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ORBITING VACUUM PUMP POWER SUPPLY WITH A FILAMENT CURRENT REGULATOR

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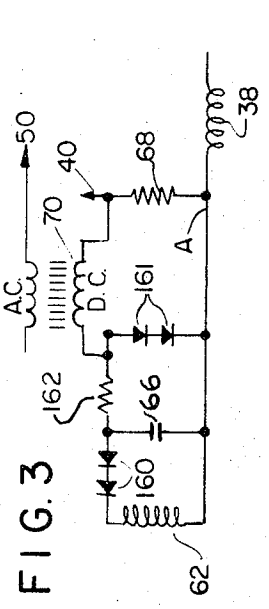

FIG. 3

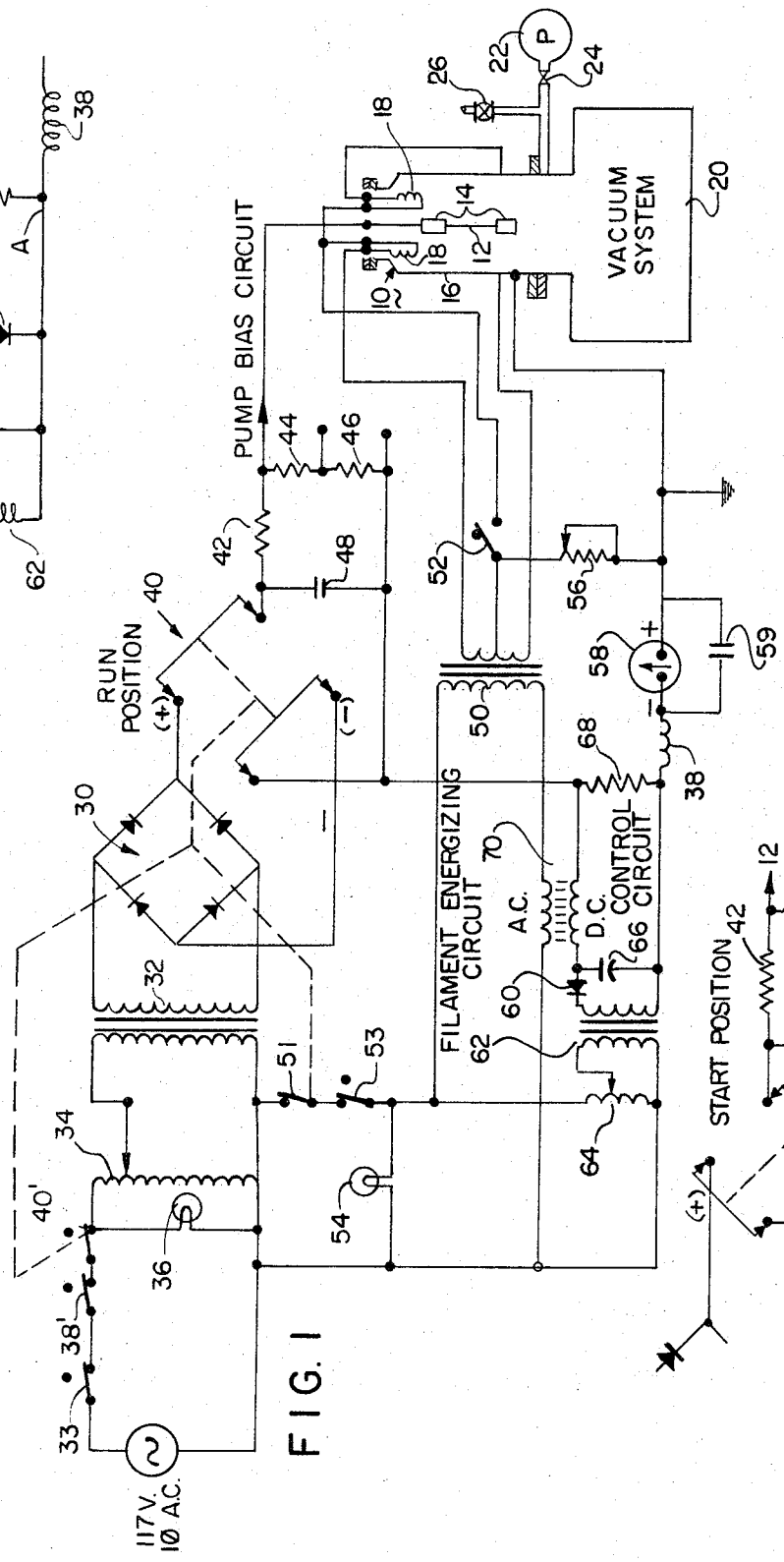

FIG. 1

FIG. 2

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ORBITING VACUUM PUMP POWER SUPPLY WITH A FILAMENT CURRENT REGULATOR

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ABSTRACT OF THE DISCLOSURE

Electrical power supply for orbitron vacuum pumps with a pump current measuring resistor coupled to the filament power control via a saturable core reactor to regulate filament electron emission without amplifiers or the like which would be vulnerable to transients. The supply comprises a polarity reversing switch which can be reversed from glow discharge clean-up (start position) to normal pump operation (run position) when a sufficiently low pressure for this purpose is indicated in a meter in series with the current measuring resistor.

The present invention relates to power supply circuitry for hot filament orbiting electron devices, such as vacuum pumps.

The principal object of the invention is to provide a power supply for orbiting electron devices which includes means for reversing the polarity of the direct current applied to the device and inexpensive overpressure control means for protecting the power supply in either setting of the polarity reversing means.

It is a further object and distinct advantage of this invention that the overpressure control means of the power supply are responsive to total current drawn by and produced within the device to give an indication of when the polarity of the device may be reversed from start to run conditions.

It is a further object of this invention that the power supply regulates filament current in response to variations in total current drawn by and produced within the orbiting electron device thereby maintaining total current in the device at a constant or a programmed level.

It is a further object of this invention to accomplish the foregoing with a simple, reliable, inexpensive circuit which provides protection against arcing within the device or at the terminals and provides such protection despite common operator errors.

The invention accordingly comprises the apparatus possessing the combination of elements and the arrangement of parts which are exemplified in the following detailed disclosure and the scope of application of which is indicated in the claims.

Reference is made to the accompanying drawings wherein:

FIG. 1 is a circuit diagram of the power supply according to a preferred embodiment of the invention with the polarity reversal switch in the run position; and

FIG. 2 is a portion of the FIG. 1 diagram with the polarity reversal switch in the starting position;

FIG. 3 is an improved embodiment of the filament current regulating circuit which is a component of the power supply of the present invention.

Structure

The illustrated preferred embodiment comprises apparatus for supplying power from the conventional line supply of 117 volts, single phase alternating current, 50–60 cycles per second to an orbiting electron vacuum pump **10**. The pump, per se, is already known in the prior art and comprises a central electrode **12** with getter sources

14 mounted thereon. The annular metal body **16** of the pump is grounded and serves as a second electrode. The orbiting electron vacuum pump is connected to a vacuum system **20** such as a coater or a furnace. Also included in the system are a roughing pump **22** with a valve **24** and a valve **26** for backfilling the evacuated system with air or an inert gas, as desired. In its cyclic operation, the system **20** is initially evacuated to a pressure of between 1 and 100 microns by the pump **22**. Then the power supply is connected to the central electrode **12** to make it highly negative (minus five to ten kilovolts, or larger, depending on pump size) with respect to the pump body **16**. This causes a glow discharge to strike within pump **10** and the glow helps clean up the pump and has a pumping effect which reduces the pressure to a level suitably low for starting the normal operation of the pump (about one to ten microns, depending on the pump). Once this requisite low pressure is reached, the operator throws a polarity reversing switch in the power supply so that electrode **12** becomes highly positive with respect to pump body **16**. The operator also throws a filament on-off switch in the power supply to energize filaments **18** in the pump.

The power supply circuit comprises a rectifier **30** connected to the power input through a transformer **32** and an autotransformer **34**. An indicator light **36** is connected across the line terminals of the autotransformer. Between the power input and the autotransformer are circuit breaker switches **40'** and **38'**. Switch **38'** is operated by solenoid **38** described below and switch **40'** is interconnected to the polarity reversing switch **40** described below.

The filaments **18** are connected to autotransformer **34**, the voltage input of which is adjusted by a transformer **50** through a series parallel switch **52**. A filament indicator lamp **54** is connected across the primary terminals of transformer **50**. A second rectifier **60** provides a source of reference voltage for an emission control circuit. The rectifier **60** is connected to a transformer **62**, the voltage input of which is adjusted by autotransformer **64**. A capacitor **66** and current comparison resistor **68** are provided in the control circuit. A saturable reactor **70** is connected between the filament energizing and control circuits. The filament bias circuit is connected to switch **52** via a bias adjusting resistor **56**. A milliammeter **58**, with a bypass capacitor **59**, and a relay solenoid **38** are also provided in the emission control circuit.

The pump bias circuit, between polarity reversing switch **40** and pump **10**, comprises load resistor **42**, bleed resistors **44** and **46**, and capacitor **48**. The polarity reversing switch **40** is movable between a (pump) running position as shown in FIG. 1 and a start position as shown in FIG. 2. The switch **40** is connected to switch **42** so that power is cut off while the switch **40** is being moved between start and run positions to avoid arcing at the terminals of switch **40**. The switch **40** is constructed so that it delays polarity reversal by at least one second (because the operator is obliged to make several mechanical motions) allowing capacitor **48** to discharge through the bleed resistors before the contact is remade.

Typically, the various circuit elements (related values) are selected as follows:

(a) Direct current circuit:
- Autotransformer **34**—5 ampere Powerstat (0 to 120 v. A.C.).
- Transformer **32**—9600 v. output @ 120 v. input.
- Bridge rectifier **30**—16,000 volts, peak inverse voltage per leg.
- Lamp **36**—neon bulb.

(b) Pump bias circuit:
- Switch **40**—See Fruzzetti, S.N. 483,719 filed Oct. 7, 1965.
- Resistor **42**—20K, 50 W.
- Resistor **44**—10M.

Resistor 46—10K.
Capacitor 48—.01μf, 15 kv. DC.

(c) Filament heating circuit:
Transformer 50—7.5 volts at 8 amperes.
Switch 52—toggle, 10 amperes.
Lamp 54—mean bulb.
Switch 51—microswitch, 5 amperes.
Microswitch 53—toggle, 10 amperes.

(d) Filament bias circuits:
Autotransformer 64—120 v. 5 a. Powerstat.
Transformer 62—isolation, 1 ampere, 1:1 ratio.
Diode 60—600 v.
Capacitor 66—40μf, 450 v.
Resistor 68—2.5 K, 25 W.

(e) Saturable reactor 70—operating level set at 7 ma. D.C. overpressure control means.

(f) Meter 68—50–0–50 D.C. milliameters capacitor 59—0.1μf. switch 38'—microswitch relay 38'—instant trip, set at 60 ma. trip current.

Operation

The sequence of a normal pumpdown cycle is that the roughing pump 22 is operated to bring the system down to a pressure on the order of 10 to 40 microns (valve 24 being open and valve 26 being closed). Then, with the polarity reversal switch 40 in its FIG. 2 start position, the operator turns on the power supply. In this position, the central electrode 12 is biased negatively with respect to the grounded annular electrode (pump body) 16. The autotransformer is turned up towards full power until a glow discharge is struck in the pump 10. This causes the meter 68 to indicate current flow. Whenever the reading of the meter runs the design value (e.g., 50 milliamperes for a six-inch pump) the operator cuts back on the autotransformer 34 to hold the current down. The solenoid 38 is set to instantly open switch 38' if the current goes over 60 milliamperes.

After a period of about ¼ hour to 2 hours, cleanup of the pump and weakening of the discharge will cause the current reading on meter 68 to drop. The operator then turns up the autotransformer 34 to increase the discharge and raise the reading of meter 58 back to 50 milliamps. After repeating this process several times, the operator will reach rated pump power on the transformer and the meter reading will be back to zero. At this point, the pump is ready for running.

The operator opens the main switch 33 and then throws polarity reversal switch 40 from its FIG. 2 start position to its FIG. 1 run position. If the operator forgets to cut off power by opening switch 33, the same result is accomplished by switch 42 which opens in response to movement of switch 40. After throwing switch 40 to the FIG. 1 position, the operator recloses switch 33 and closes switch 53 to heat the pump filaments. The pump power is adjusted to rated value through autotransformer 34. The filament heating current is adjusted through autotransformer 64 and the filament bias is adjusted via resistor 68.

After stable operation of pump 10 is achieved, the operator cuts off pump 22 and closes valve 24.

During the "running" of the pump 10, the total current drawn by the pump comprises electron emission from the filaments 18 to the anode 12, occasional impact of electrons into the cathode 16, positive ion collection from the anode and secondary emission from the cathode. The principal component of this invention is the electron emission from the filament. Variations in total current are reflected in a change in voltage drop across resistor 68, and in turn, by a change in voltage drop across the D.C. windings of the reactor 70. A corresponding change is induced in the impedance of the A.C. windings, thus changing the power input to the filaments 18. I have built several power supplies, as described herein, and have found that this arrangement provides a smooth,

stepless, control of total pump current and provide high efficiency and pumping speed in operation of the pump 10.

Whenever an excessive current is generated in the power supply circuit, as by runaway discharge or arcing in the pump during starting or running conditions or by a short in the power supply circuit, then the instant trip relay 38 cuts off power to the pump bias circuit, the filament energizing circuit and the control circuit. This saves all components, except that in some instances the rectifier 60 may fail as the result of such an overload and the automatic regulation of emission function is lost. However, the operator may continue manual control of emission via autotransformer 64 since the mode of failure of rectifier 60 is by shorting through.

I have invented an improved form of emission control circuit which is particularly useful in the power supply circuit of FIG. 1 and a portion of which is shown in FIG. 3. The components of the improved emission control consist of:

A 500 ohm, 10 watt, resistor 162; two diodes 160 each having a peak inverse voltage of 600 volts at one ampere; and two Zener diodes 161; each having a limiting voltage of 200 volts with a maximum tolerable surge current in excess of the rated current of the diodes 160 and a surge time tolerance in excess of the time required for tripping by relay 38.

In the particular circuit of FIG. 1, since the relay 38 requires milliseconds to operate, a particularly suitable Zener diode is the Unitrode UZ5210 which tolerates a maximum surge of 1.4 amperes for 8.3 milliseconds.

The components 62, 66, 70, 68, 38 are as in FIG. 1.

I have built the circuit of FIG. 1, including the improved emission control of FIG. 3. I have deliberately created shorts several times, putting 10,000 volts, positive, at the junction A in FIG. 3. In every instance, the relay 38 tripped and there was no failure of any of the diodes in the emission control circuit nor of any other portion of the power supply. Even if one of the diodes 160 should fail, the other diode 160 would continue to function and automatic regulation of emission would still be available.

Thus I have provided basic and improved forms of a power supply with self regulation and safety devices as described above without resort to choke coils, thyratrons, amplifier tubes and pressure gauges normally provided in power supply circuitry for devices of this character. Consequently, I am able to provide economy of size and cost and improved reliability of the power supply.

It will be obvious to those skilled in the art that the components of the power supply or emission regulator can be scaled up and down or replaced with structurally equivalent circuit arrangements. Also, while I have described the utility of my power supply particularly in connection with orbiting electron vacuum pumps, it will be apparent that the invention may be applied to other hot filament power tube devices where an equivalent control function is desired. It is therefore intended that the above description shall be read as illustrative and not in a limiting sense.

What is claimed is:

1. An improved power supply circuit for orbiting electron vacuum pumps, and the like, comprising in combination:

(a) a direct current source of high voltage,
(b) a pump bias circuit for connecting the said high voltage source to a first electrode of the pump and comprising polarity reversal switch means,
(c) an alternating current source,
(d) a filament energizing circuit for connecting the said alternating current source to a thermionic emitting filament of said pump,
(e) a control circuit comprising a direct current source of a reference low voltage and a current sensing resistor, said current sensing resistor being located

in series between the said polarity reversing switch and an electrode of said pump, and

(f) a saturable reactor with its alternating current windings in said filament energizing circuit and its direct current windings in said control circuit constructed and arranged so that increasing current drawn by said current sensing resistor is counteracted by decreasing filament heating power output and so that decreasing current drawn by said current sensing resistor is counteracted by increasing filament heating power output.

2. The power supply of claim **1** further comprising:

(g) an instant trip relay actuator located in series with said current sensing resistor and said pump electrode and constructed and arranged to cut off sources in (a), (c), (e).

3. The power supply of claim **2** wherein the said sources in (a), (c), (e) draw power through a common adjustable power supply and are in parallel circuit relationship with each other, the direct current sources in (a) and (e) comprising solid state rectifiers.

4. An improved solid state control circuit for controlling a variable alternating current power supply for a filament or the like in response to variations in total current in the electric device incorporating the thermionic filament and comprising, in combination, an input transformer, a plurality of rectifier diodes, at least one Zener diode, a saturable core reactor and a current comparison resistor, and a control element for regulating power input to said filament and a current sensing resistor, the said components being arranged to form a series loop of the said secondary winding of said input transformer, said rectifier diodes, said control element and said current sensing resistor, said Zener diode being connected in parallel across the rectifier diodes and the secondary winding.

5. An orbiting electron vacuum pump with the power supply of claim **1** in combination therewith, the orbiting electron pump having a central anode electrode and annular cathode electrode and a filament for thermionically emitting electrons between said electrodes, the said electrodes being connected to the voltage source (a) via the pump bias circuit and control vircuit (e) and the said filament being connected to said filament energizing circuit (d)—at the end.

6. In an orbiting electron vacuum pump comprising a central anode electrode and an annular cathode electrode and a filament for thermionically emitting electrons between said electrodes, and a power supply for said pump comprising:

(a) a direct current source of high voltage,

(b) a pump bias circuit connecting the positive side of said voltage source to said anode,

(c) an alternating current source,

(d) a filament energizing circuit connecting said alternating current source to said filament,

(e) a control circuit comprising a direct current source of a referene low voltage and a current sensing resistor, said resistor being located in series between the negative side of said voltage source and the cathode electrode, and

(f) a saturable reactor with its alternating current windings in said filament energizing circuit and its direct current windings in said control circuit constructed and arranged so that increasing current drawn by said current sensing resistor is counteracted by decreasing filament heating power output and so that decreasing current drawn by said current sensing resistor is counteracted by increasing filament heating power output.

7. The pump of claim **6** wherein the said control circuit of the power supply (e) comprises an input transformer secondary winding, a plurality of rectifier diodes, a control winding of said reactor (f) and said current sensing resistor arranged in a series loop and also a zener diode connected in parallel across the rectifier diode and the secondary winding.

References Cited

UNITED STATES PATENTS

2,230,558	2/1941	Bowen	315—106 X
2,236,195	3/1941	McKesson	315—106
2,748,316	5/1956	Stevenson	315—106
3,078,388	2/1963	Hanks et al.	315—107

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