Jan. 4, 1938. J. W. CONKLIN 2,104,554

LINE RESONATOR

Filed Sept. 21, 1935

Fig. 2

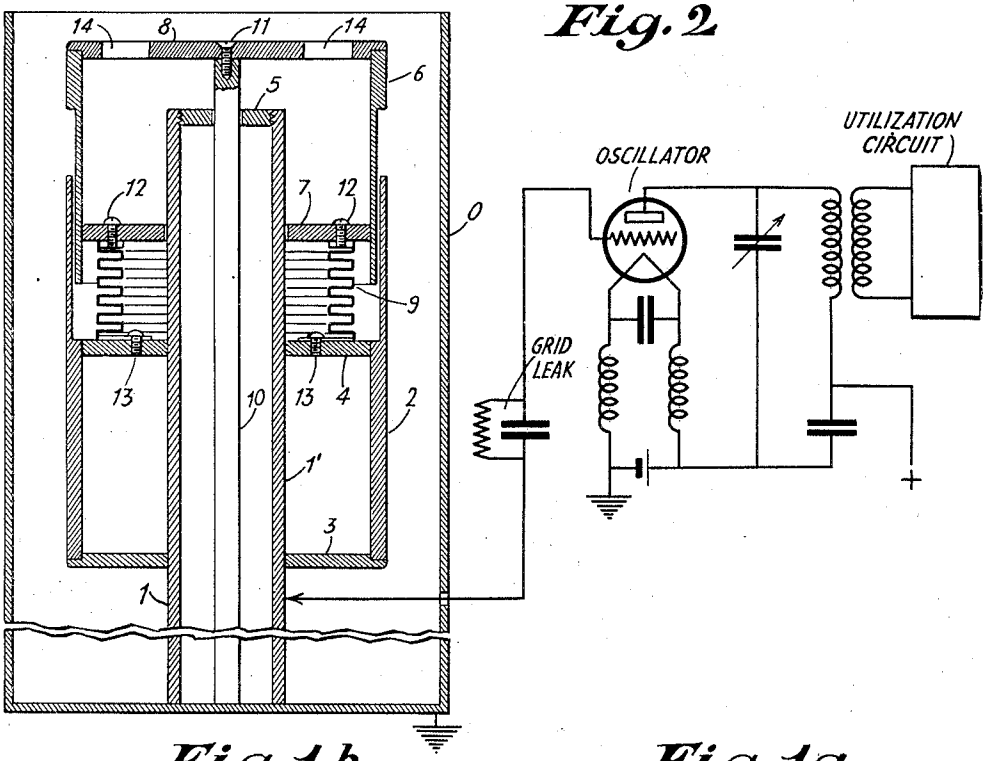


Fig. 1b

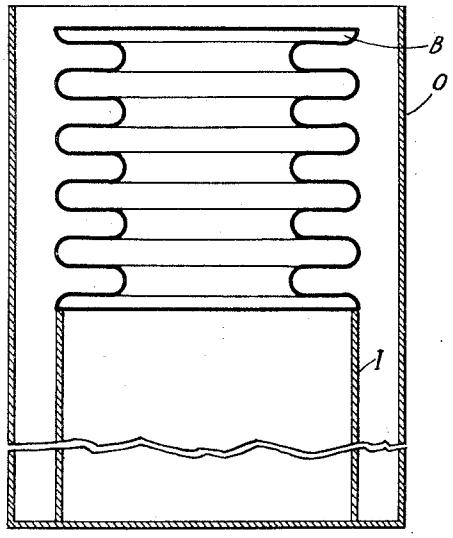
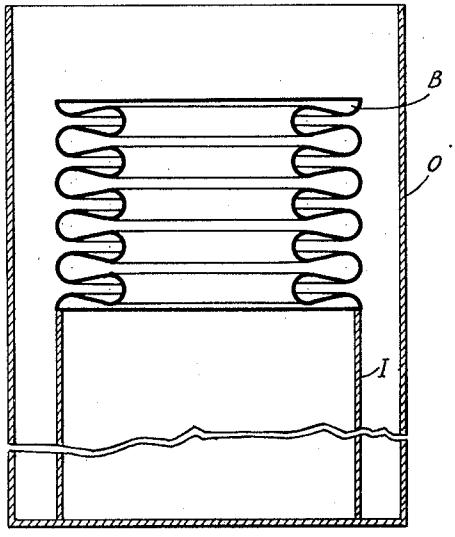


Fig. 1a



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LINE RESONATOR

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8 Claims. (Cl. 178—44)

This invention relates to improvements in tuned circuits in the form of concentric line resonators, and particularly to such of these resonators which employ an inner conductor constructed of two sections of different diameters.

It is well known that the resonant frequency of a properly designed concentric line is determined chiefly by the projection of the inner conductor upon the outer conductor which determines the length of the line. To maintain a high degree of frequency stability and obtain freedom from ambient temperature variations, it is known to employ compensating units actuated by variations in temperature. Such compensating units may consist of a metal bellows arrangement attached to the free end of the inner conductor and connected by means of a rod of low temperature coefficient, such as invar, to the junction of the inner and outer conductors of the line. Circuits describing concentric line resonators having compensating units of this type are adequately described in copending United States applications Ser. No. 1,489, filed January 12, 1935, by Fred H. Kroger, and Ser. No. 25,572, filed June 8, 1935, by James W. Conklin et al., to which reference is made for a more detailed description.

In copending application Ser. No. 25,572, supra, there is described a concentric line wherein the inner conductor has two sizes of diameter for reducing the overall length of line required to tune to a given frequency. The lengths of the two sizes of inner conductor are preferably made to be substantially equal, and the overall length of both sizes is held constant by an invar rod and bellows system. In such a line, the smaller diameter portion of the inner conductor and the outer conductor form an effective inductance while the larger diameter portion of the inner conductor and the outer conductor form an effective capacity. The inductance and capacity are each very nearly proportional to the lengths of the respective conductors. Since the overall length of the two inner conductors is constant, and the two are equal in length, any elongation or contraction of the smaller diameter portion of the inner conductor, due to change in temperature, causes an equal and opposite percentage change in the larger diameter portion of the inner conductor. Thus, changes in temperature vary the inductance and capacity of the circuit equally and oppositely and there is little if any change in natural frequency. In order to maintain the overall length of the inner conductor constant despite temperature changes, the larger diameter section of the inner conductor is made mechanically extensible by means of a bellows whose motion is controlled by a rod of low temperature coefficient.

The foregoing types of concentric line resonators employing extensible bellows have been found to suffer from certain disadvantages, one of which is due to the fact that the extensible bellows is not electrically equivalent to a continuance of the conductor itself. This is because of the necessary depth of the corrugations compared with the comparatively close spacing between the inner and outer conductors. The bellows when extended will have a capacity to the outer conductor which is considerably less than that between a cylinder of the same length and outside diameter as the bellows and the outer conductor; consequently the bellows is not the equivalent of a continuously extensible cylinder, and furthermore, its capacity is not a linear function of its extension, a requirement which is desirable in this type of line resonator.

Another difficulty of the bellows lies in the limited longitudinal adjustments obtainable with the number of corrugations it is practicable to use in its design, consistent with mechanical rigidity and electrical constancy.

A further disadvantage of this type of construction employing a bellows is that there is required a bellows of a specific outside diameter, as determined by the desired electrical constants. It is, therefore, seldom possible to use standard stock sizes and the methods of manufacture are not conveniently adaptable to odd sizes.

In order to avoid introducing electrical resistance by relying on surface contact, it has heretofore been necessary to solder all metal to metal contacts entering into the radio frequency circuit. Because of the large masses of copper sections involved, it is impractical to heat any localized section for soldering the elements of the final assemblage together because of the high thermal conductivity of the heavy copper parts. This has made it necessary in the past to complete all soldering operations at one time by heating the entire unit to solder melting temperatures or even to forego soldering. A further disadvantage lies in the fact that the extensible section formed by the bellows is difficult to remove for changing the overall length of the inner conductor so as to obtain greater frequency changes than can be accommodated on the adjustments of a particular bellows.

It is known that alternative arrangements have been proposed for the bellows, such as the use of an end cap in the form of a sliding or telescoping sleeve, wherein the end section of the cap slides over the outside of the conductor. Such an arrangement is described in an application, Serial No. 5,058, filed February 5, 1935, by Fred H. Kroger, now United States Patent No. 2,077,800. This last arrangement, however, is not as satisfactory as it might be because there is involved a sliding contact between large surfaces with varying contact resistance, and also occasional arcing when the line resonator is used for stabilizing an oscillator; accordingly, the electrical constants of the line are not stable.

A primary object of the present invention is to provide an extensible bellows for resonators of the concentric conductor type which, for electrical purposes, shall be as nearly as possible the equivalent of a continuous extension of the conductor itself.

A further object of the invention is to provide greater range of longitudinal adjustment for purposes of adjusting the resonant frequency and temperature compensation than has been practical with means heretofore available.

Another object is to provide a design wherein all special parts, such as bellows, may be of standard stock sizes or even dimensions.

Still another object is to provide a form of construction and assemblage which can be made with simple machine operations and which is inherently self-aligning and rigid.

A still further object is to prevent all sliding contacts and bearings from entering into the electrical circuit or conducting part of the resonator, whereby arcing and varying contact resistance are avoided.

Another object is to provide an extensible end section for a concentric line resonator which can be easily removed and interchanged with sections of different lengths for providing greater range of adjustments than previously furnished by the sliding adjusting arrangements.

Although the invention is herein described with special reference to the concentric type of line resonator having an inner conductor of two sizes of diameters, it will be understood that the invention is not limited thereto, since it may be employed with other types of line resonators wherever the feature of an extensible bellows is required or desired.

In general, the invention comprises an extensible end section consisting of a cylindrical extension to the inner conductor, and in the case to be hereinafter described wherein an inner conductor of two diameter sections is employed, the invention comprises an extension to the large diameter section of the inner conductor, which extension is partially inserted in said large diameter section. Throughout the range of the overlap, the diameter of the extension and the diameter of the adjacent section of inner conductor are so designed as to give sufficient spacing to preclude danger of arcing across the overlapping elements, and the length of the overlap is made sufficient to form a high coupling capacity between the conductor and the extension, such that for radio frequency purposes the conductor and extension form substantially a continuous conductor. The small diameter section of the inner conductor extends through the large diameter section, furnishing a rigid support for the large diameter section and a double bearing for the sliding extension. The whole unit is thus inherently aligned and rigidly supported. Motion of the sliding section is controlled by a central rod of low temperature coefficient material which may be actuated in any suitable manner, such as by an external micrometer adjustment of the type disclosed in copending application Serial No. 25,572, supra. This rod of low temperature coefficient also acts as an end bearing for the sliding section. The bearing contacts appearing in the unit of the invention are shielded electrically by either a bellows or a flexible connection between the bearing flanges of the end section and the large diameter section of the inner conductor. The bellows in the present instance does not enter, to any degree, in the radio frequency circuit, and may be of any mechanically convenient length and diameter.

A better understanding of the invention may be had by referring to the following detailed description which is accompanied by a drawing, wherein:

Figs. 1*a* and 1*b* indicate bellows in contracted and extended form. These figures are merely given by way of illustration, to show the disadvantage of using bellows as extensible end sections of a concentric line resonator, and

Fig. 2 illustrates the invention as applied to the inner conductor of a concentric line resonator, wherein the inner conductor is made up of two sizes of diameters.

Referring to Fig. 1*a*, there is shown in part a concentric resonant line comprising an outer conductor O and an inner conductor I, the inner conductor being provided with a bellows B attached to one end thereof. Bellows B is arranged to open or close in response to any decrease or increase in length of the inner conductor due to a change in temperature. This bellows constitutes one plate of a capacitor, the other plate of which is the outer conductor O. In the compressed condition shown in Fig. 1*a* the bellows has substantially the same capacity as a continuous cylinder of the same length and outside diameter.

In Fig. 1*b*, however, the bellows is shown extended and it will be seen that the depth and length of the corrugations are such that the capacity of the bellows B to the outer conductor O is considerably less than that of a cylinder of the same length and outside diameter as the bellows with respect to the same outside conductor. Consequently, in its extended form, the bellows, as shown in Fig. 1*b*, is no longer the equivalent of a continuously extensible cylinder and hence does not conform with a desired requirement in this type of line resonator, wherein the capacity of the bellows should be a linear function of its extension.

In Fig. 2, which illustrates the invention in great detail, the disadvantages inherent with the type of system disclosed in Figs. 1*a* and 1*b* are overcome. In Fig. 2 there is shown a concentric line comprising an outer conductor O and an inner conductor composed of two sections of different diameters, namely, a smaller diameter section 1 and a larger diameter section 2. Sections 1 and 2 in the preferred form of this type of resonator are made to have substantially the same length. A rod of low temperature coefficient 10, such as invar, is located within the conductor 1, 2 and extends substantially the entire length thereof, and is connected to an extensible section 6 at the top thereof by means of a screw 11, for the purpose of maintaining the overall length of the inner conductor constant.

In circuit with the line there is shown, by way of example only, an oscillation generator comprising an electron discharge device whose frequency is controlled by the line. Since this particular circuit forms no part of the present invention, per se, and is adequately described in the foregoing copending applications, it will not be further referred to herein.

Heretofore, the extensible section which was connected directly to the rod 10 has been an extensible bellows, but this bellows is now replaced by applicant's arrangement comprising a cylindrical conductor 6 which is slidably mounted within the larger diameter section 2 and is connected to the invar rod by means of a metal end plate 8. The large diameter section 2 is connected to the smaller diameter section and is mounted thereon by means of flanges 3 and 4, which are supported on shoulders of inner conductor 1 and its extension 1'. Upper sliding cylindrical conductor or extension 6 is supported by the end plate 8 and the bearing flange 7, the flange 7 of which slides over extension 1' of the inner conductor 1. The smaller diameter section 1 of the inner conductor, it should be noted, extends into the larger diameter section 2 and slidable extension 6, and is terminated by an end plate 5 which is slidably associated with the rod 10 and enables relative motion between the rod and extension 1' of the smaller diameter portion 1. A bellows 9 electrically connects the flanges 4 and 7 and is fastened thereto by machine screws 13 and 12, respectively, as shown in the drawing. For enabling a removal of the slidable extension 6, there are provided in the end plate 8 apertures 14 which extend through the end plate and enable the loosening of the machine screws 12, whereby with the removal of screw 11 fastening the end plate 8 to the rod 10, the sliding section 6 can be removed and replaced with another of different length. In this manner there can be obtained, whenever desired, greater length of the inner conductor merely by the substitution of another cylindrical plate 6 which may extend beyond the position of the end plate 8 shown in the drawing. In one particular embodiment which was constructed, all the elements were made of copper excepting the screws and the invar rod 10.

The overall length of the inner conductor consisting of the smaller diameter section 1 and the larger diameter section 2, is maintained constant, thereby giving substantial freedom from the effects of variations in the ambient temperature in the following manner. An increase in ambient temperature will cause an increase in length of small diameter section 1 of the inner conductor and an increase in length of the sliding section of the large diameter section 2. This sliding section will thus move upward towards the fixed section 6 of the large diameter section and will compress the bellows 9. Inasmuch as the position of section 6 is fixed by means of the invar rod 10, which is connected to the end plate 8, in turn fastened to section 6, it will be quite evident that the overall length of the inner conductor, as measured from the lowermost portion 1 to the end of end plate 8, will remain constant. Any decrease in ambient temperature will likewise not change the position of end plate 8, although the lengths of small diameter section 1 and sliding section of the larger diameter section 2 will decrease, with a consequent expansion of the bellows 9.

An advantage of the present invention is the fact that the whole stationary assemblage can easily be machined on a lathe, merely by using the end bearing plate as a center, in which case the whole assemblage is first pinned and then soft soldered together.

The manner of assemblage shown in Fig. 2 enables the use of a heavy sliding section and the accurate maintaining of a close capacity spacing between the fixed section 2 and the sliding section 6, the internal bellows 9 or flexible connection being used herein to shield the sliding bearings. The bellows here forms a flexible electrical connection or short circuiting path around the sliding contacts or bearings 7 and 5 and thus prevents small leakage currents from flowing through the variable contact resistance of these bearings. Without this provision, the currents which would flow through the bearings would vary with the changing contact resistance at the surfaces, and while these currents would be small compared to the currents in the primary electrical circuit they would produce noticeable variations in the electrical characteristics of the resonator. The bellows can be replaced by any type of flexible connection such as a corrugated ribbon or Belden braid; however, the bellows is preferable for the reason that it completely shields the bearing surface more effectively than can one or more flexible conductors.

It will be understood, of course, that the invention is not limited to the precise arrangements of parts shown since various modifications can be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A resonant line comprising inner and outer substantially concentric conductors, said inner conductor comprising overlapping movable and fixed portions electrically coupled to each other, and a flexible connection electrically connecting said portions together.

2. A resonant line comprising inner and outer hollow, substantially concentric conductors, said inner conductor comprising an inner portion which is relatively fixed with respect to said outer conductor, and an overlapping movable outer portion slightly spaced away from said fixed inner portion so as to form a continuous conductor for radio frequency energy, a metallic bellows within said portions and having one end thereof attached to and supported by said movable portion and the other end attached to said fixed portion, said inner portion being fixed in position by means of a material having a very low temperature coefficient of expansion which is attached to both said fixed portion and to said outer conductor.

3. A resonant line having inner and outer conductors electrically coupled together at one of their adjacent ends, a metallic end plate at the other end of said inner conductor, a rod of low temperature coefficient connected to said end plate for maintaining the overall length of said inner conductor including said end plate substantially constant with respect to said outer conductor despite temperature fluctuations, said inner conductor being extensible and comprising a relatively fixed portion connected to said end plate and a movable portion, said portions overlapping over at least a portion of their lengths and being closely spaced apart with respect to one another such that they form a continuous conductor for radio frequency energy, and a flexible electrical connection directly connecting said portions together.

4. A resonant line in accordance with claim 3, characterized in this that the overlapping part of said relatively fixed portion of said inner conductor is located within the inner surface of said movable portion, and said flexible connection is a bellows whose opposite ends are connected to said portions.

5. A low loss resonant line having inner and outer hollow concentric conductors, said inner conductor having two sections of different diameters directly connected together, the smaller of said sections being electrically coupled at one end to the adjacent end of the outer conductor, the larger of said sections comprising overlapping movable and fixed portions electrically coupled to each other, and a flexible connection within and electrically connecting said portions together, said fixed portion being maintained in position by means of a material having a very low temperature coefficient of expansion linked to both said portion and said outer conductor.

6. A low loss resonant line having inner and outer hollow concentric conductors, said inner conductor having two sections of different diameters directly connected together, the smaller of said sections being electrically coupled at one end to the adjacent end of the outer conductor, the larger of said sections comprising a relatively fixed inner portion and an overlapping movable outer portion slightly spaced away from said fixed portion, said movable portion being affixed to and supported by said smaller diameter section, an end plate for said fixed portion, and a rod of low temperature coefficient connected to said end plate, said rod being located within and extending substantially throughout the length of said inner conductor for maintaining the overall length of said inner conductor constant with respect to said outer conductor, said smaller diameter section extending into said larger diameter section beyond the overlapping part of said fixed and movable portions, a first flange attached to said fixed portion of and within said larger diameter section, said first flange surrounding said extended portion of said smaller diameter section, said flange being slidable over the extended portion of said smaller diameter section, a second flange within said larger diameter section of inner conductor and attached to both said movable portion thereof and said extended portion of said smaller diameter section, and a flexible electrical connection between and secured to both said flanges.

7. A frequency control line in accordance with claim 6, characterized in this that said flexible connection is secured to said flanges by means of screws, and said end plate has apertures therein for enabling removal of said screws and substitution of said fixed portion with another portion of different length.

8. A resonant line having inner and outer conductors electrically coupled together at one of their adjacent ends, a metallic end plate at the other end of said inner conductor, a rod of low temperature coefficient connected to said end plate for maintaining the overall length of said inner conductor including said end plate substantially constant with respect to said outer conductor despite temperature fluctuations, said inner conductor being extensible and comprising a relatively fixed portion connected to said end plate and a movable portion, said portions overlapping over at least a portion of their lengths and being closely spaced apart with respect to one another such that they form a continuous conductor for radio frequency energy.

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