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TEMPERATURE COMPENSATED RESONANT CAVITY

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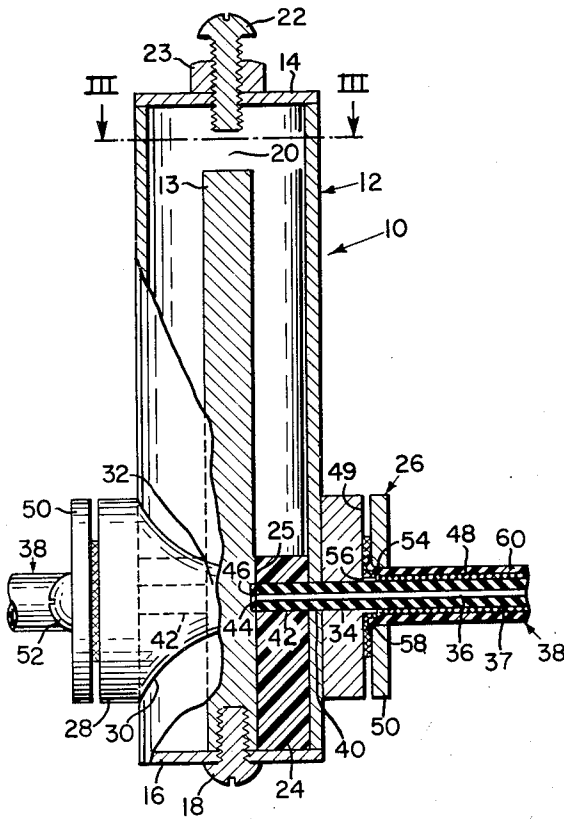


Fig. 2

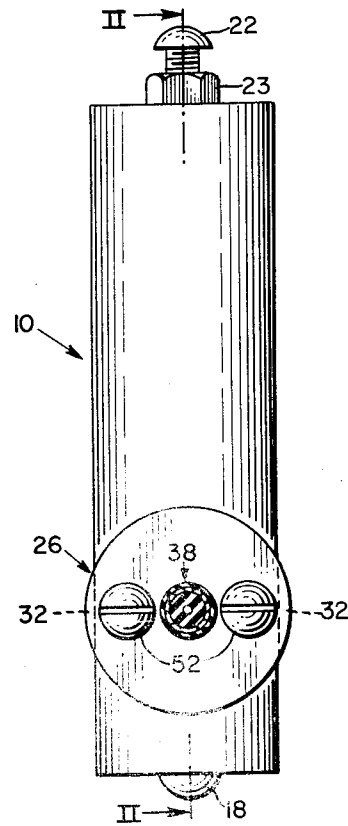


Fig. 1

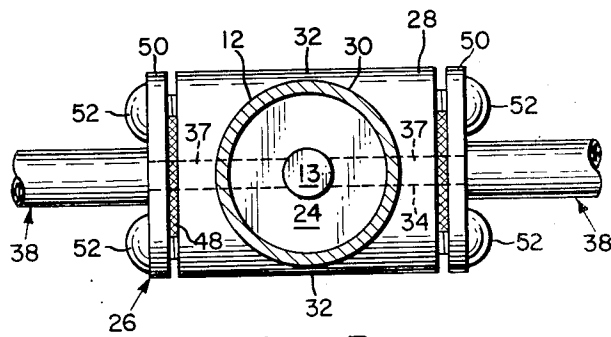


Fig. 3

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TEMPERATURE COMPENSATED RESONANT CAVITY

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to reactive devices and more particularly to cavity resonators or the like having compensating means for the physical changes in the resonator resulting from temperature variations.

It is well known that the resonant frequency of a resonant cavity fluctuates with dimensional changes caused by temperature variations. One known method employed to reduce this effect on frequency is to construct the cavity of an iron-nickel alloy, known as Invar, which has a very small coefficient of thermal expansion. As would be expected, the cost of resonant cavities made of this material is quite expensive and, further, cavities of this type do not provide complete compensation especially where the cavity is subjected to extreme temperature variations, as may occur in aircraft installations.

Another temperature compensating means that has been utilized consists of filling a resonant cavity made of conventional material with a gas having a dielectric constant which at high frequencies decreases with increasing temperature. Although use of such a gas obviates the disadvantages previously mentioned, there are inherent disadvantages in the use of a gaseous dielectric material, namely, a gas-tight cavity construction is required to prevent the gas from escaping which increases construction costs, and also reduces the versatility of the cavity so far as adjusting the degree of coupling.

Another disadvantage of both of the foregoing constructions resides in the necessity for providing additional means to support a coupling loop or probe extending within the cavity where it is subjected to severe shock and vibration.

According to this invention, the reactive device is provided with a solid dielectric substance having a dielectric constant that varies inversely with temperature and which substantially compensates for reactance variations due to dimensional changes in said device with changes in temperature. In a preferred embodiment the device is a resonant cavity, or in effect a short section of a transmission line, having inner and outer spaced conductors between which is positioned the solid dielectric material. The relative lengths of the dielectric material and the cavity depends on the relation between the coefficient of dielectric constant of the dielectric material and the coefficients of expansion of the cavity materials. The rigid dielectric material, which may be in a solid or granular form, is preferably located within the cavity at points of low impedance and also at the entrance position of a coupling probe to provide a support therefor when the cavity is subjected to shock or vibration.

Another feature of the invention resides in a novel connector for electrically coupling the resonant line or cavity to input and output conductors, such as R. F. coaxial

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cables. The connector comprises a body member having a transverse opening conforming to and slightly smaller than the cross-sectional configuration of the cavity to insure a force fit and a snug electrical connection without resort to brazing or the like. A longitudinal passage in the body intersecting the transverse opening enables the introduction of an inner coaxial conductor or probe into the cavity with clamping means provided for electrically and mechanically connecting the outer coaxial conductor to the body member.

A principal object of this invention is to provide a reactive device with a rigid dielectric material having a dielectric constant capable of stabilizing the reactance variations due to dimensional changes in the device with changes in temperature.

A further object is to provide the foregoing device with a dielectric material which will support a coupling probe extending into the device from shock and vibration.

Another object is to provide an improved connector for coupling the device to coaxial cables and the like, and which will enable the degree of coupling to be adjusted.

Still another object is to provide a resonant cavity which is made of inexpensive materials and simple to manufacture.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is an elevation view of a cavity resonator;

Fig. 2 is a partial section of the resonator taken along line II—II of Fig. 1; and

Fig. 3 is a top plan view of the resonator taken along line III—III of Fig. 1.

Referring now to the drawings where like reference characters designate like or corresponding parts throughout the several views, there is shown a resonant cavity 10 which may be used as a tuned filter or like component for radio or other electrical circuits. Resonant cavity 10 comprises an outer hollow conductor 12 and an inner conductor 13 securely disposed in spaced relation therein forming in effect a short section of a transmission line. Outer conductor 12 can be a cylindrical or rectangular tube, or a drilled block and having conductive end closure walls 14 and 16 preferably sealed thereto. One end of inner conductor 13 is electrically connected to end closure 16 by a screw 18 and extends toward end closure 14 but is spaced therefrom at 20 forming a $\frac{3}{4}$ wavelength resonator. Space 20 may be varied by an adjustable screw 22 threadedly mounted in end closure 14 and locked by a nut 23, screw 22 being movable along the longitudinal axis of inner conductor 13 cooperating with the end of inner conductor 13 as a variable capacitor for tuning the resonance of the cavity to the input frequency.

Inner and outer conductors 13 and 12, which may be constructed of copper and brass, respectively, expand or contract with changes in temperature, and when the outer and inner conductors are made of such metals having similar temperature coefficients of expansion, spacing 20 remains substantially constant throughout any temperature change. However, since inner conductor 13 undergoes a change in length, there is a change in the physical length of the resonant cavity.

In order to prevent a change in the electrical length of the cavity, a solid dielectric body 24 having a longitudinal passage 25 to receive conductor 13 is employed within the cavity and is made of a substance having a negative temperature coefficient of dielectric constant, that is to say, the dielectric material has a dielectric constant that varies inversely with temperature so as to substantially compensate for resonant frequency variations due to the

dimensional changes in the resonator with changes in temperature. The length of the dielectric material to provide such a compensation factor will depend on the temperature coefficient of dielectric constant of the dielectric material selected. Where the dielectric materials fill less than the entire cavity that which remains can be an air space. One dielectric material having the foregoing properties that has been found to work satisfactorily is polyethylene, the dielectric material present in a type RG-17/U radio frequency cable manufactured by the Federal Telephone and Radio Corporation, and the length of such dielectric material necessary to accomplish the desired results being determined by the following derivation:

The physical length of the resonant line is:

$$(1) \quad l = l_a + l_p$$

where

l = length of the inner conductor

l_a = length of the air space between the free end of the inner conductor and polyethylene material and

l_p = length of the polyethylene material.

The known constants are:

C_c = temperature coefficient of expansion of copper and brass = $0.18 \times 10^{-4}/^\circ\text{C}$. (approx.)

C_p = temperature coefficient of expansion of polyethylene = $0.18 \times 10^{-4}/^\circ\text{C}$. (approx.)

C_k = temperature coefficient of dielectric constant of polyethylene = $-2 \times 10^{-4}/^\circ\text{C}$. (approx.)

K = dielectric constant of polyethylene = 2.25 (approx.).

At temp T electrical length of resonant line is:

$$(2) \quad L = (l - l_p) + \sqrt{K}l_p$$

At temperature T' , such that $T' - T = \Delta T$, the electrical length is:

$$(3) \quad L' = (l' - l'_p) + \sqrt{K'}l'_p$$

where,

$$l' = l(1 + C_c \Delta T)$$

$$l'_p = l_p(1 + C_p \Delta T)$$

$$\sqrt{K'} = \sqrt{K(1 + C_k \Delta T)}$$

with the proper choice of l and l_p complete compensation will result making the electrical lengths at L and L' equal. Assuming such compensation is achieved, it is desired to find the necessary relation between l and l_p . Thus, assume:

$$(4) \quad L = L'$$

Substituting (2) and (3) into (4)

$$l - l_p + \sqrt{K}l_p = l' - l'_p + \sqrt{K'}l'_p$$

Introducing unprimed equivalents into the primed terms:

$$l - l_p + \sqrt{K}l_p = l(1 + C_c \Delta T) - l_p(1 + C_p \Delta T) + \sqrt{K(1 + C_k \Delta T)}l_p(1 + C_p \Delta T)$$

$$l - l_p + \sqrt{K}l_p = l + lC_c \Delta T - l_p - l_p C_p \Delta T + \sqrt{K(1 + C_k \Delta T)}l_p(1 + C_p \Delta T)$$

Dividing all terms by $l_p C_p \Delta T$ and collecting terms:

$$(5) \quad \frac{l}{l_p} = \frac{C_p \Delta T + \sqrt{K}(1 - \sqrt{1 + C_k \Delta T} - C_p \sqrt{1 + C_k \Delta T})}{C_c \Delta T}$$

Values of ΔT are restricted to temperature variations over which the variation of dielectric constant with temperature is essentially linear, thus C_k is considered constant over the temperature range normally encountered. For simplicity assume $\Delta T = 1^\circ\text{C}$. and evaluate (5) with the constants noted above:

$$\frac{l}{l_p} = \frac{1.8 \times 10^{-4} + 1.5(1 - \sqrt{1 - .0002} - .00018\sqrt{1 - .0002})}{.18 \times 10^{-4}}$$

(6)

$$\frac{l}{l_p} = 3.33, \text{ or } \frac{l_p}{l} = \frac{1}{3}$$

Any correction of this ratio to allow for electrical discontinuity at the junction of the air and polyethylene dielectric is negligible. Using polyethylene at one-third, the length of the inner conductor 13 exhibited an inconsequential change of resonant frequency with temperatures from -25°C . to 75°C .

The term solid dielectric material is meant to include a dense and rigid material, such as polyethylene, or any confined granular material having the desired negative temperature coefficient of dielectric constant, as long as the dielectric material is capable of supporting against shock and vibration either a magnetic loop or electrostatic coupling probe that may be inserted into the cavity.

Referring again to Fig. 2, another novel feature of the invention resides in providing an electrical connector 26 for coupling suitable coaxial cables to resonant cavity 10 to provide an inductive or capacitive coupling, the latter being illustrated.

The coupling or connector comprises a body member 28, which preferably is a cylindrical rod having formed therethrough a transverse opening 30 conforming to but slightly smaller than the configuration of outer conductor 12 to provide a force or press fit and consequently a good electrical connection without the need of soldering, brazing or other time-consuming means of making the connection. When a cylindrical cavity is employed, opening 30 may be drilled slightly smaller in diameter than both outer conductors 12 and the diameter of rod body member 28, the latter being such that a thin and reduced wall section 32 remains on each side of the body member giving the body member sufficient resilience to grip outer conductor 12 at all times, which is especially important if the cavity is to be subjected to wide temperature variations. In the intersection of two cylinders as shown in Fig. 2, wall sections 32 are smaller in height at the thinnest point forming a recessed mouth to opening 30 at each side of the body member which greatly facilitates the insertion of outer conductor 12 into the body during assembly by enabling the former to be gradually forced into the opening.

Body member 28 also has a drilled longitudinal passage 34 intersecting opening 30 and through which may be inserted at each end an inner conductor 36 and insulation 37 of input and output R. F. coaxial cables 38 to be electrically coupled to the cavity. The details of only one of the coaxial cables 38 and the corresponding section of connector body 28 is illustrated since the other cable and body section can be of a duplicate construction. The wall of outer conductor 12 and dielectric material 24, when it consists of a rigid material such as polyethylene, are provided with a pair of drilled passages 40 and 42, respectively, aligned with passages 34 to permit the free end of inner coaxial conductors 36, which function as input and output probes, to be closely spaced and coupled to inner conductor 13. One of the advantages of dielectric material 24, whether it be a compact or loose material, resides in the support that it offers the probe against shock and vibration. The degree of coupling is controlled by positioning between inner conductors 13 and 36 one or more thin discs 44 of hard dielectric material having a high melting point, such as polytetrafluorethylene plastic known as "Teflon." If the discs are made about 0.10 inch thick a convenient range of adjustability is afforded by use of as many discs as are needed. The peripheral surface of inner conductor 13 may be flattened at 46 on each side to receive the dielectric discs 44 and ensure a constant coupling.

The end of outer coaxial conductor 48, usually of a braided construction, is expanded and clamped by a washer 50 and bolts 52 to the end face 49 of connector body 28 for electrical connection to outer conductor 12. Washer 50 has a bore opening 54 through which is

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passed the coaxial cable prior to assembly. Connector body face 49 is formed with an integral collar 56 which cooperates with a beveled neck 58 of washer 50 to wedge outer coaxial conductor 48 and coaxial cable jacket 60 against the connector body and ensure a sealed joint. This clamping action also forces the inner coaxial conductor 36 inwardly which seats discs 44 against inner conductor 13.

The use of a solid dielectric material in a transmission line which may form a part of a cavity resonator furnishes the needed temperature compensation for physical variations without resort to expensive conductive metals, such as "Invar" or to complicated constructions. The solid dielectric material, which can be in a rigid or loose form, functions also to support the magnetic loop or electrostatic probe within the transmission line against shock and vibration. When a compact dielectric material is employed, such as polyethylene, the dielectric material may be fabricated of a single piece, as illustrated, or separated into spaced beads secured within the outer conductor of the transmission preferably located at points of low impedance and at the entrance area of the coupling probe into the transmission line to provide the needed support therefor. A simple force-fit connector is provided for coupling the transmission line to R. F. coaxial cables which connector eliminates costly and tedious soldering operations or the like. The inner and outer conductors of R. F. cables are securely attached to the transmission line by the connector and sealed from atmospheric elements.

Obviously many modifications and variations of the present invention are possible in the light of the above teaching. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

We claim:

1. A temperature-compensated electrical apparatus including an enclosed resonant device adapted to receive a coupling conductor extending therein, a solid dielectric substance in said device and capable of supporting said coupling conductor, said dielectric having a dielectric constant that varies inversely with temperature substantially to compensate for resonant frequency variations due to dimensional changes in said device with changes in temperature.

2. A temperature-compensated electrical apparatus including an enclosed resonant device adapted to receive a coupling conductor extending therein, a solid and rigid dielectric substance in said device and having an aperture to receive and support said coupling conductor, said dielectric having a dielectric constant that varies inversely with temperature substantially to compensate for resonant frequency variations due to dimensional changes in said device with changes in temperature.

3. A temperature-compensated resonant cavity comprising an elongated outer hollow electrical conductor made of brass and a concentrically spaced inner electrical conductor made of copper secured to one end of said outer conductor and extending toward and spaced from the other end of the outer conductor, a solid dielectric material positioned in the space between said inner and outer conductors and having a dielectric constant that varies inversely with temperature substantially to com-

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pensate for resonant frequency variations due to dimensional changes in said resonant cavity with temperature changes, said dielectric material being polyethylene and having a length substantially one-third of the length of the inner conductor.

4. A temperature-compensated resonant cavity comprising an elongated outer hollow electrical conductor and an inner spaced electrical conductor secured to one end of said outer conductor and extending toward and spaced from the other end of the outer conductor, a solid dielectric body positioned in the space between said inner and outer conductor, said dielectric having a dielectric constant that varies inversely with temperature substantially to compensate for resonant frequency variations due to dimensional changes in said resonant cavity with changes in temperature, a coupling body for connecting input and output coaxial cables to the cavity, said dielectric body, outer conductor, and coupling body each having aligned openings for receiving the inner coaxial conductor.

5. A temperature-compensated resonant cavity comprising an elongated outer hollow electrical conductor and an inner spaced electrical conductor secured to one end of said outer conductor and extending toward and spaced from the other end of the outer conductor, a solid dielectric body positioned in the space between said inner and outer conductors, said dielectric having a dielectric constant that varies inversely with temperature substantially to compensate for resonant frequency variations due to dimensional changes in said resonant cavity with changes in temperature, a coupling body for connecting input and output coaxial cables to the cavity, said dielectric body, outer conductor, and coupling body each having aligned openings for receiving the inner coaxial conductor, an insulating disc positioned in the opening of the dielectric body for spacing the inner cavity conductor from the inner cable conductor.

6. A temperature-compensated resonant cavity comprising an outer cylindrical hollow electrical conductor and a concentrically spaced inner electrical conductor secured to one end of said outer conductor and extending toward and spaced from the other end of the outer conductor, a solid dielectric body positioned in the space between said inner and outer conductors, said dielectric having a dielectric constant that varies inversely with temperature substantially to compensate for resonant frequency variations due to dimensional changes in said resonant cavity with changes in temperature, a coupling for connecting input and output R. F. coaxial cables to the cavity, said coupling including a coupling body formed of a round rod member having a transverse circular opening with a smaller diameter than the diameter of the outer cylindrical conductor to receive the latter in a force fit, said dielectric body, outer cylindrical body, and coupling body each having aligned openings for receiving the inner coaxial conductor, and a washer mounted on the coupling body for clamping the outer coaxial conductor to the coupling body.

References Cited in the file of this patent

UNITED STATES PATENTS

2,475,035	Linder	July 5, 1949
2,694,183	Edlen et al.	Nov. 9, 1954