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HIGH POWER VACUUM TUBES

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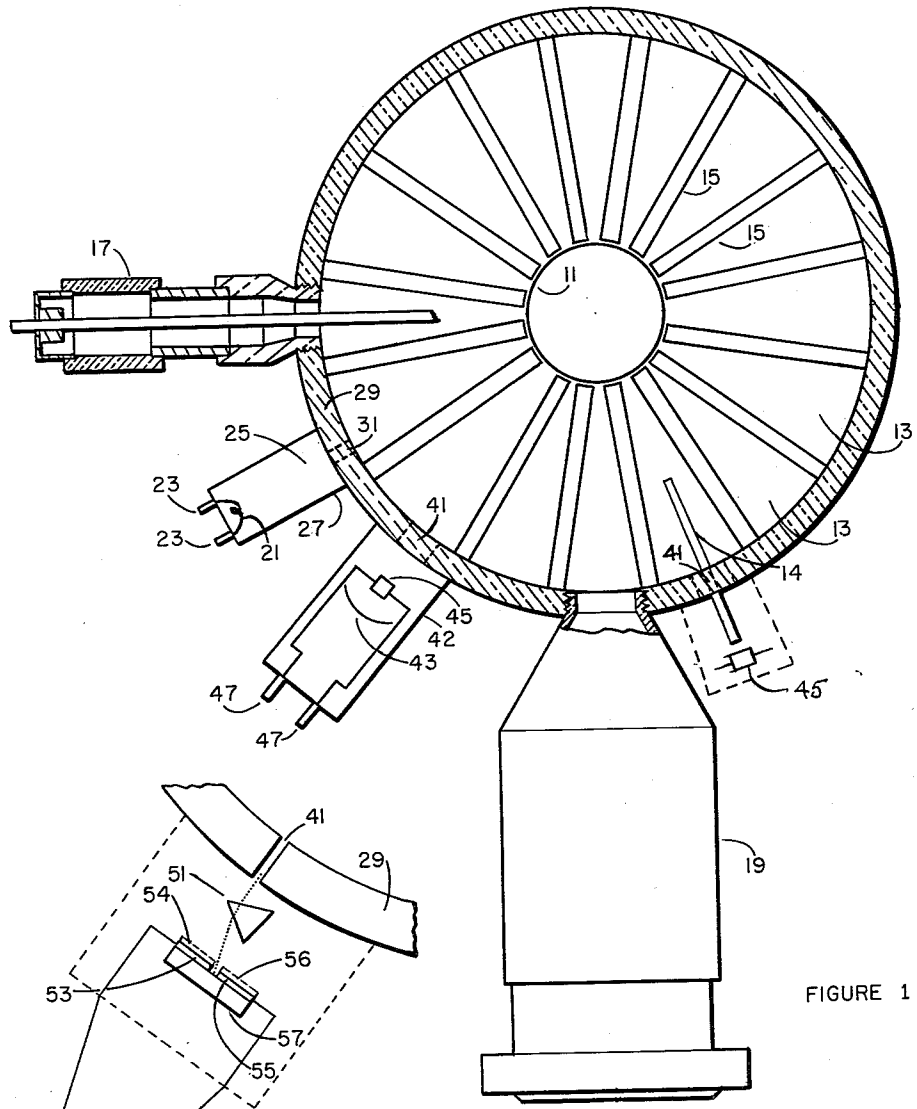


FIGURE 1

FIGURE 2

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HIGH POWER VACUUM TUBES

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This invention relates to built-in testing devices for high powered vacuum tubes. It is particularly directed towards providing high powered magnetron tubes with a built-in device to provide for a simple check on the condition of the vacuum within the tube. This invention also provides a built-in device to monitor the cathode temperature thereby providing a detector that may be used in controlling the power supplied to the heating element.

At present there are two accepted techniques for testing a completely fabricated magnetron tube for gas content. In one instance a high voltage pulse is applied to the tube. By means of an "arc counter" the number of times the tube breaks down is indicated. This is taken to be a measure of gasiness. Another accepted technique employs a source of filament current which is impressed upon the heater of the tube. A voltmeter placed across the heated terminals is used to indicate the rate of resistance change in the heater of the magnetron. Experience has been that on high power tubes the chemical action between the gas in the tube and the heater element produces a significant effect on this rate of change of resistance. Both of these techniques are indirect and require a substantial amount of test equipment in that either high voltages or high current capabilities are required. A third technique utilizes a Tesla coil for a leak indicator but the high voltage produced by the coil is capable of cracking and destroying good tubes and therefore is not used to any extent.

Because of the limitations imposed by the above methods of testing a magnetron tube for gas content, it has frequently been difficult to establish a cause for failure of high powered magnetron tubes when employed in the equipment into which they have been designed. At least partially to compensate for the lack of exact knowledge as to the condition of vacuum there have been proposed, and are now in use, automatic run-up circuits which are used to increase the supply voltage to the tube until arcing occurs at a given rate. Automatic control circuits are then used to reduce the applied voltage thereby reducing the number of arcs whereupon the plate voltage is again increased. Frequently the use of the arc counter and automatic run-up circuits are used to age-in a magnetron. This practise has been resorted to in the past when it was felt that the residual gas in the tube could be cleaned up, or absorbed, by the various components in the tube as a result of operating the tube. Under these circumstances it is usually found necessary to operate the tube at reduced voltage and currents in order to protect both the tube and the modulating circuits thereof.

A recent innovation in the automatic run-up operation has dispensed with arc counting, and has used a current measuring device as a control element for the automatic circuits in order to maintain a constant anode current. This has proven to be more reliable than the arc count. The average anode current serves as an indicator of the power being supplied to the magnetron. In operation the average plate current may also be monitored and controlled for purposes of insuring frequency stability, power output, etc.

Another practise that has been employed in high powered tubes to stabilize their operation provides for a regulated source of filament current, frequently of 50 amperes magnitude. It has also been the practise to regulate the filament voltage and make compensation for the heating of the cathode caused by back bombardment in magnetrons. Also used, but to a lesser extent, is a

feedback arrangement to run the heater element at constant resistance.

The above described presently used techniques, used singularly or in combination, have failed to provide those qualities desired in testing or operating high powered magnetron tubes. This fact is commonly accepted. It is well known within the armed services, and in the industries supplying and using these tubes. The magnitude of this problem has caused serious concern from an economic viewpoint and from a military operational readiness viewpoint.

Accordingly, it is an object of this invention to provide a simple, economical, easy-to-operate device built into a magnetron, or similarly related high power vacuum tube, to enable the technicians to determine, with a high degree of certainty, as to whether the tube has lost its vacuum to the point where it can no longer be relied upon to operate.

Another object of this invention is to provide means for monitoring the cathode temperature of a magnetron tube, or other high powered tubes, in order to provide a sensing element to be used in a control circuit that will regulate the power supplied from external sources that is used in heating the cathode of the tube.

The first objective is achieved by providing high powered electron tubes with a supplementary heater that may be operated at low voltages with a power consumption in the order of 1 watt. This heater may be similar to that used in ordinary receiving tubes. It is well known that these heater elements when operated will be destroyed if the tube vacuum has gone to air. Hence, once this supplementary heater element is provided, all that is required is an elementary test to cull those tubes which obviously would be non-operable. This may be done before the tube is installed in the equipment, which is highly desirable. It should be mentioned that auxiliary cathodes have been used in magnetrons heretofor for the purpose of controlling the frequency. In the present invention, it is actually preferred that the supplementary heater be isolated electrically from the RF sensitive regions; it being used in this instance to determine the condition of vacuum within the tube.

The second of the objectives is achieved by making use of the color temperature of the cathode. Means are provided within the tube to pick up and transmit a portion of the visible radiation emitted by the cathode of the tube. Use may then be made of techniques employed in conventional radiation pyrometers and optical pyrometers. In general the radiation pyrometer is sensitive to the total radiation. It is a broad band detector. The optical pyrometer is sensitive to monochromatic radiation; it is a narrow band detector. In the radiation pyrometer a thermistor, thermopile, or thermocouple may be used. In the optical pyrometer a method of color matching is used. Both classes of devices are generally of a laboratory, or a factory, type requiring calibration charts, physical manipulation, etc.

In factory tests on the cathodes of high power tubes, or in the research and development of these tubes, it is customary to check the cathode temperature by means of an optical pyrometer. It is often the practise to attempt to hold the cathode temperature within $\pm 50°$ C. of the selected operating temperature. This invention advances the art in that it simplifies the temperature indicating arrangement to the point where it may be made a component of the tube. It is thereby made possible to include the detector in a feedback arrangement that automatically maintains the cathode temperature within definable limits when the tube is in operation in the prime equipment.

The novel features which are characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following

description considered in connection with the accompanying drawing. In the drawing,

FIGURE 1 is a cross sectional view of an LCW magnetron. The complete description of this tube may be found on page 743 of "Microwave Magnetrons," edited by George B. E. Collins, vol. 6 of the Radiation Laboratory series published by McGraw Hill Co., 1948.

FIGURE 2 contains the block diagram of the cathode filament control circuits and illustrates the photo-conductive, or otherwise photo-sensitive, split element that is impinged upon by the radiation of the cathode.

In FIGURE 1, the cathode **11** is to be heated by a filament which is not shown. A series of resonant chambers **13** are formed by vanes **15**, the cathode **11**, and the wall **29** surrounding the vanes. A magnetic field is supplied parallel to the longitudinal axis of the cathode of the tube. Oscillations are obtained when a pulsed unidirectional voltage is applied between the vanes **15** and the cathode **11**, in the presence of a suitable magnetic field. The cathode pipe is shown at **17** and the output pipe is indicated at **19**. The manner in which a coupling loop extends outward from the pipe, **19**, into the cavity is not shown nor are the heater connections shown as they are not necessary for a proper understanding of this invention.

Element **21** comprises a filament the leads of which are brought out through pins **23** in such a manner as to preserve the vacuum in chamber **25**. Housing **27** is affixed to the wall **29** of the cavity structure by welding or soldering, in a manner similar to that used for sealing pipe **17**, or **19**, to the structure. A small opening **31** connects chamber **25** with the evacuated resonant chambers, **13**, of the magnetron tube. Opening **31** may be very small in size so as to shield chamber **25** from the RF currents in the main cavity. It is clear that when the evacuated cavity of the magnetron looses its vacuum that the same will happen to chamber **25**. Under these conditions the behavior of filament **21** will provide a positive indication of this loss of vacuum. By impressing a low voltage and low power source to terminals **23**, the filament **21** will be energized. Upon its deterioration, usually resulting in an open filament, there will be provided an indication that due to loss of vacuum the entire magnetron tube is non-operable.

It is well known that filaments of receiving type tubes will be affected by any substantial air content within the tube and that the filament will disintegrate upon application to it of normal rated power. By way of illustrative example, the filament **21** may be the same as that utilized in the heater of a 6AU6 vacuum tube. The heater in this receiving type tube operates at 6.3 volts and draws 300 milliamperes thereby consuming approximately 2 watts. It is only necessary then to measure, or monitor, the current in the filament **21**. Loss of filament current generally will indicate the loss of vacuum within the tube. Thus, with a simple 2 watt source of power and a simple indicating instrument, it is possible to cull those high power tubes, the vacuums of which have gone to air. This culling procedure may be employed at the depot, or in the field, and it may be employed without requiring that the tube be connected into the equipment into which it is to operate. This test may also be performed just prior to installation of any tube in its equipment. After installation this same device may be used to provide a continuous indication of the presence of vacuum, or lack thereof.

It is clear that the life of filament **21** should be considerably in excess of that normally expected of the high power tube in which it is located. It may therefor be desirable to provide a plurality of these loss-of-vacuum indicators in order to insure that the high power tube will not be rejected on the basis of a faulty vacuum indication.

In the event that more accurate vacuum indication is required, as may be the case when the tubes are returned to the depot or factory for retest, then filament **21** may be designed to be a Pirani gage element. Alternatively the housing **27** may comprise, in addition to the heater element, an electron emitting cathode and a collector plate; or an ionization gauge. Reference is made to techniques for alternative embodiments of vacuum gauging devices on pages 77–79 of Photo-Electricity, by Zworykin and Ramberg, published by J. Wiley and Sons, 1949. Reference is also made to U.S. Patent 2,824,246. The fundamental considerations are that the housing containing the vacuum indicator should be permanently vacuum sealed to the tube; the elements comprising the vacuum indicator should be removed from the RF field; and connections between the tube and the indicator chamber should provide for passage of the "atmosphere" therebetween.

Also shown in FIGURE 1 is a housing **42** attached to the body of the magnetron. Contained therein is a thermistor **45**, a parabolic reflector **43**, and pins **47** which are electrically connected to thermistor **45**. Part of the radiation from cathode **11** is transmitted through **41** to be focused by reflector **43** upon the radiation sensitive thermistor. Under normal operating conditions the resistance of the thermistor reaches a stable value depending upon the temperature thereof, which in turn is effected by the amount of radiation which impinges upon it from the cathode. This resistance element may then become one arm of a Wheatstone bridge which may be used as a control circuit that regulates the amount of power delivered to the heater of the magnetron. This regulation may be accomplished in many ways using conventional control circuitry, e.g. as in bolometer bridges. The result is that the variations in the temperature of the cathode normally experienced in magnetron operation are reduced substantially.

This feature of the invention stabilizes the operation of the tube by tending to maintain a constant electron emission from the cathode and by reducing the variations in the mechanical configuration of the frequency determining elements that normally occur due to thermal expansion and contraction. Also the stresses and strains to which the cathode is subjected are reduced thereby providing a greater life expectancy for one of the more critical elements in the tube.

When **41** comprises an opening in the structure **29** then clearly housing **42** should be vacuum sealed to **29** as was described for housing **27**. Alternatively it is possible to have other arrangements whereby **41** comprises a radiation transmitting element, such as a lens, which is vacuum sealed to structure **29**. In these cases housing **42** need not be vacuum sealed to the magnetron.

In FIGURE 2 another arrangement is shown for detecting and utilizing the radiation from cathode **11**. A portion of the structure **29** is shown with an opening **41** similar to that described with relation to the operation of FIGURE 1. The opening **41** may constitute or comprise collimating means. A prism **51** is used to disperse the radiation emitted by the cathode which is transmitted to impinge upon detector **57**. Detector **57** is comprised of elements **53** and **55** which are adjacent but separated from each other. The elements are photo-conductive, photo-voltaic, or otherwise photo-sensitive. The electrical connections to detector **57** and the associated circuits depend upon the specific nature of the detector element and therefore are represented here in schematic but symbolic form. Reference is made to U.S. Patent 2,816,283 for a more complete description of a detector which may be used in this case.

It is desirable, as stated heretofore, that during normal operation of the tube that the cathode be maintained at a prescribed temperature. Detector **57** is disposed with relation to prism **51**, opening **41**, and cathode **11** so that when the prescribed temperature is reached the total radiation impinging upon element **53** is equal to that impinging upon element **55**. Under this condition the electrical signals from elements **53** and **55** are equal. When

the temperature of cathode **11** changes the distribution of radiation emitted also changes. This change, of the amplitude vs. wavelength curve, occurs in accordance with Wien's displacement law. Due to the dispersion of the prism the radiation impinging upon elements **53** and **55** then becomes unequal. The differential output betwen elements **53** and **55** may then be amplified in **61**. The output of **61** in turn may be connected to the control windings of magnetic amplifier, or saturable reactor, **63**. The input to **63** is from a primary power source; the output of **63** supplies the thus controlled power to the filaments that heat cathode **11**.

The heating of the cathode in a magnetron is a function of the power supplied to the filament, the magnitude and distribution of the D.C. and A.C. currents, and the back bombardment. When the filament is first energized the magnetic amplifier is at a set "gain," there being no input from the differential amplifier **61**. The power supplied to the filaments raises the temperature of the cathode. When the prescribed cathode temperature is reached there is a null in the output of amplifier **61**. When this temperature is exceeded there is a differential output from detector **57**. This in turn reduces the heating of cathode **11** thereby reducing its temperature. This process of regulation will compensate for variations in the filament power source, in the current heating effects, and in the back bombardment; it will compensate for changes in the filament-cathode heat transfer mechanism; it will also compensate for changes in ambient temperature; thereby achieving the desired objective of reducing temperature variations of the cathode. Reference is made to U.S. Patent 2,805,385 for additional details of circuits that may be used in this connection.

At this point a number of alternative embodiments may be considered. Instead of prism **51**, or in addition to it, filters may be used on the element **53** and **55**, to regulate the radiation impinging upon said elements. The filters **54** and **56** preferably are narrow band transmission devices. Filter **54** is peaked to one frequency; filter **56** is peaked to a second frequency. Together they straddle the hump of the amplitude-wavelength radiation emission curve of the cathode when operating at its prescribed temperature. Under this condition there should be a null in the output of **57**. It is clear that this arrangement then produces a differential output from detector **57** when the temperature of the cathode changes.

It is also possible to use the vacuum sensing element as the temperature sensing, or comparing, element. This may be done by utilizing the filament **21** in a manner frequently used in optical pyrometers of the laboratory type. The temperature of filament **21** is controlled by the power fed into it. This temperature is adjusted, color-wise, to match that of the cathode **11** at its prescribed setting. Variations by cathode **11** from its prescribed temperature may be utilized, by means of a control loop, as hereinbefore described, to reduce these variations.

It is also possible to use the element **21** in conjunction with certain types of getters to clean up emitted gases. The element **21** may be raised to a temperature to heat the getter material to its optimum value. The getter may be coated on **21**, on part of **21**, or may be located nearby. By way of example, a material CermAlloy 400 produced by New Process Metals, Inc., Newark, New Jersey, may be used in this connection.

Another alternative is that in which the cathode **11** contains particles that emit radiations which are temperature sensitive. Certain phosphors and other radiation emitting substances are known to possess this property. Metallic particles or bands may also be used.

It is also possible to pick up the radiation from the cathode **11**, or from the filament **21**, and to transmit these radiations to a situs external of the tube where they may be utilized as set forth in this specification. Radiation transmitting means **14** may comprise a rod of fused silica. The rod may be arranged as illustrated in the drawing; or it may be embodied in a vane; or it may be combined with the assembly of cathode **11** or heater **21**. Arrangements of means **14** that may be used, and advantages derived therefrom, are described in my co-pending application Serial #634,019 filed January 14, 1957.

Additional advantages which are derived from the teachings in this specification will become apparent from the following discussion. Normal distribution of the manufactured tubes entails shipment to warehouses, depots, or operational stations. It is possible that these tubes will be stored for a considerable period of time without being used. Under these conditions a schedule may be set forth that will require testing before further shipment or before use of the tubes. At the operational station this test should at least consist of determining the condition of vacuum of the tube. As hereinbefore described, this test is quite elementary. It should be capable of being made while the tube is still packaged in the shipping crate. If the tube passes this test and shows no visible signs of damage in shipment it may be installed into the equipment. The testing process at the warehouse, or depot, should likewise include a test for vacuum while the tube is still packaged in the shipping crate. It is also desirable to test the strength of the magnetic field in those tubes that have an integral magnet. It may be desirable still further to D.C. test the tube at rated voltages. The nature and extent of this type of test should be decided upon based upon the operational history of the tube. It is to be realized that to perform this test requires the uncrating and subsequent repackaging of the magnetron; requires substantial amounts of equipment; and provides a test which can at best only simulate the final conditions under which the tube is to operate.

To assist in the maintenance of the equipment after the tube is installed it is recommended that monitoring and control circuits be incorporated into the main equipment. The condition of vacuum should be monitored continually. The error, or correction, signal in the cathode temperature regulating loop should be monitored. The magnetron anode current should be automatically regulated between specified limits. Automatic run-up and run-down circuits, sensitive to arc-count but controlling anode current, should be incorporated. Cathode electron emission should be checked with a low voltage, low duty cycle signal impressed between anode and cathode; or by the use of "current-dip" test; or by employing a fine needle pointed anode that will monitor the cathode emission. Lastly, consideration should be given to monitoring the video pulse that modulates the tube, monitoring the power output, or effective range, and monitoring or controlling the oil bath temperature when such a bath is used.

Having thus described the invention and the ways in which it may be used to achieve the desired objectives I claim:

1. A high power vacuum tube, which is capable of providing a positive indication when it cannot operate properly, comprising a cathode element adapted to yield a copious supply of electrons which generates the useful output of the tube in combination with a supplementary fuse-like non-electron-emissive filament used solely for the purpose of conducting a test current, to determine the condition of vacuum within the tube, whereby the supplementary filament burns out to interrupt the test current when the tube has lost its vacuum.

2. A tube in accordance with claim 1 wherein the supplementary filament is at least partially coated with a getter, so that said filament is also capable, by passage of a current therethrough, of raising the temperature of the getter to improve its gas absorbing properties.

3. A tube in accordance with claim 1 which also includes a getter located near the supplementary filament so that radiation from said filament, generated by the passage of a current therethrough, is capable of raising the

temperature of the getter to improve its gas absorbing properties.

4. A failure indicating device comprising a tube defined in accordance with claim 1 in combination with means responsive to the interruption in said test current for signaling the nonoperability of the tube.

5. An evacuated electron discharge device which is capable of providing a positive indication when it cannot operate properly comprising: means, including a cathode, for providing a copious supply of electrons which are used to generate the useful output of the tube, and permanently located within the device, a supplementary fuse-like element, not associated with said cathode, adapted to be heated by a test current, said element characterized by the features that (1) the test current it draws uses substantially less power than is required to energize said cathode; (2) said element normally, in the absence of air, has a substantially greater life expectancy than the aforesaid means for providing a copious supply of electrons; and (3) it ruptures upon application of the test current when the device has gone-to-air.

6. A vacuum tube comprising a cathode that emits electrons when heated, means for heating said cathode, and a supplementary filament adapted to be heated by a small current, in combination with means responsive to the electro-magnetic radiation from said cathode and said supplementary filament for controlling the heating of said cathode, said supplementary filament being further characterized by the fact that it disintegrates upon application of the small current when the tube has lost its vacuum.

7. An evacuated electron discharge device comprising

getter means for absorbing gases within the device, a cathode for providing a copious supply of electrons which are used to generate the useful output of the device, and a filament not associated with said cathode adapted to raise the temperature of said getter to increase its effectiveness, said filament characterized by its ability to conduct a heating current when the tube is evacuated and which ruptures upon application of the test current when the device has gone-to-air.

8. A device in accordance with claim 7 in combination with means for providing the heating current that raises the temperature of the getter to its optimum value.

9. A failure indicating arrangement comprising the combination defined in claim 8 in combination with means responsive to the interruption in the said heating current for signaling the non-operability of the tube.

References Cited in the file of this patent

UNITED STATES PATENTS

1,649,016	Buckley	Nov. 15, 1927
2,144,509	Renatus	Jan. 17, 1939
2,159,767	Liebich	May 23, 1939
2,242,638	Balsley	May 20, 1941
2,413,760	Graf	Jan. 7, 1947
2,443,189	Jenkins	June 15, 1948
2,445,257	Atlee	July 13, 1948

FOREIGN PATENTS

312,100	Great Britain	May 21, 1929