June 16, 1942. C. W. HANSELL 2,286,408

CONCENTRIC RESONANT LINE

Original Filed April 7, 1938

Fig. 1

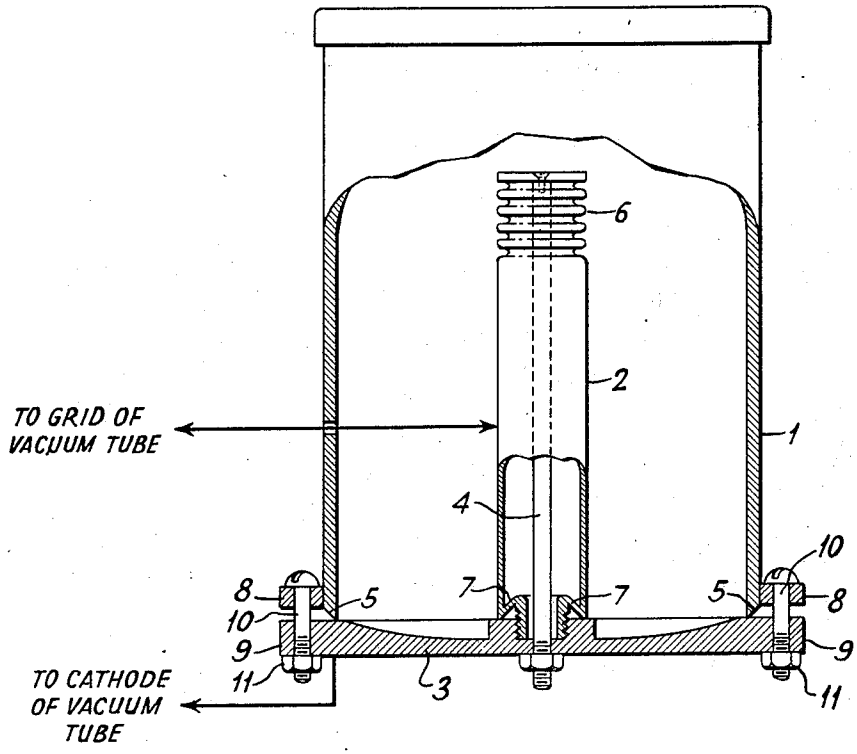


Fig. 2

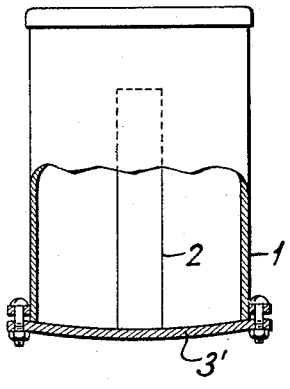
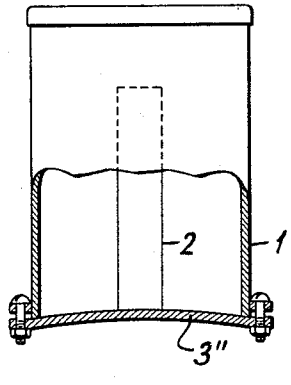


Fig. 3



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CONCENTRIC RESONANT LINE

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21 Claims. (Cl. 178—44)

This invention relates to improvements in tuned circuits, and particularly to electrical resonators having substantially uniformly distributed inductance and capacitance, as for example, the concentric resonant line.

As is well known, a concentric resonant line consists of an inner conductor and an outer conductor having such dimensions and being so coupled as to form a tuned circuit for a predetermined frequency. The conductors of the line have substantially uniformly distributed inductance and capacitance, and because of their construction form a very low loss circuit. Concentric resonant lines have been used wherever there is need for a tuned circuit; for example, as the frequency stabilizing element of an oscillator, as an interstage coupling element, and as a filter. For a more detailed description of the general operation of such line, reference may be had to the following publications: United States Reissue Patent No. 20,189, granted to Roosenstein December 1, 1936; United States Patent No. 2,104,554, granted to Conklin January 4, 1938; United States Patent No. 2,106,776, granted to Trevor et al. February 1, 1936; "Electrical Engineering" for August, 1935, pages 852 to 857, article by Hansell; "Proceedings of the Institute of Radio Engineers" for April, 1936, paper by Hansell and Carter; "Proceedings of the Institute of Radio Engineers" for November, 1931, article by Conklin, Finch and Hansell; "Electrical Engineering," July, 1934, article by Terman; and United States Patent No. 1,937,559, granted to Franklin December 5, 1933.

One difficulty experienced with previous types of concentric resonant lines is that the flat end plate connecting the inner and outer conductors is liable to buckle in one direction or the other, unpredictably, due to internal stresses which are set up, relieved, or modified as a result of temperature differences between inner and outer portions. When the line is in use to stabilize the frequency of a radio transmitter, or for any other purpose requiring rather large high frequency currents to flow in surfaces of the conductors, there are energy losses which increase the temperature of the inner conductor, and of the center of the end plate, more than the increase of temperature of the outer conductor and outer portion of the end plate. This difference in temperature tends to expand the material near the center of the plate against a restraining force of the cooler material around the rim. These forces can be considerably relieved by a bulging or buckling of the plate in one direction or the other to make one of the broad surfaces convex and the other concave. However, if we start with a perfectly flat end plate, it is impossible to predict which way the end plate will buckle and therefore it is impossible to provide reliably in advance to compensate for the effect of the bulging upon the resonant frequency of the line. My present invention removes this uncertainty as to which way the plate will bulge or buckle and, in addition, by giving the plate an initial bulge or buckle, in the process of manufacture reduces the amount of internal stress so that it is less likely to result in strains which result in permanent dimensional changes while the line is being used.

Of course, under ordinary circumstances, the bulging and change of dimensions are so small as not to be discernible to a casual observer but nevertheless they exist and are important. Resonant lines for frequency control of radio transmitters should hold their resonant frequencies constant to within about one part in a million and this requires elimination of even very small uncompensated changes in dimensions during operation.

Another difficulty in prior types of concentric resonant lines has been caused by the points of contact between the outer and inner conductors and the connecting end plate, which points of contact have been unpredictable on account of slight changes in dimensions with changes in temperature. As a result of this, it has been difficult to calculate the exact location of the engaging metallic elements, and consequently difficult to calculate the length of path of current. As the length of path increases with change of dimensions, there naturally results a greater power loss in the tuned circuit and a change in the resonant frequency which is an appreciable number of cycles per second, even though it may be small in percentage. For example, a change in resonant frequency of one part in a million amounts to 100 cycles per second in a line designed to operate at 100,000,000 cycles per second.

The present invention overcomes the foregoing difficulties by providing the resonant line with a bowed or dished end plate, and with tapered surfaces for the inner and/or outer conductors of the line and by holding removable parts together with screws or bolts strong enough to crush the joined materials together slightly at the line of contact, and elastic enough to hold the close contact in spite of effects of changes in temperature.

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

Fig. 1 illustrates, by way of example only, a vertical section of a concentric resonant line equipped in accordance with the invention with a bowed end plate, and with inner and outer conductors having tapered surfaces at the points of contact with the end plate; and

Figs. 2 and 3 show schematically, vertical sections of other concentric lines equipped in accordance with the invention, with bowed or dished end plates.

Referring to Fig. 1, there is shown a concentric

resonant line comprising an outer cylindrical conductor 1 and an inner cylindrical conductor 2 joined together by a metallic end plate 3. A flexible metal bellows 6 at the open end of the inner conductor 2 is used in combination with an invar rod 4 to maintain the overall length of the inner conductor constant with change in temperature. Since the length of the projection of the inner conductor 2 upon the outer conductor 1 determines, generally, the resonant frequency of the concentric line, it will be appreciated that adjustment of the bellows 6 through rod 4 will change the effective length of the inner conductor and the resonant frequency of the line.

It has been found that the hottest part of the resonant line is the end at which the conductors 1 and 2 are closely coupled together, that is, at the shorted end of the resonant line where the end plate 3 is located. Since the center of the plate 3 is hottest, if the plate were perfectly flat there would be a tendency for it to warp or buckle in or out, thus tending to change the position of the inner conductor 2 to some unpredictable position with a consequent change in the resonant frequency of the line for which compensation could not be determined in advance. In order to prevent such an unpredictable change in frequency due to buckling, which in some cases could be a sudden snapping, or warping of the end plate by heat, the end plate 3 is, in this particular figure, bowed out, as shown. The position of conductor 2 is thus predictable and may be compensated for in the adjustment of rod 4 as taught in some of the publications which have been mentioned above.

The bowing effect desired may be obtained either by bending the end plate, as shown more clearly in Figs. 2 and 3, or by machining a more or less cup or ball shape on one or both sides of the end plate. In Fig. 1, the inner side of end plate 3 has been cut or machined away somewhat to provide the bow effect. The bowing could just as well have been machined on the outside surface and, in practice, I have usually given some bowing, in the same direction to both inside and outside surfaces.

In order to insure predictable points of contact between the inner and outer conductors 1, 2 and the end plate 3, so as to provide a smooth, continuous, high frequency path for the current, the contacting surfaces of these conductors are tapered, as shown in Fig. 1 in an exaggerated manner at 5 and 7, to insure continuous contact at the inner surfaces of the end plate and of the conductors. These tapered surfaces are made to wedge into the end plate. It should be noted that the outer surface of the outer conductor is tapered at 5, while the inner surface of inner conductor 2 is tapered at 7 to produce this result. In practice I may taper the end plate in addition to, or instead of, tapering the ends of the cylindrical conductors. The force used for wedging the outer conductor into the end plate is obtained by employing flanges 8 and 9 on the adjacent portions of the outer cylindrical conductor 1 and the end plate 3 and using bolts 10 and nuts 11 to force these flanges together. Preferably the flanges are equipped with two dowel pins and holes to assure exact positioning of the end plate, if for any reason it is removed and replaced. As for the inner conductor 2, the desired wedging effect is produced by tightly screwing the inner conductor down into the end plate 3. In most cases I prefer to solder, braze or weld the joint between inner cylindrical conductor 2 and the end plate but in many cases this is undesirable because of a desire to facilitate exchanging inner conductors to change the range of resonant frequencies.

Fig. 2 illustrates, very schematically, a concentric line arrangement wherein both inside and outside surfaces of the end plate 3' are bowed outwards.

Fig. 3 shows, very schematically, a concentric line arrangement wherein both inside and outside surfaces of the end plate 3'' are bowed inwards.

It should be distinctly understood that the invention is not limited to the arrangements shown and described, since various modifications may be made without departing from the spirit and scope thereof. The principles of the invention are applicable to any type of electrical resonator where the problem arises of controlling the direction of buckling of electrical conductors which are subjected to unequal temperatures.

What is claimed is:

1. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, said end plate being bowed to prevent warping due to heat engendered therein whereby the relative positions of said inner and outer conductors at the location of said end plate are predictable and the tendency for permanent dimensional changes of said end plate is reduced.

2. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, said end plate being bowed inwards to prevent warping due to heat engendered therein, whereby the relative positions of said inner and outer conductors at the location of said end plate are predictable and the tendency for permanent dimensional changes of said end plate is reduced.

3. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, said end plate being bowed outwards to prevent warping due to heat engendered therein, whereby the relative positions of said inner and outer conductors at the location of said end plate are predictable and the tendency for permanent dimensional changes of said end plate is reduced.

4. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, said end plate having one of its surfaces partly cut away to provide a bowing effect to prevent warping, whereby the relative positions of said inner and outer conductors at the location of said end plate are predictable and the tendency for permanent dimensional changes of said end plate is reduced.

5. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, a metallic bellows at the other end of said inner conductor, a rod of temperature coefficient of expansion located within said inner conductor and connected at one end to said bellows, said end plate being bowed out-

wards to prevent warping due to heat engendered therein, whereby the relative positions of said inner and outer conductors at the location of said end plate are predictable and the tendency for permanent dimensional changes of said end plate is reduced.

6. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, the end of one of said conductors contacting said end plate being tapered to produce a wedging effect, and means for forcing said end of said one conductor into said end plate for insuring continuous predictable points of electrical contact therebetween.

7. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, the ends of both conductors contacting said end plate being tapered to produce a wedging effect, and means for forcing said ends of both said conductors into said end plate for insuring continuous predictable points of electrical contact between said conductor and said end plates.

8. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, the outer surface of said outer conductor being tapered at the end engaging said end plate to produce wedging effect, and means for forcing said end of said outer conductor into said end plate for insuring continuous predictable points of electrical contact therebetween.

9. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, the inner surface of said inner conductor being tapered at the end engaging said end plate to produce a wedging effect, and means for forcing said end of said inner conductor into said end plate for insuring continuous predictable points of electrical contact therebetween.

10. A tuned circuit comprising a concentric line having an inner conductor and an outer conductor, and an end plate for conductively coupling said conductors together at one of their adjacent ends, said end plate being bowed to prevent warping due to heat engendered therein, whereby the relative positions of said inner and outer conductors at the location of said end plate are predictable and the tendency for permanent dimensional changes of said end plate is reduced, the end of one of said conductors engaging said end plate being tapered to produce a wedging effect.

11. A resonant line circuit comprising inner and outer metallic cylindrical electrical conductors joined together at one end by a metallic electrically conducting plate, said plate being shaped so that buckling, due to heat applied near its center, will be in only one direction, whereby the relative positions of said inner and outer conductors at the location of said end plate are predictable.

12. A tuned circuit of low loss having substantially uniformly distributed inductance and capacitance including a substantially cylindrical conductor tapered at one end to produce a wedging effect, an end plate closing said one end of said conductor, and means for forcing said end of said conductor into said end plate for insuring continuous predictable points of electrical contact therebetween.

13. A tuned circuit of low loss having substantially uniformly distributed inductance and capacitance including a substantially cylindrical conductor closed at one end by an end plate, said plate being so constructed and arranged as to prevent warping due to heat engendered therein, whereby the relative positions of end plate and conductor are predictable and the tendency for permanent dimensional changes of said end plate is reduced.

14. A tuned circuit comprising an electrically conducting surface, a metallic plate attached to one end of said surface, said plate being bowed as to prevent warping due to heat engendered therein, whereby the dimensions of said tuned circuit are predictable.

15. A tuned circuit comprising an electrically conducting surface of revolution having means at the ends thereof completely enclosing said surface, said means at one end of said surface of revolution being curved on its interior to prevent warping, whereby the dimensions of said tuned circuit are predictable at all working temperatures.

16. A high frequency electrical resonator comprising a closed electrically conducting surface of predetermined dimensions, having an end permanently bowed inwardly to prevent warping.

17. A high frequency electrical resonator comprising an electrically conducting surface of revolution of predetermined dimensions having a substantially completely enclosed hollow interior, an end of said surface being bowed, whereby the dimensions of said resonator are predictable at all working temperatures.

18. A high frequency electrical resonator having substantially uniformly distributed inductance and capacitance including an electrically conducting surface of revolution, electrically conducting means closing at least one end of said surface of revolution, the portion of said surface contacting said means being tapered to produce a wedging effect, and means for forcing said portion into said means for insuring continuous predictable points of electrical contact therebetween.

19. A high frequency electrical resonator having substantially uniformly distributed inductance and capacitance including an electrically conducting surface of revolution, electrically conducting means closing both ends of said surface of revolution, the portion of said surface at one end contacting said means being tapered to produce a wedging effect, and means for forcing said portion into said means for insuring continuous predictable points of electrical contact therebetween.

20. A high frequency electrical resonator comprising a closed electrically conducting surface of predetermined dimensions, having an end permanently bowed outwardly to prevent warping.

21. A high frequency electrical resonator having substantially uniformly distributed inductance and capacitance including a hollow electrically conducting surface, electrically conducting means closing both ends of said surface, the portion of said surface at one end contacting said means being tapered to produce a wedging effect, and means for forcing said portion into said first means for insuring continuous predictable points of electrical contact therebetween.

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