Sept. 20, 1960 A. V. JAMES 2,953,745

MIDGET CALORIMETRIC POWERMETER

Filed Dec. 6, 1957

FIG. 1

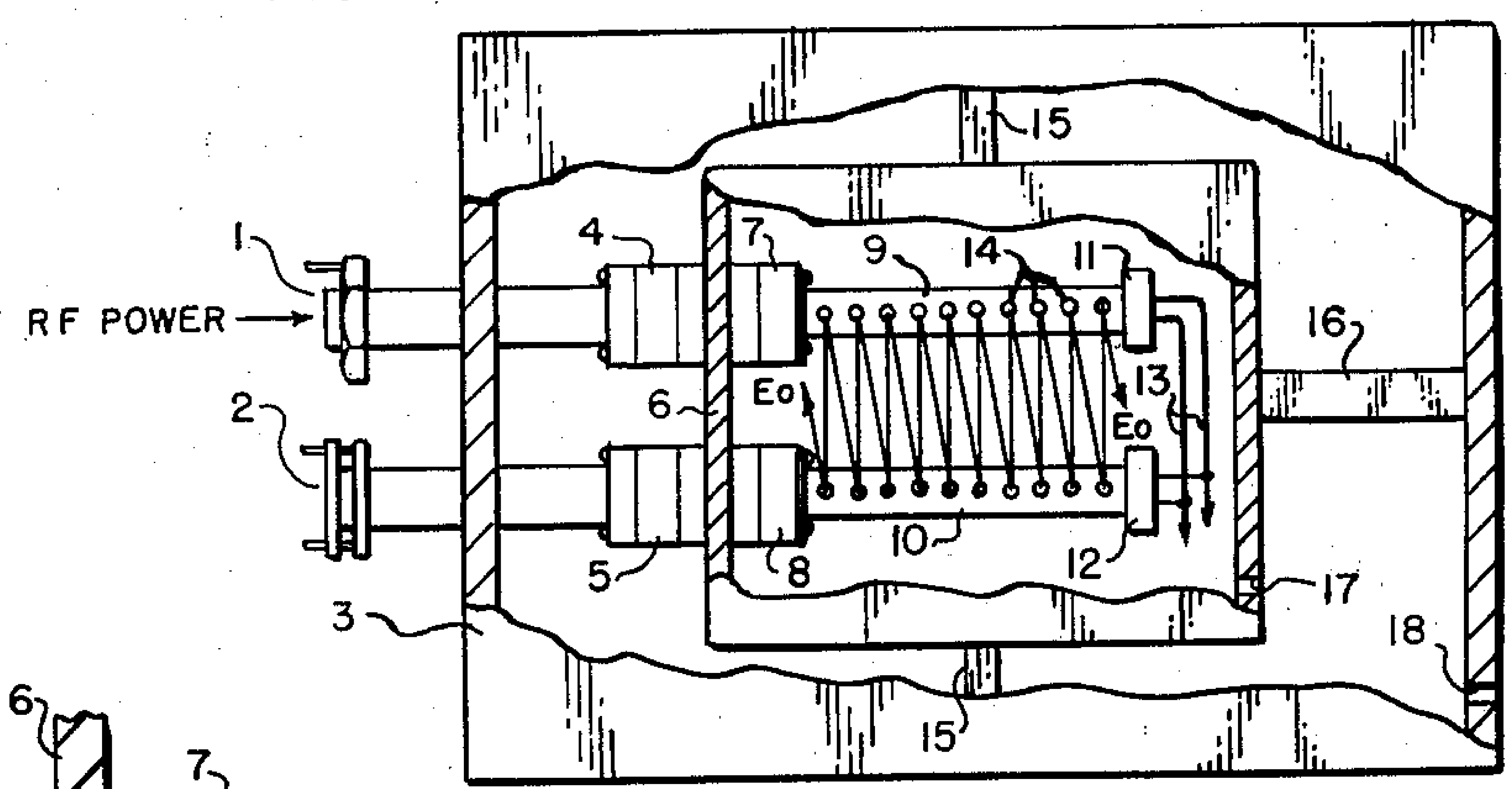



FIG. 1a

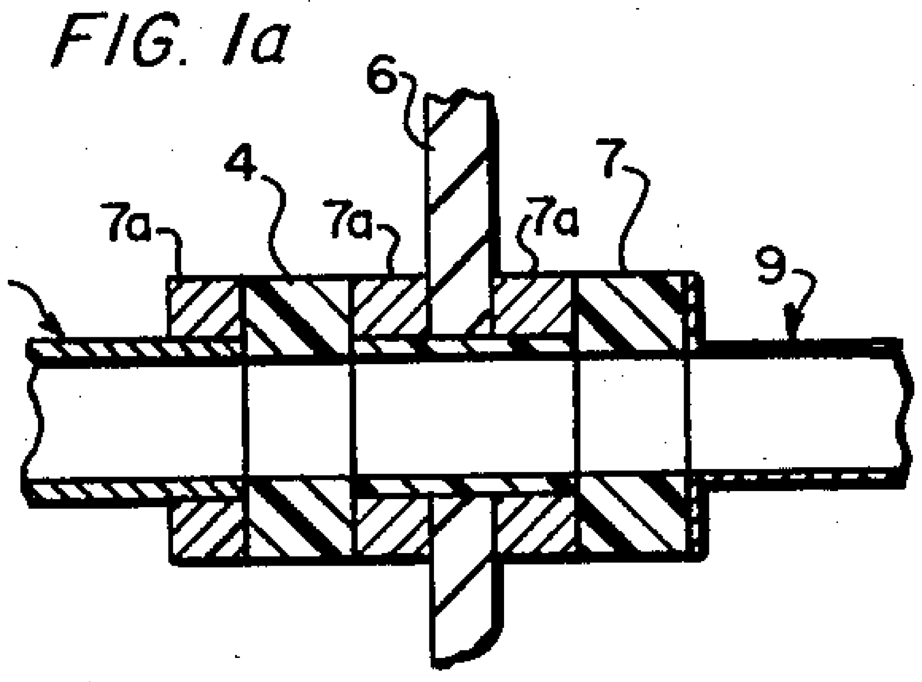



FIG. 2

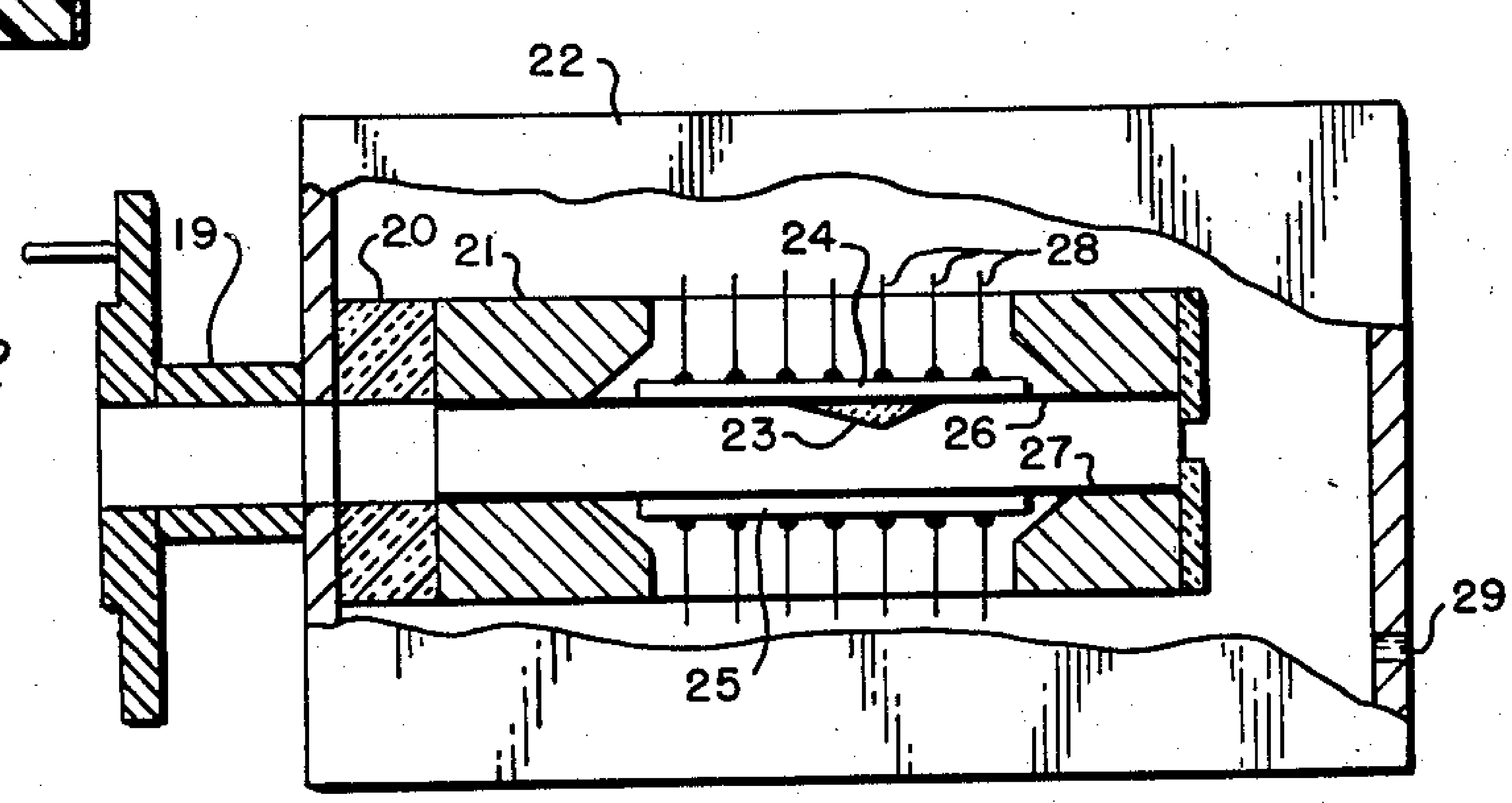



FIG. 3

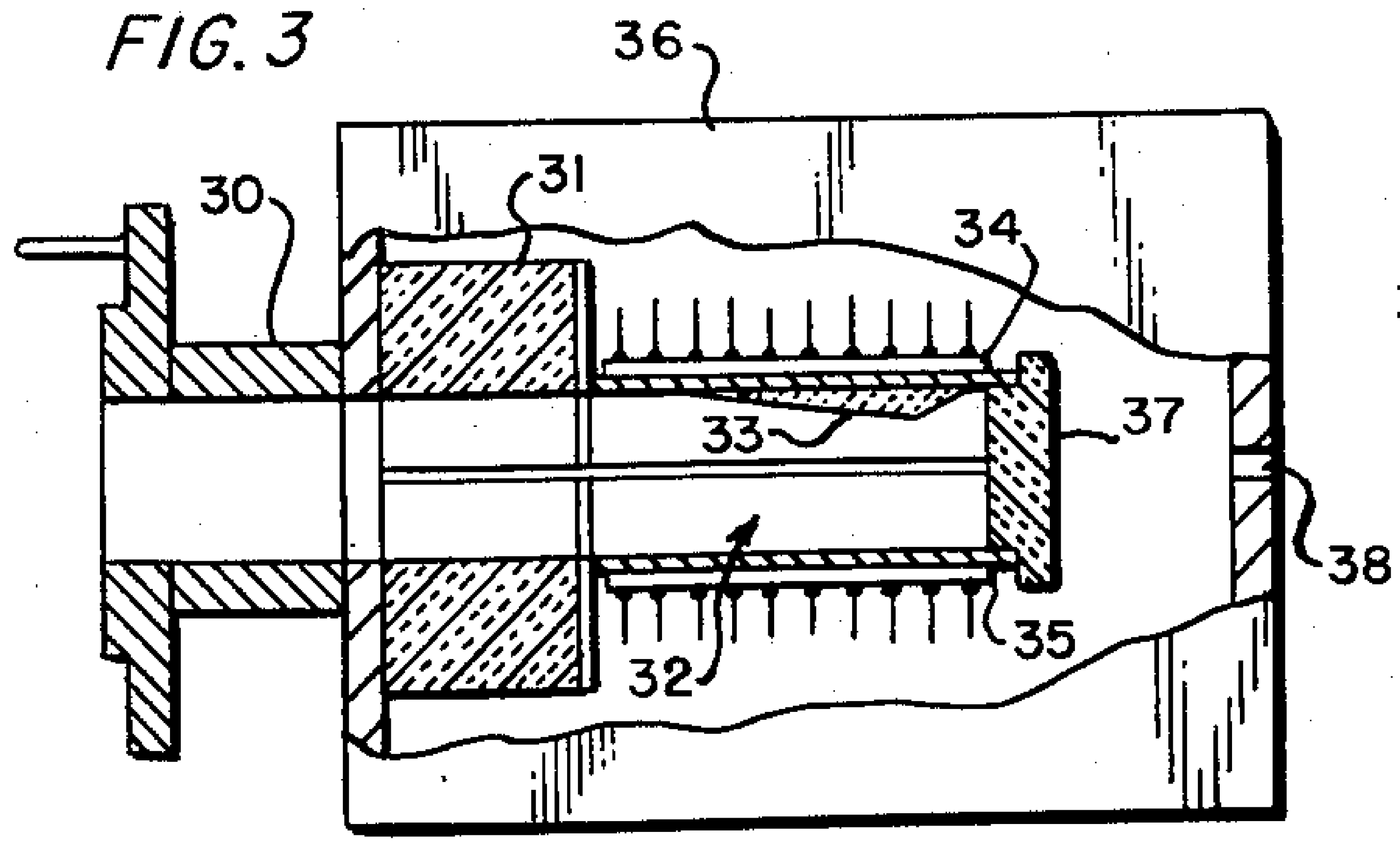
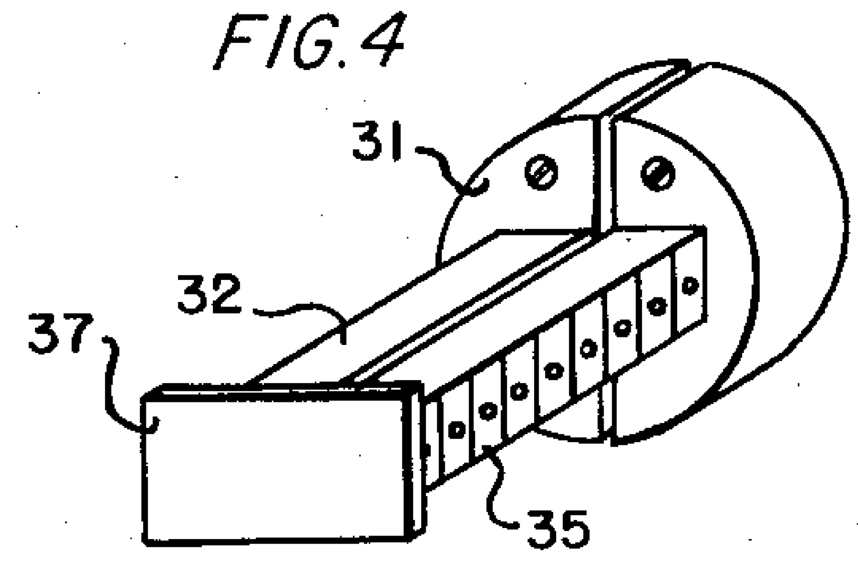



FIG. 4

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# MIDGET CALORIMETRIC POWERMETER

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This invention relates to a calorimetric powermeter and more particularly to such a powermeter which is smaller in size and quicker reading than previous calorimetric powermeters.

In the present state of the art a time interval of several minutes is required for the output of the calorimetric powermeter to reach constant level after the application of the RF power which it is desired to measure. Some instrumentation systems have already been suggested for the reduction of the time necessary to make an RF power measurement. These systems, however, do not change the time constant of the powermeter; instead, they give a constant output indication which is a function of the output characteristics of the powermeter. In addition, these instrumentation systems introduce additional errors in the reading of RF powers and the additional equipment necessary can become both bulky and expensive.

It is among the objects of this invention to provide a calorimetric powermeter for measuring RF power which will give a quick and accurate output indication of the level of RF power at its input port within a time interval of a few seconds without the aid of auxiliary equipment.

Other objects of the invention are to provide a calorimetric powermeter which will be relatively small and compact in size, will be extremely broadband in operation, and whose output will be insensitive to ordinary variations in room temperature. The power range of the instrument may be from the order of microwatts to several hundred milliwatts or more.

The exact nature of the invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawing in which:

Figure 1 is a side view of a prior art calorimetric powermeter with part of the output casing broken away to show the inner construction;

Figure 1*a* is a sectional view of part of Figure 1;

Figure 2 is a partial cross-sectional view of one embodiment of the invention;

Figure 3 is a partial cross-sectional view of another embodiment of the invention; and

Figure 4 is a perspective view of the embodiment shown in Figure 3.

Referring now to the drawings, wherein like reference numerals designate like or corresponding parts, there are shown in Figure 1, which is a view of a prior art device, two sections of waveguide **1** and **2** which extend through the outer metal jacket **3**. Bakelite thermal insulators **4** and **5** are interposed between the input waveguide and the inner metal jacket **6**. A second set of Bakelite thermal insulators **7** and **8** are utilized to separate the thin-walled sections **9** and **10** of the waveguide from the inner metal jacket. Waveguides **1** and **2** are generally of standard thickness while waveguides **9** and **10** are special waveguides which are extremely thin, approximately 0.010″ thick. The manner in which the thermal insulation is accomplished is best seen in Figure 1*a*, which is a cross-



sectional view of the junction of inner metal jacket **6** and waveguide **1**, with like reference numerals designating like elements. The metallic sections labeled **7*a*** in Figures 1*a* are utilized to secure the Bakelite insulators **4** and **7**.

The inner metal jacket is supported by Bakelite standoff insulators **15** and **16**. Broadband tapered loads are held in place inside the thin-walled waveguide sections by load holders **11** and **12**. Low frequency power is applied to both loads by means of conducting wires **13** which are permitted to pass through openings **17** and **18** in the two metal jackets by way of a shielded cable, the cable not being shown. The thermocouple junctions **14** are bonded in pairs to the thin-walled waveguide sections **9** and **10**. The output leads of the thermocouple junctions, indicated as $E_0$ in the figure, pass through the shielded cable to an appropriate voltage indicator. Waveguide **1** is the active waveguide into which the RF power desired to be measured is introduced and waveguide **2** is a reference waveguide into which no RF power is introduced. The low-frequency power is applied for calibration purposes. It is assumed that when the low-frequency power is removed and RF power applied, the same output indication will result from equal amounts of low-frequency and RF powers.

When RF power enters waveguide **1**, it is dissipated in the form of heat by the load. The temperature of the active waveguide rises above that of the reference waveguide. This difference in temperature between the active and the reference waveguides causes the thermocouples to develop a voltage that is a function of the magnitude of the RF power and the length of time that the RF power is applied. The output is of the form:

$$E_0 = Sq\frac{R_cR}{2R+R_c}\left(1-e^{-\frac{2R+R_c}{R_cRC}t}\right)$$

where:

$E_0$ is the output voltage in microvolts.

S is the sensitivity of the array of thermojunctions in microvolts-per-degree centigrade.

$q$ is the heat flow into the thin-walled waveguide (waveguide No. 1) in calories-per-second.

$R_c$ is the thermal resistance between the two thin-walled waveguides in seconds-per-caloric times degrees centigrade.

R is the convective thermal resistance between the two thin-walled waveguides in the same units as for $R_c$.

$e$ is the base of the natural logarithms and is approximately 2.71828.

$t$ is the time in seconds that the RF power is applied.

C is the thermal capacity associated with the thin-walled waveguide.

It can be noted from the equation that thermal resistance components R and $R_c$ affect both the magnitude of $E_0$ and the length of time it takes the output voltage $E_0$ to reach an appreciable percentage of its final value. On the other hand, the constant C affects only the rise time of $E_0$. Practical design limitations of powermeters of the type shown in Figure 1 prevent C from becoming small enough to make the powermeter quick reading. This limitation is overcome by the calorimeter of this invention, separate embodiments of which are shown in Figures 2 and 3.

Referring now to Figure 2, which is a view in cross-section of one embodiment of the invention, RF power enters the input waveguide **19** and is conducted through the thermal isolator **20** to the waveguide block **21**. The thermal isolator serves to separate the waveguide block from the metal jacket **22** and may be formed of any suitable material such as Bakelite. A matched load **23** of any suitable semi-conducting dissipative material is provided as shown. The RF power is conducted to the load by means of two thin RF conducting ribbons or strips **26** and **27**. Two thermocouple mounting strips **24** and **25** are provided as shown, mounting strip **24** being located on conducting ribbon **26** adjacent to load **23** and mounting strip **25** being located on conducting strip **27**. The matched load is heated by the RF power causing a difference in temperature between the two thermocouple mounting strips. The thermocouples **28** on the two mounting strips are connected together in the same manner as the thermocouples of Figure 1 and the leads are brought out through the opening **29** in the metal jacket. The output voltage developed by the battery of thermojunctions is directly proportional to the heating effect of the RF power. Since Figure 2 is a sectional view, the waveguide block is therein seen as cut away in the center in order to accommodate the thermocouple mounting strips and leads.

The two thin conducting ribbons serve a double purpose: they provide a conducting path for the RF power leading to the load and they also serve as thermal isolators for the thermocouple mounting strips.

It should be noted that the powermeter of Figure 2 uses no reference waveguide; one continuous waveguide path extends from the input waveguide to the temperature sensitive elements of the meter. Thermal symmetry is obtained without the use of a reference waveguide. All parts of the waveguide block are at a nearly uniform temperature, this being accomplished through thermally insulating the block from fluctuations in outside temperature by means of the thermal isolator **20** and the jacket **22**. The material used in making the block should be one of high thermal diffusivity.

The mass of the thermojunction mounting strip of Figure 2 is very small as compared to the mass of the thin-walled waveguide of Figure 1. Therefore, it can be seen that the value of C in the equation for the voltage developed, as given above, can be made very small and the powermeter output voltage quickly reaches its final value.

Calibration for the powermeter may be accomplished by locating direct-current heating elements on the thermocouple mounting strips and relating the outputs for comparable RF and D.C. heating as is conventional for calibration purposes. The D.C. heating is used in Figures 2 and 3 in place of the low frequency power used in Figure 1.

A second embodiment of the improved powermeter of this invention is shown in Figures 3 and 4. The principal difference between this embodiment and that of Figure 2 lies in the fact that use is made of a split thin-walled waveguide without the use of a waveguide block. As shown in Figure 3, RF power enters input waveguide **30** and is conducted through the thermal isolator **31** to the split thin-walled waveguide **32**. A matched load **33** is placed on one section of the split waveguide and thermocouple mounting strips **34** and **35** are placed on either section of the waveguide, strip **34** being adjacent to load **33** as shown. A metal jacket **36** is provided and a waveguide end cover which could be any suitable insulator is designated by reference numeral **37**. An opening **38** for an electric cable is provided in the metal jacket as shown.

A perspective view of the embodiment of Figure 3 is shown in Figure 4, with like reference numerals designating like parts. Figure 4 shows only the portion of



Figure 3 within jacket **36**. The operating principle of the powermeter of Figures 3 and 4 is the same as that of Figure 2.

The construction of the calorimetric powermeter of this invention as described herein has the advantages of short reading time, excellent temperature drift characteristics, small size due to the elimination of the reference waveguide and, in the case of the embodiment of Figure 2, the obviation of the need for a thin-walled waveguide.

Various modifications are contemplated and may obviously be resorted to by those skilled in the art without departing from the spirit and scope of the invention, as hereinafter defined by the appended claims, as only preferred embodiments thereof have been disclosed.

What is claimed is:

1. A compact calorimetric powermeter comprising an input waveguide for conducting radio-frequency power into the powermeter, a thermal isolator and a power dissipating section, a metal jacket surrounding said thermal isolator and said power dissipating section, said input waveguide leading successively into said thermal isolator and said power dissipating section, said power dissipating section comprising two substantially identical halves symmetrically arranged on either side of the waveguide axis so as to be equally accessible to R.F. power and each comprising a thin conducting member having a thermocouple mounting strip and thermocouples mounted thereon, said thermal isolator supporting said halves in said jacket, and a power dissipating load mounted on one of said halves.

2. A compact calorimetric powermeter comprising a single input waveguide for conducting radio-frequency power into said powermeter, a waveguide block, a thermal isolator, a rigid metal jacket completely enclosing said thermal isolator and said waveguide block, said thermal isolator supporting said waveguide block in said jacket in alignment with said input waveguide, said waveguide block having two elongated openings symmetrically arranged on opposite sides thereof, two substantially identical members inside the respective openings, each member comprising a thin elongated radio-frequency conducting ribbon covering the opening and having a thermocouple mounting strip and thermocouples thereon, and a matched power-dissipating load adjacent one of said ribbons.

3. A calorimetric powermeter comprising an input waveguide, a thin-walled waveguide longitudinally split into substantially identical halves, a thermal isolator supporting said split thin-walled waveguide and coupling it to said input waveguide, a metal jacket completely enclosing said thermal isolator and split thin-walled waveguide, a matched dissipative power load placed on the inside of one half of said split thin-walled waveguide, a thermocouple mounting strip and a plurality of associated thermocouples symmetrically mounted on each half of the split waveguide, one of said mounting strips being located adjacent said load.

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