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HIGH-FREQUENCY PROTECTIVE CIRCUITS

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FIG. 1

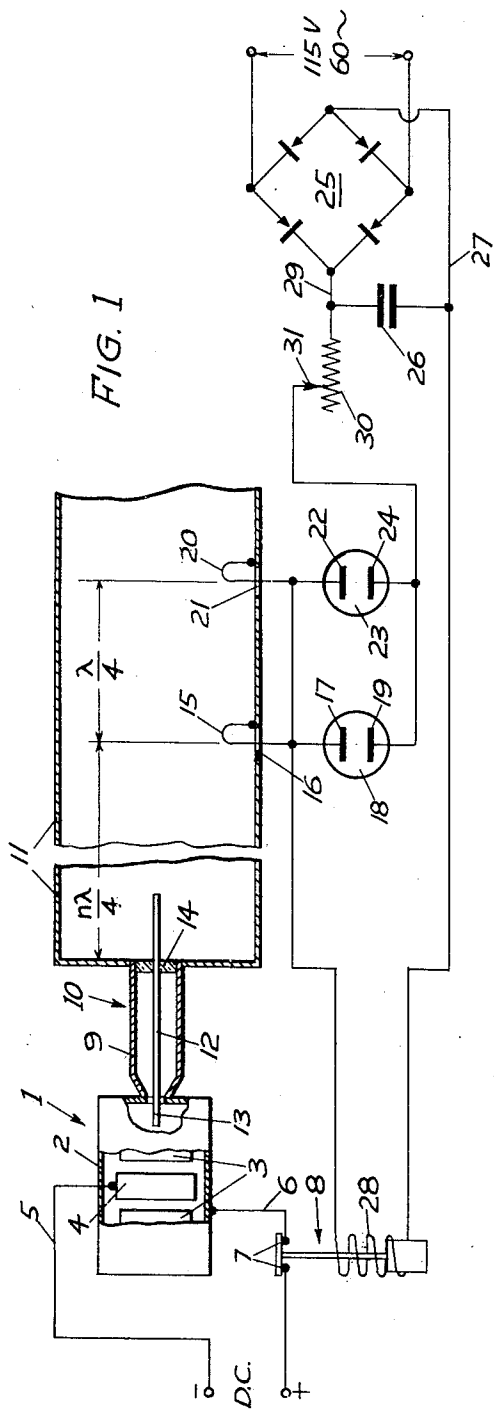
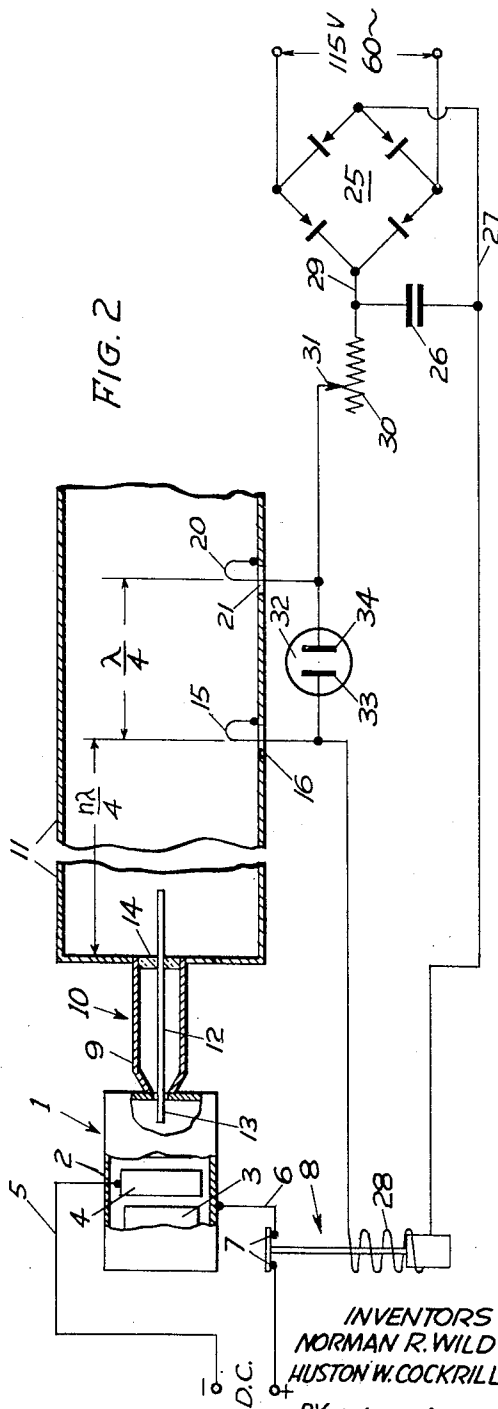


FIG. 2



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HIGH-FREQUENCY PROTECTIVE CIRCUITS

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2 Claims. (Cl. 250-17)

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This invention relates to electrical circuits, and more particularly to a system for automatic protection of a high-radio-frequency generator or microwave generator.

An object of this invention is to devise a system for automatic protection of a microwave generator against high-voltage breakdown at the window or seal thereof.

Another object is to devise a protective system which will automatically afford protection against standing wave amplitudes in a radio-frequency transmission line which are in excess of a predetermined value, such value being manually variable at will.

A further object is to provide a protective system for a microwave transmission system which will afford protection against an unduly high ratio between standing wave maxima and minima herein.

The foregoing and other objects of the invention will be best understood from the following description of some exemplifications thereof, reference being had to the accompanying drawing, wherein:

Fig. 1 is a diagrammatic representation of one form of protective system according to our invention; and

Fig. 2 is a diagrammatic representation of a modified protective system.

Now referring to the drawing, and particularly to Fig. 1 thereof, the numeral 1 generally designates an electron-discharge device of the magnetron type, which includes, for example, an evacuated envelope 2, made of highly conductive material, such as copper, and provided with a plurality of anode vanes 3. The arrangement is such that each pair of adjacent anode vanes 3 forms, together with that portion of the envelope lying therebetween, a cavity resonator whose natural resonant frequency is, as is well known to those skilled in the art, a function of the geometry of the physical elements making up the same. The dimensions of each such cavity resonator are preferably such that the wavelength of the electrical oscillations adapted to be generated therein has a predetermined value lying in the high-radio-frequency or microwave region of the frequency spectrum.

Centrally located in envelope 2 is a highly electron-emissive cathode member 4, for example of the well-known alkaline-earth metal-oxide type, said cathode member being provided with conventional means (not shown) for raising the temperature thereof to a level sufficient for thermionic emission.

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The electron-discharge device 1 is completed by magnetic means (not shown) for establishing a magnetic field in a direction transversely of the electron path between the cathode and anode members thereof.

In order to supply an operating voltage to magnetron 1, to energize the same and to thereby cause it to act as a source of radio-frequency energy, cathode 4 is connected, by means of a lead 5, to the negative side of a suitable direct current source, while envelope 2 is connected, by means of a lead 6, through the normally-closed contacts 7 of a relay 8, to the positive side of said direct current source. As long as contacts 7 are closed, magnetron 1 will be energized, and hyper-frequency oscillations will be generated in the cavities provided between adjacent vanes 3, but when contacts 7 are open, the operating voltage is removed from said magnetron and such oscillations are no longer produced.

The outer conductor 9 of a coaxial output pipe 10 has one end sealed into envelope 2 and has its opposite end fastened securely to the end wall of a hollow metallic waveguide 11 which may be termed a transmission line, since it is adapted to transmit radio-frequency energy therealong. Inner conductor 12 of coaxial pipe 10 has a loop 13 formed on one end thereof, this loop extending into one of the cavities between adjacent vanes of magnetron 1 and serving to couple the radio-frequency energy output of said magnetron to output pipe 10. The end of conductor 12 opposite loop 13 extends beyond the end wall of waveguide 11 into said waveguide to serve as an exciting rod or probe therefor. A disk 14 of dielectric material is mounted between outer conductor 9 and inner conductor 12 of pipe 10 at the end of the outer conductor 9 or at the end wall of waveguide 11, this disk providing a hermetic seal between these two conductors and being termed the window or seal of the magnetron 1.

Transmission line or waveguide 11 may have any desired length, and a first coupling loop 15 extends into the interior of said guide, through a suitable opening 16, at a point spaced a distance of an integral number of quarter-wavelengths from the end wall of said guide, or from the window or seal of magnetron 1, the term "wavelength" referring to the wavelength of the oscillations of oscillator 1. The end of loop 15, which extends through opening 16 to the exterior of the guide 11, is connected to one electrode or element 17 of a discharge device 18 of the cold-cathode gaseous diode type, such as an ordinary neon

bulb, the second element of device 18 being denoted by 19.

A second coupling loop 20 extends into the interior of guide 11 through a suitable opening 21, loop 20 being located at a point spaced a distance of a quarter-wavelength beyond loop 15 in the direction therefrom opposite from the magnetron window or seal. The end of loop 20, which extends through opening 21 to the exterior of guide 11, is connected to one electrode or element 22 of a discharge device 23 which is similar to discharge device 18, the second element of device 23 being denoted by 24. Although discharge devices 18 and 23 are shown as diodes, gaseous tubes of the multiple-element type may also be used.

The input terminals of a full-wave bridge rectifier 25, which is adapted to serve as a current and voltage source, are connected to a suitable alternating current source, for example the ordinary 115-volt, 60-cycle commercial power lines. A suitable smoothing or filtering condenser 26 is connected across the direct current output terminals of rectifier 25. A lead 27 is connected at one end to one of the output terminals of rectifier 25 and is also connected, in series with the operating winding 28 of relay 8, to the electrode 17 and 22 of devices 18 and 23. A lead 29 is connected at one end to the other output terminal of rectifier 25 and is also connected to one end of a resistor 30 having a movable tap 31 thereon, this tap being in turn connected to the electrodes 19 and 24 of devices 18 and 23.

It will be apparent, from the above-described circuit, that devices 18 and 23 are connected in parallel across the direct voltage source 25, and that the discharge paths between the elements of the respective devices 18 and 23 are connected in parallel with each other, each of such paths being in series between the D. C. source 25 and the winding 28 of relay 8. Therefore, when the gaseous atmosphere in either of the devices 18 or 23 ionizes or breaks down to provide a current-conducting path between the two elements of the ionized device, current can flow from the current source 25, through such conducting path and relay winding 28, energizing relay 8 and opening contacts 7. Radio-frequency energy of a predetermined wavelength is supplied by source 1 to waveguide 11 and is propagated therealong to some reactive load (not shown), causing standing waves to be established in the radio-frequency transmission system including waveguide 11. Tubes of the magnetron type have the inherent characteristic that, for stable operation of the tube, there is an optimum standing wave phase value which is desired at the window or seal thereof. In other words, for stable operation, the tube "wants to look at" either a standing wave maximum or a standing wave minimum at the seal thereof. It is also desirable to limit the amplitude of the standing waves in the guide to a certain value, in other words, to in effect maintain the standing wave ratio in the radio-frequency transmission line below a predetermined value, in order to prevent high-voltage breakdown at the window or seal of the tube or source.

The radio-frequency energy in guide 11 is coupled with devices 18 and 23 by means of the respective coupling loops 15 and 20. A direct voltage bias is applied to devices 18 and 23 from the direct voltage biasing source 25, this bias being adjustable by tap 31. The atmosphere in either one of the devices 18 or 23 is ionizable by the radio-frequency energy if the standing wave

amplitude added to the direct voltage bias applied to these devices from bias source 25 produces a total voltage equal to or greater than the ionization voltage of the devices. Since devices 18 and 23 are a quarter-wavelength apart and since they are biased equally, one or the other of the devices will become ionized when the standing wave amplitude is above a predetermined value, regardless of the standing wave phase relations set up in the guide. The bias can be adjusted, by means of tap 31, in such a manner that the devices 18 or 23 will break down at any predetermined standing wave amplitude, or any predetermined standing wave ratio, in the guide. When such a predetermined standing wave ratio has been reached, due to changes in the load or other reasons, the atmosphere in device 18 or in device 23 will be ionized to provide a conducting path in the ionized device, resulting in the energization of relay 8, the opening of contacts 7, and the consequent deenergization of magnetron 1. It will be seen, therefore, that the system of this invention automatically in effect maintains the standing wave ratio in a radio-frequency transmission line below a predetermined manually-adjustable value, since if it goes above this value the magnetron 1 is deenergized.

Two ionizable devices 18 and 23 are provided, connected in parallel and spaced a quarter-wavelength apart, so that one or the other of said devices will be ionized, no matter what standing wave phase relations may be established by the unknown characteristics of the load, provided, of course, that the standing wave ratio in the transmission line rises above the predetermined value. Of course, the relay 8 is energized to deenergize the magnetron when either one of the devices 18 or 23 is ionized.

If a standing wave maximum is desired and is known to be at the tube window 14 when excessive standing wave ratios are likely to occur, the factor n in Fig. 1 should be made an even number, so that loop 15 is spaced an even number of quarter-wavelengths from seal 14, while if a standing wave minimum is desired and is known to be at the tube window when excessive standing wave ratios are likely to occur, the factor n should be made an odd number, so that loop 15 is spaced an odd number of quarter-wavelengths from seal 14. In both these known phase cases, therefore, loop 15 is located at a standing wave maximum and functions, when such maximum becomes greater than a predetermined value, to deenergize magnetron 1 by causing the ionization of device 18 and the consequent energization of relay 8, thus affording protection against excessive standing wave amplitude in these cases of known phase, as well as in the conditions of unknown phase relations in the guide.

If desired, the bias on devices 18 and 23 may be so adjusted that any increase above the voltage present in a "flat line," that is, one in which there are no standing waves, will cause breakdown of one or the other of such devices. In this case, the system of our invention may be made to give protection of the magnetron at an absolute minimum value of standing wave amplitude in the transmission system.

Now referring to Fig. 2, which shows a modified protective system, elements similar to those of Fig. 1 are denoted by the same reference numerals. In this modification, only a single discharge device 32 is used, this device being similar to devices 18 and 23 of Fig. 1 and including a pair of electrodes or elements 33 and 34. A pair of

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coupling loops 15 and 20, spaced a quarter-wavelength apart, project through the respective openings 16 and 21 into waveguide 11 and are connected, outside of the guide, to the respective elements 33 and 34 of device 32, thus serving to couple the radio-frequency energy of the transmission line or waveguide 11 to said device.

Movable tap 31 on resistor 30 is connected to element 34 of device 32, while lead 21 is connected, through relay winding 28, to element 33 of device 32. From the above connections, it will be seen that rectifier 25 serves as a variable direct voltage biasing means for device 32, and that, when the atmosphere in device 32 is ionized, current can flow from current source 25 through winding 28 and current path 33—34 in series, energizing relay 8 to open contacts 7 and de-energize magnetron 1.

As in Fig. 1, standing waves of radio-frequency are set up in guide 11, and a direct voltage bias is applied to discharge device 32. Since loops 15 and 20 are a quarter-wavelength apart, the standing wave maxima may be considered as coupled to one loop and the standing wave minima to the other. When the ratio between said maxima and said minima becomes high enough to produce, in combination with the bias voltage applied to device 32, a total voltage equal to or greater than the ionization voltage of said device, the gaseous atmosphere in said device becomes ionized, or said device breaks down, allowing current from the source to pass through the path 33—34 of said device to energize relay 8, opening contacts 7 to deenergize magnetron 1.

It is thus apparent that when the ratio between standing wave maxima and standing wave minima in the guide is above a predetermined but adjustable value, the magnetron is automatically deenergized. In this case, as in Fig. 1, the discharge device becomes ionized by radio-frequency energy in the guide, but this ionization can occur only when the ratio between standing wave maxima and minima in the guide is above a predetermined value which is variable at will by varying the bias applied from the biasing source to device 32. It is to be further understood that reliable operation of this system is obtained only when the standing wave phase in the transmission line is fixed and known approximately, and when the factor n is made such as to place coupling loop 15 in the vicinity of a standing wave voltage maximum or a standing wave voltage minimum, depending on the phase that the tube 1 "wants to see" in order to operate in a stable manner. Of course, if loop 15 is at a minimum, loop 20 will be at a maximum, and vice versa, because of the quarter-wavelength spacing between these loops.

Of course, it is to be understood that this invention is not limited to the particular details as described above, as many equivalents will suggest themselves to those skilled in the art. For example, the predetermined point at which the discharge devices will break down may alternatively be varied by adjusting the coupling of these devices to the waveguide, rather than by adjusting the direct voltage bias thereon. Also, alternating voltage bias may be used on the discharge devices, rather than direct voltage, if desired, and if this is done, an alternating voltage relay would be needed in the controlled part of the

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system. Various other variations will suggest themselves. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of this invention within the art.

Some features of invention which are disclosed but not claimed herein are disclosed and claimed in copending application Serial No. 753,180, filed June 7, 1947, and owned by the same assignee as the present application.

What is claimed is:

1. A protective system, comprising a source of radio-frequency energy of a predetermined wavelength, controllable means for supplying an operating voltage to said source, a transmission line connected to said source, a pair of gaseous-discharge devices each having a plurality of elements, said devices being coupled to said line at points spaced a quarter of said wavelength apart in such a way that the gaseous atmosphere of either of said devices is ionizable by standing wave peaks in said line to provide a current-conducting path between the elements of the ionized device, means independent of said transmission line for biasing said pair of devices in parallel so that said ionization can occur only above a predetermined value of standing wave ratio in said line, and means coupling said devices in parallel to said controllable means for controlling the same.

2. A protective system, comprising a source of radio-frequency energy of a predetermined wavelength, controllable means for supplying an operating voltage to said source, a transmission line connected to said source, a gaseous-discharge device having a plurality of elements, two of said elements being coupled to said line at points spaced a quarter of said wavelength apart in such a way that the gaseous atmosphere of said device is ionizable by standing wave peaks in said line to provide a current-conducting path between said elements, means independent of said transmission line for biasing said device so that said ionization can occur only when the ratio between standing wave maxima and minima in said line is above a predetermined value, said biasing means being variable at will to vary said predetermined value, and means coupling said device to said controllable means for controlling the same.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,180,075	Pichon	Apr. 18, 1916
1,779,259	Meissner	Oct. 21, 1930
1,913,588	Francis	June 13, 1933
2,165,848	Gothe et al.	July 11, 1939
2,262,932	Guanella	Nov. 18, 1941
2,304,015	Peterson et al.	Dec. 1, 1942
2,366,660	Uselman	Jan. 2, 1945

OTHER REFERENCES

Radio News, article by McQuay, pp. 36 and 37, February 1946.