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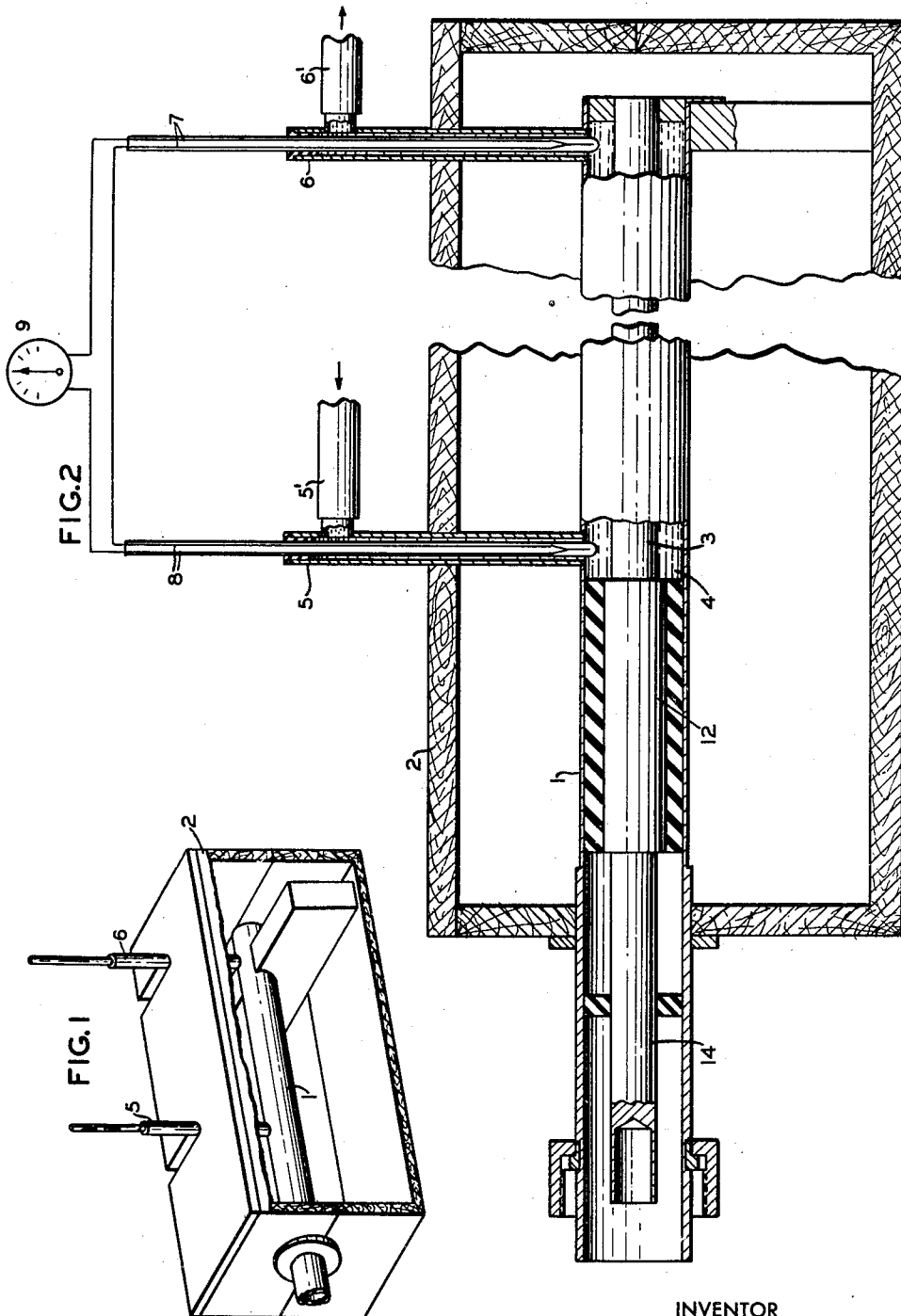
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HIGH-FREQUENCY WATTMETER

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HIGH-FREQUENCY WATTMETER

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This invention relates particularly to wattmeters and has reference more particularly to a novel calorimeter type of ultra high frequency wattmeter suitable for measuring the power in concentric lines and wave guides.

The novel wattmeter of this invention serves to dissipate the electromagnetic energy of the concentric line or waveguide directly in the coolant employed, thereby not only simplifying the structure of the wattmeter but also obtaining high accuracy in adapting the wattmeter for use in the high power ranges as well as for low powers.

The principal object of the present invention is to provide a novel high frequency wattmeter employing a coolant as the dielectric of a concentric line or wave guide, as the case may be.

Another object of the present invention is to provide a novel wattmeter that has very broad band response, being operable substantially independent of frequency of the supplied energy over a wide band.

Still another object of the present invention is to provide a novel wattmeter of the above character especially valuable for use in the higher power ranges, said wattmeter being extremely accurate and of unvarying characteristics.

A further object of the present invention is to provide a novel wattmeter wherein the energy-absorbing medium is accurately matched to the supply line through the intermediary of a line section employing a different suitable dielectric material such as polystyrene. This line section performs the dual function of matching the liquid-filled section to the supply line and sealing the liquid in the line.

Other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is a perspective view, partly broken away, of one form of wattmeter of the present invention adapted for use in connection with a concentric line;

Fig. 2 is enlarged central sectional view of the structure of Fig. 1;

Fig. 3 is a sectional view of a somewhat modified construction;

Fig. 3a is a fragmentary portion of the structure of Fig. 3 showing a somewhat modified construction; and

Fig. 4 illustrates the wattmeter of the present invention as applied to a waveguide.

Similar characters of reference are used in all

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of the above figures to indicate corresponding parts.

Referring now to the structure illustrated in Figs. 1 and 2 of the drawings of the novel wattmeter of this invention, an outer conductor 1 is shown mounted within a housing 2, the said conductor 1 having an inner conductor portion 3 surrounded by a liquid dielectric 4, which may be water for example, and which dielectric serves directly to absorb the electromagnetic energy travelling down the concentric line. The increase in heat of the dielectric 4, which when taken with the rate of flow is a measure of the power, is indicated by calorimetric methods.

In the drawing the dielectric is shown circulating within the concentric line section surrounding the inner conductor portion 3. To facilitate this circulation, tubes 5 and 6 are attached to the outer conductor, one at each end of the liquid dielectric section, and the liquid dielectric is forced through these tubes via branch tubes 5' and 6', thereby maintaining a steady flow of dielectric in surrounding relation to inner conductor 3 and within the outer conductor 1.

In order to measure the amount of heat absorbed by the dielectric, i. e. to indicate the power of the line, a suitable thermocouple arrangement may be employed, using thermocouples 7 and 8 mounted in the tubes 6 and 5 respectively, the said thermocouples being connected to the meter 9 directly or through a suitable amplifier if desired. Means for measuring the rate of flow of the liquid is preferably employed to obtain uniform results. The meter 9 may be calibrated directly in power units if desired. Instead of using the thermocouple arrangement shown, it is possible to employ thermometers 10 and 11, as shown in Fig. 3, mounted in the tubes 5 and 6 respectively and by subtracting the readings of the thermometers and measuring the rate of liquid flow, the energy absorbed may be measured.

In order that the wattmeter present a matched load to the line, the length of liquid-filled line should be such as to provide sufficient attenuation so that the reflected wave of energy from the shorted end of the line is small enough to be neglected. The impedance of the liquid-filled line is then transformed to that of the air-filled line by the use of an intermediate section, which employs a solid dielectric such as polystyrene to provide a water seal. The dimensions of this section of line employing a low-loss solid dielectric are chosen so that it will perform the required electrical transformation. For example, the transformation will be effected when the inter-

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mediate section of line is electrically a quarter-wavelength long and has a characteristic impedance that is the geometric mean of the characteristic impedances of the adjoining air-filled and liquid-filled line sections.

This is an approximation that neglects any imaginary component in the characteristic impedances of these adjoining line sections, but these imaginary components, if they are appreciable, may be taken into account by more precise calculations.

The following is a typical approximate calculation, such as is performed in designing a wattmeter of this type.

The loss per unit length in the water-filled line is given by

$$\alpha = 27.3 \sqrt{\frac{\epsilon_1'}{\lambda}} \tan \zeta \text{ db./unit length}$$

wherein

ϵ_1' is the dielectric constant of water,

λ is the wavelength 20 cm. in this calculation, and $\tan \zeta$ for small values of ζ is substantially equal to the power factor of a condenser using the dielectric.

Assuming that ϵ_1' is equal to 75, and the tangent of ζ equal to .13,

$$\alpha = 27.3 \sqrt{\frac{75}{20}} \times .07 = .826 \text{ db./cm.}$$

20 db. are ample for a termination, so ten inches of water line would be suitable. The polystyrene section must be electrically a quarter wavelength, i. e. $\lambda/4$ long.

$$\lambda/4 \text{ in air} = 1.97$$

$$\epsilon_{\text{poly.}} = 2.5$$

$$\lambda/4 \text{ in polystyrene} = 1.97/$$

$$\sqrt{\epsilon_{\text{poly.}}} = 1.97/\sqrt{2.5} = 1.24''$$

The impedance of the polystyrene section must be such as to match the air line section to the water line section.

Z_0 = impedance of the air-filled line.

$Z_0/\sqrt{75}$ = impedance of the water-filled line.

Z_0' = impedance of the polystyrene line.

$$Z_0 = Z_0'/75^{1/4}$$

The form of wattmeter so far described is somewhat limited in band width, it being noted that a definite length of transformer section is required for a given wavelength. In order to make this wattmeter present a matched impedance over a wide band of frequencies, it is necessary to choose the diameters of the polystyrene and water-filled sections so as to maintain a constant impedance along the line (neglecting the phase angle in the characteristic impedance of the water section). For the impedance in the dielectric-filled line section to be equal to that of the air-filled line, the radius of the inner conductor a' in the dielectric filled region should be

$$a' = \frac{b}{\left(\frac{b}{a}\right)\sqrt{\epsilon}}$$

where

a is the inner radius of the air-filled line,

b is the outer radius of both lines, and

ϵ is the dielectric constant of the dielectric medium separating the conductors.

For example, if $2b = .805$, $2a = .375$.

$$\epsilon_{\text{poly.}} = 2.52$$

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a' in the polystyrene dielectric region =

$$\frac{.402}{(2.15)\sqrt{2.52}} = \frac{.402}{2.15^{1.50}} = \frac{.402}{3.38} = .119$$

5 $\epsilon_{\text{water}} = 75$

a' in the water dielectric region =

$$\frac{.402}{(2.15)\sqrt{75}} = \frac{.402}{2.15^{8.66}} = \frac{.402}{760} = .00053''$$

Such a constant impedance wattmeter is shown in Fig. 3. In this figure, the outer conductor is designated 16 and the small inner conductor of the water-filled line is designated 17, while 18 is the polystyrene section, which may be quite short, and not necessarily a quarter-wavelength in length. The inner conductor of the air-filled line is designated 19 and that of the polystyrene section is designated 20.

Also, if desired, the small central conductor of the liquid dielectric line section can be reinforced by suitable means, such as a polystyrene coating shown at 21 in Fig. 3a and the diameters adjusted to maintain a constant impedance.

It will be noted that with water as the power absorbing liquid, the central conductor becomes extremely small, i. e., .00053'' radius, if it is desired to have the wattmeter matched at all wavelengths for which there is sufficient attenuation in the water-filled line. However, it should be noted that it is not necessary to use water as the absorbing liquid. Some other liquid could be used having a lower dielectric constant. Also, if the diameter of such water filled line is reduced a practical amount to, say, .050'', and the polystyrene section designed to match such a line to the air-filled line, the band width over which the wattmeter is matched will be considerably increased over that shown in Figs. 1 and 2.

The novel wattmeter of this invention is not designed for use in connection with concentric lines alone, but the same may also be used in connection with waveguides. The structure shown in Fig. 4 illustrates the wattmeter applied to a waveguide. In this structure the waveguide 22 is shown having a water-filled section 22' through which the water is circulated as shown in connection with Figs. 1 and 2. In order to match the impedance of the air-filled line with that of section 22', a metal insert 23 is employed together with a polystyrene insert 24, these inserts being electrically a quarter-wavelength in length. It will be borne in mind that the wattmeter will remain matched as long as there is sufficient attenuation in the water-filled section, so that reflections from the end of the line will be negligible, and this attenuation per unit length would be linearly proportional to the frequency if the dielectric constant and power factor of water remained unchanged with changing frequency.

Since 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 drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

70 1. A microwave wattmeter comprising a coaxial transmission line having a liquid filled section, temperature responsive means for measuring power absorbed by said liquid filled section, said liquid serving as a dielectric power absorbing

75 medium a supply line section, and a matching

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section between said supply line section and said liquid filled section, said matching section including inner and outer conductors whose diameters bear a different ratio to each other than the inner and outer conductors of said liquid filled section, and a body of solid dielectric material filling the space between said conductors in said matching section, said body acting as a seal to maintain said liquid in said liquid filled section.

2. A microwave wattmeter comprising a coaxial transmission line having a liquid filled section, temperature responsive means for measuring power absorbed by said liquid filled section, said liquid serving as a dielectric power absorbing medium a supply line section, and a matching section between said supply line section and said liquid filled section, said matching section including an inner conductor whose diameter is substantially greater than that of the inner conductor of said liquid filled section, and a body of solid dielectric material filling the space between said conductors in said matching section,

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said body acting as a seal to maintain said liquid in said liquid filled section.

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