooling period.

12. Apparatus for carbonizing a filament when on a mount comprising a plurality of treating bottles, means for introducing a carbonizing atmosphere thereinto, a pair of mount-holding devices, means for operating them so that when one is moved into one treating bottle the other is withdrawn from the other treating bottle, means for closing a carbonizing circuit through the filament so held in a treating bottle, and means for preventing the application of carbonizing current to a filament when held on the device not in said bottle.

13. Apparatus for carbonizing a filament, comprising a lift device for holding a mount carrying said filament, a switch and associated apparatus for causing said device to lift said mount, a treating bottle into which said mount is lifted by said device, means for supplying said bottle with carbureted gas, a timing device having a relay coil to initiate a flush-time circuit and energize an indicator lamp, means to establish a holding circuit by the operation of a relay after a time lag, means to deenergize the mount lifting circuit, means to close a circuit to pass a carbonizing current through the filament, means to establish corresponding circuits to a control ammeter and a control voltmeter in order to maintain the current through said filament constant during carbonization, until the voltage thereof rises to a predetermined value and the current

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is broken by action of said voltmeter, means to prevent withdrawal of the filament after termination of the carbonizing current until it has cooled to a predetermined extent, and means for finally withdrawing said filament and replacing it with another filament to be carbonized.

14. Apparatus for carbonizing a filament comprising a treating compartment, means comprising a chamber containing a vaporizable liquid hydrocarbon for carbureting gas, an auxiliary chamber of relatively large volume connected to said chamber, whereby the level of the liquid in the latter remains substantially constant, means for introducing gas into said carbureting chamber and causing it to pass therefrom after carburetion into said compartment, means for holding a filament in said compartment and surrounded by said carbureted gas, means for maintaining a substantially uniform carbonizing current through said filament, and means for automatically terminating the flow of said current when the voltage of said current reaches a predetermined value.

15. Apparatus for carbonizing a filament comprising a treating bottle, means for introducing a carbureted reducing gas thereinto, electrical means for moving said filament into or out of said bottle, a switch for controlling circuits for causing such movement, a push button for initiating a cycle during which said treating bottle is filled with said gas prior to the application of carbonizing current to a filament, a timer for controlling the length of said cycle, and second

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timer means for establishing a holding circuit around the push button and effecting de-energization of the filament-moving means to avoid filament withdrawal until carbonization is complete.

GEORGE A. FREEMAN.
JAMES H. GREEN.

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