March 15, 1949. H. E. WEBBER 2,464,277

THERMOMETRIC WATTMETER

Filed Dec. 13, 1943

Fig. 1.

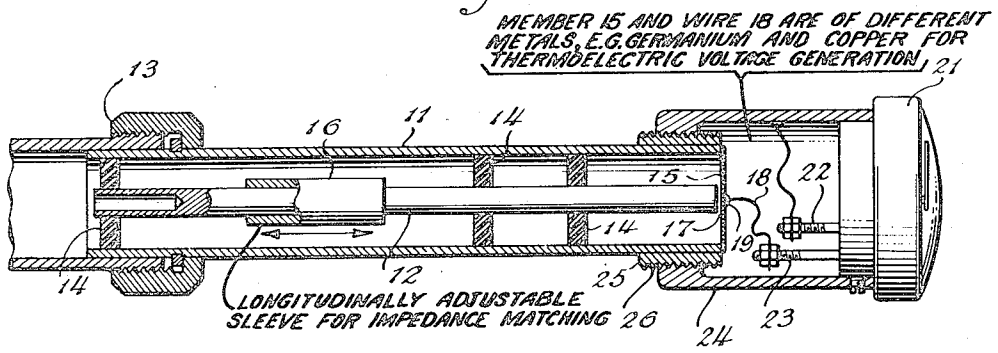


Fig. 2.

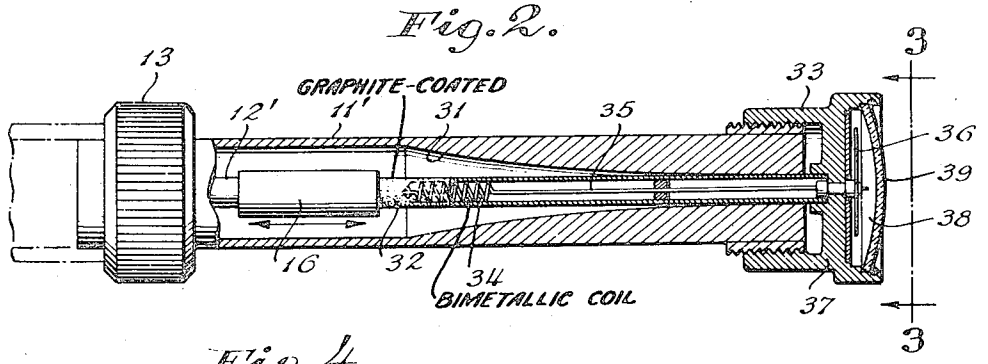


Fig. 4.

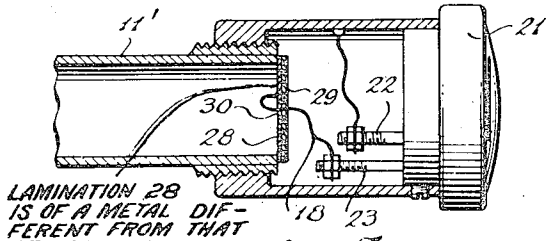


Fig. 3.

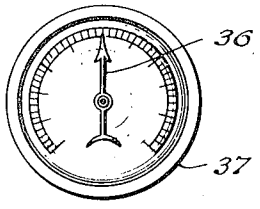
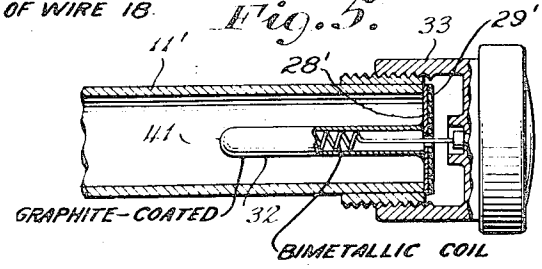


Fig. 5.



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THERMOMETRIC WATTMETER

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Application December 13, 1943, Serial No. 514,110

16 Claims. (Cl. 171—95)

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The present application is a continuation-in-part of my copending application, Serial No. 513,164, filed Dec. 6, 1943.

The present invention relates to power measurement and has for its principal object the provision of an improved thermal type microwave wattmeter.

An object of the invention is to provide methods and apparatus for measuring alternating current power by means of thermal effects.

Another object of the invention is to provide an arrangement for terminating a transmission line in its characteristic impedance. Furthermore, an object is to provide a characteristic impedance for a transmission line which serves also as a power-absorbing medium or a heater for thermal indication of power.

Another object of the invention is to provide a broad band microwave wattmeter.

Another object is to provide a thermocouple wattmeter.

Still another object is to provide a bimetallic thermometer type of wattmeter.

Other and further objects and advantages will become apparent as the description proceeds.

In carrying out the invention in its preferred form a transmission line of a coaxial type is provided for receiving microwave energy, the power of which is to be measured. In one form of the illustrated invention the transmission line is terminated in a resistance disc composed of a material having a high thermo-electric power, and another metal is joined to the disc to form a thermocouple. In another form of the illustrated invention the transmission line has an all-wave ultra high frequency power-absorber therein including an absorbing coating on the inner conductor rod. The inner conductor rod is made hollow and contains a bimetallic helix of a bimetallic thermometer, the mechanical motions of which serve as indications of the power supplied to the transmission line.

A better understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawing, in which

Fig. 1 is a sectional view of a microwave wattmeter shown as cut by longitudinal plane through its axis;

Fig. 2 is a view, mainly in section, of a microwave wattmeter having an indicating dial;

Fig. 3 is an end view of the apparatus of Fig. 2 as seen by looking in the direction of the arrows 3—3;

Fig. 4 is a fragmentary view of wattmeter with

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low thermal capacity and negligible time lag; and

Fig. 5 is a fragmentary view of the apparatus of Fig. 1 arranged for wave-guide measurements.

Like reference characters are utilized throughout the drawing to designate like parts.

As illustrated in Fig. 1, an enclosed-field transmission line of the coaxial type is provided, including an outer hollow cylindrical conductor 11, and an inner conducting rod 12. For supplying microwave energy to the transmission line, through a similar line (not shown) a conventional coaxial line coupling 13 is provided as shown at the lefthand end of the line. For supporting the inner rod 12, low-loss insulating bushings 14 are provided.

In order to avoid reflections and consequent variations in the standing wave ratio, the line is preferably terminated in its characteristic impedance. For this purpose a disc 15 is mounted at the righthand end of the hollow cylindrical conductor 11 so as to close the line, being electrically connected to the cylinder 11 in a suitable manner as by means of soldering. The disc 15 is composed of relatively high thermo-electric power metal, such as germanium. The thickness of the germanium disc 15 is so chosen as to produce a resistance equalling the characteristic impedance of the line, thus causing the line to become an all-wave line forming a broad band wattmeter suitable for measurement of power over a wide range of input frequencies.

In the event that it should not be convenient to terminate the line exactly in its characteristic impedance, by means of the disc alone, an impedance transformer or matching device of adjustable ratio may be provided, such as a hollow cylinder 16 surrounding the inner rod 12 and axially slidable thereon for the purpose of adjustment. The presence of the cylinder, however, sharpens the frequency response of the line and diminishes the breadth of frequency over which accurate indications are obtained. In case of slight mismatch radiation may also be prevented by extending the line one-half wavelength beyond the germanium disc and closing the end of the extended line by a shorting-plug.

In order to avoid direct contact between the terminating resistance disc 15 and the inner rod 12 with the consequent heat conduction from the disc 15 to the rod 12, a gap 17 is left between the rod 12 and the confronting surface of the disc 15. The gap 17, however, is made relatively small so that it serves as an air dielectric for a by-pass condenser formed between the end sur-

face of rod 12 and the confronting inner surface of the disc 15. Thus, with respect to radio frequency energy there is a low-impedance coupling between the rod 12 and the center of the disc 15.

For the purpose of forming a thermocouple, a second element composed of a different metal from the disc 15, for example, a copper wire 18, is soldered as shown at 19 to the center of the resistance disc 15.

For the purpose of providing an indication of the voltage output of the thermocouple 15, 18, a suitable current or voltage-responsive instrument, such as a millivoltmeter 21, is provided having terminals 22 and 23.

For shielding the disc 15 against radiation of energy or reception of energy from external fields, and for the purpose of protecting the disc 15 and the soldered joint 19, an end bell 24 is preferably provided which is mechanically and electrically secured to the outer conductor 11 by means of a bushing 25 soldered to the cylinder 11 and a threaded joint 26 between the member 24 and the bushing 25. For compactness, the millivoltmeter 21 may form the end of the member 24. One millivoltmeter terminal 23 is electrically connected to the copper wire 18. The other millivoltmeter terminal 22 is actually grounded to the millivoltmeter case, but is represented schematically in the drawing as being connected to the member 24 in order to show the electrical circuit.

When microwave power to be measured is supplied to the transmission line through the connection 13, the energy is dissipated in the disc 15 thereby heating the disc and setting up thermoelectric currents in the junction between the elements 15 and 18 which are proportional to the heating of the disc 15 and, therefore, substantially proportional to the input power. Accordingly, the indication of the instrument 21 is proportional to the input power or the square of the input microwave current.

Although my invention is especially useful for measurements in the frequency range where enclosed-field transmission lines are employed such as coaxial-lines and hollow-pipe wave guides my invention is not limited thereto. In the case of a wave guide of either the circular or rectangular type there is no center rod 12 and there is merely a germanium plate circular or oblong, as the case may be, closing the end of the wave guide 11' as indicated in Fig. 4

In order to maintain any time lag of indication at a minimum it is desirable to make the thermal capacity of the germanium plate 15 small. A thin plate is thus advantageous. If desired the germanium plate may be formed as illustrated in Fig. 4 by evaporating or sputtering a layer 28 of germanium on to a thin plate 29 of low heat conductivity and heat capacity, electrically insulating material such as "Bakelite." In this case the thermocouple 19 is formed in the inner surface of the germanium and an opening 30 is provided for the copper lead 18.

Although, as thus far described, the thermoelectric effect is employed for indication of power, it will be understood the invention is not limited to the precise arrangement described and illustrated, nor to the use of thermojunctions employing the particular metals mentioned by way of illustration.

Furthermore, the invention is not limited to the absorption of the heating power in a terminating resistance mounted across the end of the hollow conductor 11. If desired, the center

rod 12 may be arranged for absorption of the measured power. For example, as illustrated in Fig. 2, an outer conductor 11' is employed having a tapered inner surface 31 which is convex inwardly so as to form an all-wave power-absorber.

As illustrated in Fig. 2, a hollow center conductor rod 12' is provided and the portion of the outer surface of the rod 12' within the tapered inner surface 31 is coated with a suitable power-absorbing substance, such as graphite 32, for example, or a Pyrex tube with a platinized surface film may be employed.

The shape of the curve defining the surface 31 may be expressed by the formula:

$$b_x = ae^{\frac{-rx}{k}}$$

where

b_x is the radius of the outer conductor
a is a constant
e is the base of the Naperian logarithm
r is the resistance per unit length of the resistance coating on the center conductor
x is the distance from the righthand end of the center conductor
k is a constant

The characteristics of the tapered conductor may by approximated by a series of stepped sections as described more in detail in the copending application of William W. Hansen, Serial No. 496,715, filed July 30, 1943, now Patent No. 2,438,915, issued April 6, 1948, and assigned to the same assignee as the present application.

Such a shaped inner surface is advantageous but is by no means necessary to the satisfactory operation of the apparatus. A simple conical surface may be employed. Even a straight cylinder will serve the purpose if the resistance coating 32 has the proper value and extends such a distance that no power will return to the line, so as to approximate an infinitely long line or termination. To make certain that the proper impedance is "seen" looking into the unit, to avoid reflection at the input, there may be a gradual tapering of the resistance value of the coating to progressively greater values toward the end of the line. Each succeeding quarter-wave length might be increased in resistance, in the ideal case making each such quarter-wave resistance the geometric means of those on either side of it.

For measuring variations in the temperature of the surface 32 produced by variations in power input through the connection 13, a thermometer 33 is provided having a temperature bulb or element 34 mounted inside the hollow rod 12'. For example, the thermometer 33 may be of the bimetallic type in which the temperature-responsive element 34 constitutes a bimetallic helix with an axial rod 35 extending outward through the center of the hollow conductor rod 12' and carrying an indicating needle 36 at its outer end.

For protecting the needle 36, and providing support for elements within the hollow conductor 11', a thermometer casing 37 may be provided having an opening 38 containing the needle 36, the opening being closed by a cover-glass 39.

When the power is introduced through a wave guide instead of a coaxial line, the thermometer 33 may be arranged as shown in Fig. 5. A stem 41, serving as the thermometer bulb, extends into the wave guide and acts to absorb power arriving therethrough. The wall of this stem is coated with a resistive material 32 and preferably is very thin in order to have very low heat

capacity. This stem 41, 32 is attached to an end disc 28', 29' corresponding to the laminated resistive disc end stem 28, 29 of Fig. 4. The radio frequency power arriving through the wave guide 11' is converted into heat in the stem 41, 32, and the angular deflection of the pointer 36 (Fig. 3) accordingly corresponds to the magnitude of the arriving power.

Zero resetting devices may be provided for the needle 36 and for the instrument 21, to correct for change in zero which might result from the units being subjected to excessive ambient temperature variations.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A microwave wattmeter, comprising in combination a coaxial transmission line having inner and outer conductors, a germanium disc closing the end of the outer conductor, the inner conductor having an end surface separated from the inner surface of the germanium disc to form a gap, a copper wire joined to the outer surface of the germanium disc to form a thermocouple, and an electro-responsive instrument electrically connected to the germanium disc and the copper wire.

2. A microwave wattmeter, comprising in combination a coaxial transmission line having inner and outer conductors, a terminating resistor in the form of a disc of thermo-electric material mounted over an end of the outer conductor, an element composed of a different metal from the disc, connected thereto to form a thermocouple, and an electro-responsive instrument connected to said thermocouple elements.

3. A microwave wattmeter, comprising in combination a coaxial transmission line having inner and outer conductors, a thermocouple having one transverse resistive disc element forming a terminating impedance for the transmission line and a further conductive element of a different material in contact therewith, and an electro-responsive instrument connected to the elements of said thermocouple.

4. A microwave wattmeter, comprising an enclosed-field transmission line having a hollow conductor, a stationary terminating impedance disc across one end of the hollow conductor and in contact therewith, and indicating means responsive to the temperature rise in the central region of the disc above the temperature along the edge thereof for indicating the power dissipated in said disc.

5. A microwave wattmeter, as in claim 4 in which the terminating resistor has a resistance substantially equalling the characteristic impedance of the line.

6. A wattmeter, comprising a tubular type transmission line, a stationary disc terminating impedance fixed to the line and closing the line in its characteristic impedance, and means responsive to temperature rise of the inner region of said terminating impedance for indicating electric power dissipated therein.

7. A microwave wattmeter, comprising in combination an enclosed-field transmission line having a hollow conductor, a germanium plate closing the end of the conductor, a copper wire joined to the surface of the germanium plate to form a thermocouple, and an electro-responsive instrument electrically connected to the germanium plate and the copper wire.

8. A microwave wattmeter, comprising in combination a transmission line having a hollow conductor, a terminating resistor in the form of a plate of thermo-electric material mounted over the end of the hollow conductor, an element composed of a different metal from the plate, connected thereto to form a thermocouple, and an electro-responsive instrument connected to said thermocouple elements.

9. A wattmeter, comprising in combination an enclosed-field transmission line, a disc terminating resistor connected thereto forming an element of a thermocouple, said disc resistor being bonded to the conductive sheath of said transmission line at a plurality of points thereabout and an electro-responsive instrument connected to the thermocouple.

10. A wattmeter, comprising a coaxial transmission line having inner and outer conductors, a stationary terminating impedance disc across one end of the outer conductor, and means responsive to variations in the temperature of the inner region of said disc relative to the outer region thereof for indicating electric power dissipated in said disc.

11. In combination, a transmission line, a disc impedance terminating said line in its characteristic impedance, composed of solid material variable in temperature in response to variations in power absorption, and thermocouple means integral with said disc impedance and responsive to variation in the temperature of the terminating impedance for indicating electric power transmitted through said line.

12. A thermocouple termination for a microwave transmission line, comprising a plate of non-conducting material, a film of thermo-electric material on the surface of said non-conducting plate, and an element comprising a different metal connected to said film to form a thermojunction.

13. A microwave wattmeter, comprising a hollow conductor and a terminating plate at the end of the hollow conductor, comprising a non-conducting plate with a film of thermo-electric material in electrical contact with the hollow conductor, having an element, composed of a different metal, electrically connected to a portion of the film to form a thermojunction.

14. Apparatus for matched-impedance termination of an enclosed-field transmission line for dissipating all of the energy transmitted through said line and indicating the power dissipated, comprising a substantially planar resistive solid impedance element extending across said line perpendicular to the axis thereof, said resistive impedance element being thermally coupled to said line for efficient transfer of heat and also being of such impedance value as to provide matched-impedance termination of said line for the prevention of ultra high frequency energy reflections, and means connected to and cooperating with the central area of said resistive impedance element and responsive to the temperature rise of said cntral area for indicating the ultra high frequency power dissipated in said planar resistive impedance element.

15. Ultra high frequency apparatus for matched-impedance termination of an enclosed-

field transmission line for dissipating and indicating the power transmitted therethrough, comprising a substantially planar resistive stationary impedance element extending across said line perpendicular to the axis thereof, said resistive impedance element being thermally coupled to said line for efficient transfer of heat into said line and also being of such impedance value as to provide matched-impedance termination of said line for the prevention of ultra high frequency energy reflection therein, a further element connected to the central area of said resistive impedance element and cooperating therewith for responding to the temperature rise of said central area, and indicator dial and pointer apparatus supported by said line in such a manner that said planar resistive impedance element is shielded thereby, said indicator apparatus being coupled with said temperature-responsive element for actuation of the indicator pointer according to the temperature rise of said central area.

16. A wattmeter, comprising a coaxial transmission line having an inner conductor and an outer conductor, a terminating impedance disc across one end of said outer conductor connected to said outer conductor and capacitively coupled to said inner conductor, and means responsive to variations in the temperature of said disc for providing a measure of power transmitted through said coaxial transmission line.

HUGH E. WEBBER.

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