Nov. 11, 1958 J. C. CROWLEY 2,860,244

SUPPRESSION OF ARCING IN WAVE GUIDES

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FIG. 1

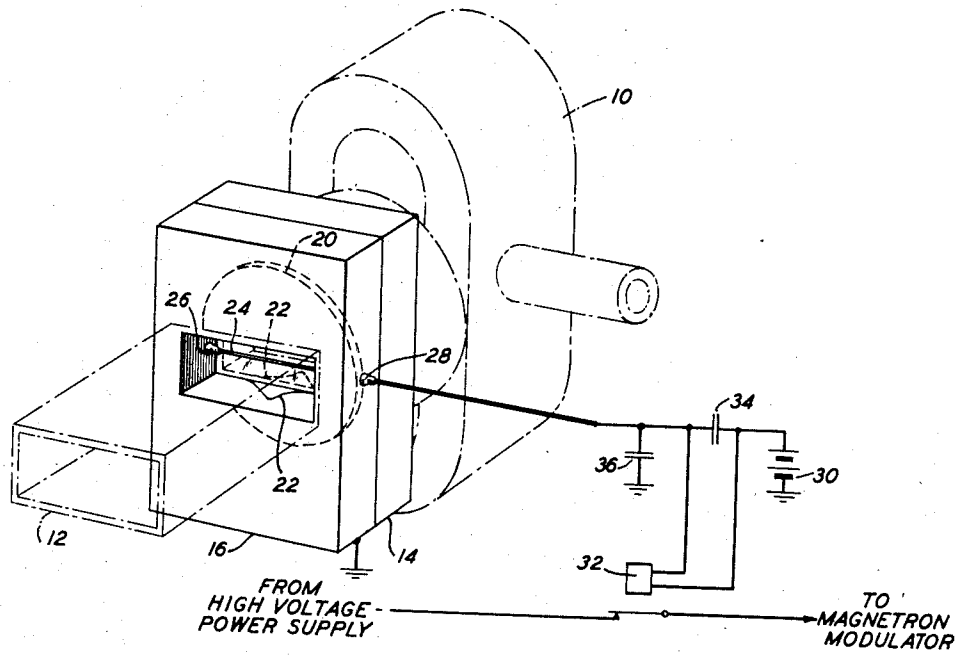
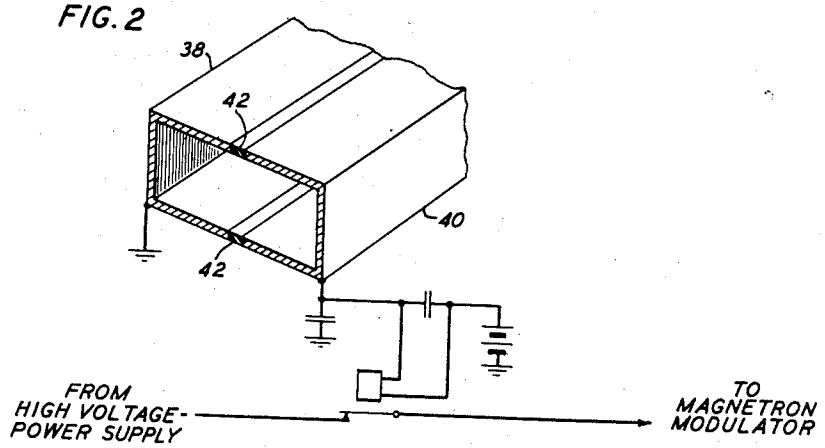


FIG. 2



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SUPPRESSION OF ARCING IN WAVE GUIDES

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9 Claims. (Cl. 250—36)

This invention relates to high power radio systems operating at frequencies in the microwave region and more particularly to arrangements for suppressing voltage break-down arcs which often occur in such systems.

One of the major problems in the design and operation of high power microwave circuits and particularly high power pulse transmitters resides in the fact that voltage breakdown arcs often occur in the interior of the wave guide circuits of the transmitter. Even though the voltages normally employed may be much lower than the nominal breakdown value for the wave guide employed, local conditions such as misaligned or faulty junctions, defective or improperly mounted transmit-receive switching tubes and the like or other discontinuities may set up local arcing which causes ionization within the wave guide and resulting breakdown. Also magnetron oscillators may generate occasional off-frequency pulses causing unusual voltages within the guide, because of a high standing wave at the off-frequency. Thus, a complete breakdown within the wave guide may result from any one of many possible causes. Such a breakdown, which is self-perpetuating, because of the ionization within the wave guide, renders the transmitter inoperative and generates a considerable amount of destructive heat.

The problem arising from the existence of sustained arcs in radar transmitters, for example, is particularly acute where, as is common, magnetron oscillators are employed as the source of microwave power. Normally such oscillators are connected to the output wave guide by way of a so-called window which separates the evacuated interior of a magnetron from the interior of the wave guide which is normally operated at or near atmospheric pressure. A breakdown initiated anywhere in a wave guide line tends to travel back to the magnetron or other generator. One explanation of this effect is that the low impedance of the arc causes a high impedance (high voltage) one-quarter guide wavelength toward the generator, with a rising voltage gradient from the center of the arc back toward this position, accompanied by ionization for some distance back from the arc. Since the arc represents an extremely low impedance, little energy appears in the wave guide further from the generator than the location of the arc. Thus the conditions for continuing the discharge as seen from the location of the arc, always look a little more favorable further along the line toward the generator and the arc travels in this direction. The magnetron window is usually the terminus for this travel. A continued arc at the location of the window rapidly heats up and melts or ruptures the window causing destruction of the magnetron as a result of the loss of the vacuum therein.

It is the object of the present invention to eliminate damage to high frequency transmitters caused by the existence of sustained voltage breakdown arcs in the wave guide circuits thereof.

According to the invention means are provided for detecting the presence of an arc within the wave guide structure and extinguishing it automatically before any damage is done. For this purpose two conductors insulated from one another are positioned at the point in the wave guide at which voltage breakdown arcs tend to become sustained. When an arc is intercepted by the two conductors it completes a circuit therebetween which may also include an external source of power and a control device such as a relay. This relay, operating whenever a sustained arc exists in the wave guide, may be employed to remove or reduce power in the system, thereby to extinguish the arc.

The above and other features of the invention will be described in detail in connection with the drawings, in which:

Fig. 1 is a perspective view, partially in phantom, illustrating one embodiment of the arc suppression device according to the invention; and

Fig. 2 is a perspective view illustrating a modification of the insulated conductor arrangement of the arc suppression device of Fig. 1.

In the arrangement shown in Fig. 1 a magnetron oscillator **10** is associated with and supplies microwave energy to a wave guide circuit **12**. To this end the magnetron is connected to the wave guide through a coupling comprising a flange **14** mounted on the output guide of the magnetron which is arranged for engagement with a similar flange **16** mounted on wave guide **12**. For simplicity of illustration, the choke structure normally employed to prevent leakage of energy between flanges **14** and **16** is omitted. The evacuated interior of the magnetron is separated from the interior of wave guide **12** by a circular window **20** made of special glass or other low-loss material which will transmit microwave energy without substantial attenuation. This window is located in the face of flange **14** which abuts flange **16** and in accordance with common practice the end of rectangular wave guide **12** and that of the wave guide extending from the interior of the magnetron are chamfered as shown at **22** to reduce the discontinuity resulting from the presence of window **20**. This arrangement of wave guide sections adjacent the magnetron window is often referred to as a "waterfall."

As noted above, arcs forming elsewhere within wave guide **12** tend to travel along the interior of the wave guide to a location immediately adjacent the output window. A sustained arc quickly generates enough heat to rupture the window and destroy the magnetron. Sustained arcs at other locations in microwave circuits may similarly damage the equipment by reason of the excessive heat developed thereby.

According to the embodiment of the invention illustrated in Fig. 1, therefore, a conductor **24** insulated from the walls of the wave guide flange **16** is positioned within the wave guide at the point to which damaging arcs travel, in this case immediately adjacent the output window of the magnetron. Conveniently this conductor which may comprise a bare wire or rod is received in an insulating bead **26** in one wall of the wave guide and extends through the opposite wall by way of a second insulator **28**. The conductor **24** may be located as shown in the central H-plane of the wave guide to present minimum disturbance to the microwave fields present therein. It has been found, however, that other H-plane positions within the wave guide may be employed without any substantial deleterious effect upon the transmission of microwave energy therethrough.

Conductor **24** is included in a control circuit which also includes a battery or source of potential **30** and the winding of a relay **32**. One terminal of battery **30** is connected through the relay winding to conductor **24** while the other is connected by way of ground to the flange **16** on wave guide **12**. A capacitor **34** may be connected

across the winding of the relay for the purpose to be considered below.

Whenever an arc occurs at the location of conductor 24 or occurs elsewhere and travels along the wave guide to the magnetron window it will complete the control circuit by providing a path for current flow between conductor 24 and the wall of the wave guide. Current from battery 30 then flows through the winding of relay 32. Since in a pulsed microwave system, however, the arc is of intermittent nature determined by the pulse repetition rate, there may be insufficient time during one microwave pulse to operate relay 32. It may be desirable, therefore, to provide means in the control circuit, permitting energy to be stored therein during one or more successive microwave pulses. Thus adequate energy for the operation of relay 32 may be accumulated. For this purpose, a capacitor 34 may be connected across the winding of relay 32 as shown. When an arc has been intercepted by conductor 24, capacitor 34 receives a charge each time the magnetron produces an output pulse. After a few cycles of operation a sufficient energy is stored in capacitor 34 to operate relay 32 which may be arranged to actuate an alarm or to interrupt or reduce operation of the magnetron sufficiently to extinguish the arc. Conveniently this may be done as indicated in the drawings by interrupting the power supply to the modulator controlling the operation of the magnetron. This effectively and quickly extinguishes the arc existing within the wave guide structure and opens the control circuit, releasing relay 32 to permit continued operation of the microwave system. It will be understood that operation of relay 32 is an indication of the presence of a sustained arc and that this information may be employed in any convenient way to extinguish the arc before it can damage the high frequency system.

Inasmuch as under some circumstances slight amounts of microwave energy may be picked up by conductor 24 from the fields normally existing within wave guide 12, a bypass capacitor 36 of suitable value provides a high frequency path to ground.

Although one specific embodiment of the arc suppression arrangement of the invention has been described as applied to protect the output window of a magnetron oscillator, it will be understood that the invention is of general application in the suppression of voltage breakdown arcs at any point within a high power microwave system at which such arcs may form. It is only necessary to provide a pair of conducting surfaces insulated from one another within the wave guide at the point at which a damaging arc can occur. These conductors then form the contacts of a control circuit which are joined by the arc to detect the presence of the arc and to remove microwave power from the transmission system.

As has been suggested above, the nature of the conducting surface or surfaces employed may vary in accordance with the application to be made of the invention. For example, it may be desirable to provide at that point in the microwave path at which arcs occur a special section of wave guide which is so constructed as to provide the insulated conducting surfaces without the necessity of employing a probe-type conductor inserted in the microwave field. As illustrated in Fig. 2 this section of wave guide may be split longitudinally to provide two conducting wall portions 38 and 40 insulated from one another by strips of insulating material 42. As shown in Fig. 2 the wave guide is split along the two wide faces. It is thus divided along a plane normal to the wide faces of the guide. This plane is parallel to the electric vector for the fundamental or dominant mode supported by the guide and may be considered as an E-plane. Since the wave guide is separated longitudinally by the insulating strips no serious discontinuity is presented to the transmission of microwave energy of the usual dominant mode therethrough. The two portions of the wave guide section, however, provide conducting surfaces which may be included in a control circuit identical to that employed in the arrangement of Fig. 1. Whenever an arc is formed in or reaches this particular wave guide section a control circuit is completed between the two portions of the wave guide to operate the associated relay which may be employed to shut off the source of power until such time as the arc collapses as in the arrangement of Fig. 1.

What is claimed is:

1. In a high frequency system including a source of microwaves and a wave guide circuit associated therewith, means for suppressing voltage breakdown arcs in said wave guide comprising a conductor mounted in and insulated from said wave guide to intercept a voltage breakdown arc and control means including circuit elements outside said wave guide and connected to said conductor and said wave guide for disabling said microwave source for the production of high frequency energy when a circuit is completed between said conductor and said wave guide by an intercepted arc.

2. In a high frequency system including a source of pulsed microwaves and a wave guide circuit associated therewith, means for detecting voltage breakdown arcs in said wave guide comprising a pair of conducting surfaces insulated from each other and positioned to intercept voltage breakdown arcs in said wave guide, a relay for indicating the presence of an arc and a control circuit for said relay including a source of operating potential, the winding of said relay and said conductors and completed by an intercepted arc and means for storing successive pulses of energy transmitted through said control circuit to build up a potential sufficient to operate said relay.

3. In a high frequency system including a source of microwaves and a wave guide circuit associated therewith, means for suppressing traveling voltage breakdown arcs in said wave guide comprising a pair of conducting surfaces insulated from each other and mounted to intercept voltage breakdown arcs at a point in said wave guide at which they become stationary and a control circuit including elements outside said wave guide and connected to said conducting surfaces for reducing the output of said microwave source whenever said conducting surfaces are electrically interconnected by way of an intercepted arc.

4. In a high frequency system including a source of microwaves and a wave guide output circuit therefor, means for suppressing voltage breakdown arcs in said wave guide comprising a conductor mounted parallel to an H-plane in said wave guide and insulated therefrom to intercept a voltage breakdown arc, means for disabling said microwave source and an operating circuit for said disabling means including said conductor and said wave guide and completed by an intercepted arc.

5. In a high frequency system including a magnetron oscillator having an output window and a wave guide circuit connected thereto at said window, means for suppressing voltage breakdown arcs in said wave guide adjacent said window comprising a conductor mounted in the central H-plane of said wave guide adjacent said window and insulated from said wave guide, means for disabling said magnetron and a control circuit for said disabling means including said conductor and said wave guide and completed by a voltage breakdown arc occurring adjacent said window.

6. In a high frequency system including a source of microwaves and a wave guide circuit associated therewith, means for detecting voltage breakdown arcs in said wave guide comprising a wave guide section located in said circuit at the point at which arcs occur and split longitudinally along an E-plane to provide two conducting surfaces insulated from one another, and a circuit including said two sections and completed by a voltage breakdown arc.

7. In a high frequency system including a source of microwaves and a wave guide circuit associated there-

with, means for suppressing voltage breakdown arcs in said wave guide comprising means for detecting the existence of an arc therein, and means including circuit elements outside said wave guide responsive to said detecting means for extinguishing said arc.

8. In a high frequency system including a source of microwaves and a wave guide circuit associated therewith, means for detecting breakdown arcs in said wave guide comprising a pair of conducting elements insulated from each other and positioned inside said wave guide to intercept voltage breakdown arcs, control means for said source outside said wave guide, and a circuit including said control means and said conducting elements and completed by said arc.

9. In a high frequency system including a source of microwaves and a wave guide circuit associated therewith, means for suppressing voltage breakdown arcs in

said wave guide comprising a pair of conducting elements insulated from each other and positioned inside said wave guide to intercept voltage breakdown arcs therein, circuit means outside said wave guide for disabling said source for the production of microwave energy, and a control circuit including said circuit means outside the wave guide and said conducting elements and completed by an intercepted arc.

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