Sept. 24, 1940. H. E. GOLDSTINE 2,215,582

RESONANT LINE AND ASSOCIATED CIRCUIT

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Fig. 1

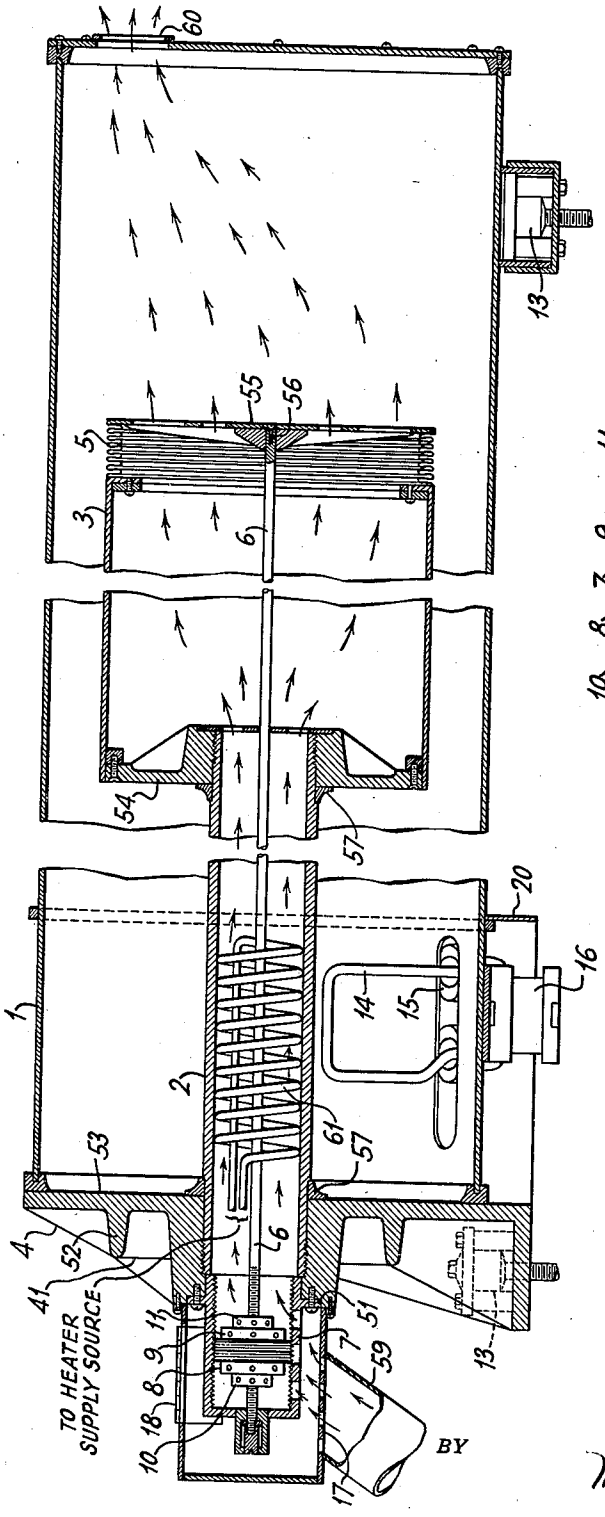
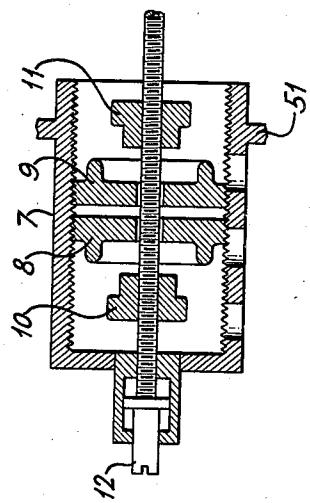


Fig. 2



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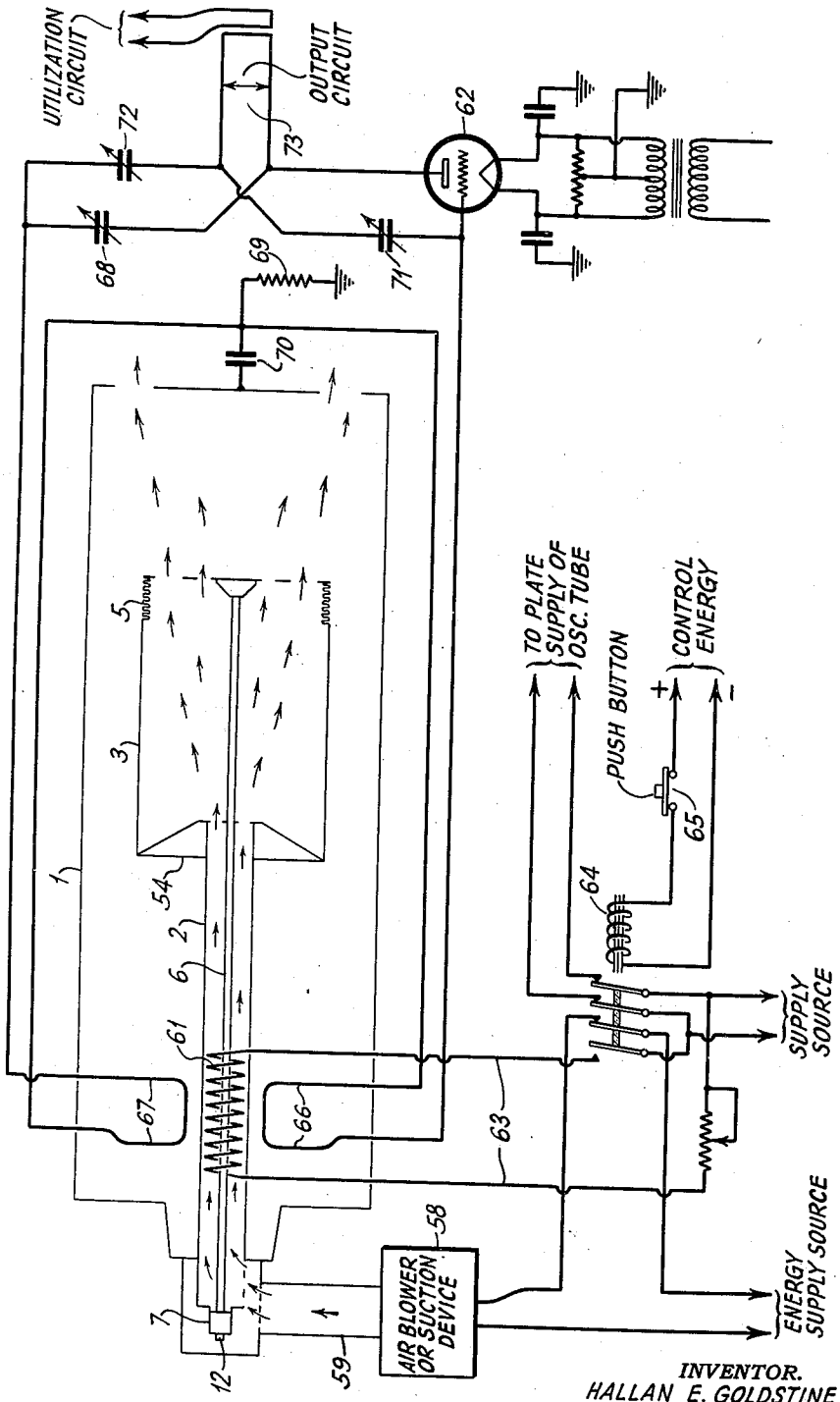
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Fig. 3



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Patented Sept. 24, 1940

2,215,582

UNITED STATES PATENT OFFICE

2,215,582

RESONANT LINE AND ASSOCIATED CIRCUIT

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Application February 2, 1938, Serial No. 188,303

11 Claims. (Cl. 250—36)

This invention relates to tuned circuits in the form of concentric resonant lines, and to associated circuits therefor.

It is known that low loss tuned circuits in the form of high Q concentric resonant lines having distributed constants may be employed in high frequency transmitting and receiving apparatus. Such concentric resonant lines may be employed wherever there is need for a tuned circuit. Arrangements of this type are known and adequately described in the literature; for example, note the article by Clarence W. Hansell entitled "Resonant Lines for Frequency Control," published in "Electrical Engineering," August, 1935, pages 852–856; United States Patents Nos. 2,077,800 and 2,095,980, respectively granted to Fred H. Kroger and Clarence W. Hansell, April 20, 1937 and October 19, 1937; and United States Patent No. 2,124,029, granted July 19, 1938, to James W. Conklin and Clarence W. Hansell, to which reference is herein made.

The present invention concerns, in general, an improved concentric resonant line of the type hereinabove referred to having, in combination, one or all of the following novel features. (1) A method of and means for heating and controlling the amount of heat imparted to the conductors of the resonant line and circulating the air therethrough; (2) a compensating unit for compensating for variations in length of the rod of low temperature coefficient of expansion located within the inner conductor; and (3) a novel electron discharge device circuit for use with the concentric resonant line.

A more detailed description of the invention follows in conjunction with the drawings, wherein:

Fig. 1 illustrates a cross-sectional view of a preferred resonant line in accordance with the principles of the present invention;

Fig. 2 is a detail, cross-sectional view of the compensating unit employed in the resonant line of Fig. 1; and

Fig. 3 is a view partly in cross-section and partly schematic, of applicant's improved line in conjunction with associated power supply and electron discharge device apparatus.

Referring to Fig. 1 in more detail, there is shown a concentric resonant line comprising an outer conductor 1 and a coaxial inner conductor 2, 3, both preferably composed of material of high electrical conductivity to radio frequency currents, such as copper, both of said conductors being mechanically and electrically connected together at one of their adjacent ends by an end plate 53. The inner conductor consists of two sections of different diameter; a smaller diameter section 2 and a larger diameter section 3 fastened to the smaller diameter section 2 by means of a metallic plate 54.

In order to maintain the length of the inner conductor substantially constant despite variations in temperature, there are provided, in accordance with known usage, a metallic bellows 5 at the free end of the larger diameter section 3 of the inner conductor, and, fastened thereto by means of a metallic plate 55 and a screw 56, a rod 6 of low temperature coefficient of expansion located within the inner conductor. Rod 6 preferably consists of a nickel-steel alloy known to the trade as Invar. So far, what has been described is generally known to the art and is shown, for example, in Fig. 3 of the article by Clarence W. Hansell, and in the copending application, supra.

In order to overcome any variations in length of the rod 6, this rod is preferably arranged, in accordance with the invention, to extend beyond the end plate 53 and to connect thereto by means of a compensator unit 7, 8, 9, 10, 11. End plate 53 is a heavy bronze casting with a bracing web 52 and a strengthening ring 41, to reduce bending in the end plate 53 and also to provide a large surface for conducting away the heat which is generated on the inside of the line. Inner conductor section 2 is also made of fairly heavy material, so that heat may be readily conducted into the end casting 53. Plate 54, which links the two inner conductor sections 2 and 3 together, is also a bronze casting which has been strengthened by webbing in a manner similar to the end casting 53. Care has been taken in the construction of the line to provide a good electrical connection between the inner conductor 2, 3 and the end plate 53, and between the outer conductor 1 and the end plate 53, so as to provide high electrical conductivity and low resistance. To aid in this, there have also been provided copper rings 57 between the end plate 53 and inner conductor section 2 and between said last inner conductor section and plate 54. In the preferred arrangement, control line 1, 2 is mounted in a horizontal position, though not necessarily limited thereto, the inner conductor being supported by means of the strong end plate 53 in cantilever fashion. In this way, there is no need for the use of supporting dielectrics between the inner conductor 2, 3 and the outer conductor 1, thus pre-

venting the introduction of extra losses between the inner and outer conductors. A heating coil 61 is provided within the inner conductor, small diameter section 2 for an appreciable portion of its length for a purpose to be described later.

By means of the compensating unit now to be described, the attachment position of the Invar rod 6 to the compensator unit can be so adjusted as to minimize frequency variations of the resonant line with change in length of the Invar rod, due to changes in temperature. The compensator unit (note Fig. 2) consists of an outer shell 7 which is rigidly secured to the end casting 53 by means of a flange 51. Shell 7 is threaded in the interior thereof to cooperate with two threaded adjustment nuts 8, 9, which follow the threads on the shell 7. A small clearance hole is provided in the center of each nut 8 and 9, so that the Invar rod may move freely through these nuts. There are also provided on the Invar rod 6, which is threaded at the end thereof protruding into the compensator unit, a pair of threaded nuts 10 and 11 which can be moved over the Invar rod. By means of nuts 8 and 9, the actual point of connection of the Invar rod 6 to the casing 7 is determined. One of these nuts 8 or 9 will serve as a lock nut for the other to prevent movement thereof. Nuts 10 and 11 are used to change the overall effective length of conductor 2, 3 by moving the position of the Invar rod 6 either to the right or to the left with respect to the nuts 8 and 9. If it is desired to change the degree of compensation, the nuts 10 and 11 are first moved free of the nuts 8 and 9, and these last nuts are moved to a different position of compensation, after which the effective length of the Invar rod 6, and hence the frequency of the line, is adjusted by means of nuts 10 and 11. Adjustment of the nuts 8, 9, 10 and 11 may be effected by means of a pin wrench through a slotted portion in the outer shell 7. To understand more clearly how this compensation is effected, it should be noted that there is a tendency for the Invar rod 6 to move lengthwise with increase in temperature, say, for example, to the right of the nut 11. The compensator unit 7 functions to provide a movement of the rod 6 in one direction, diametrically opposite to the movement of the rod 6 in the other direction, due to changes in temperature, in order to maintain the relative position of the rod 6 constant with respect to the end casting 53. Assume as an illustration, if the rod 6 expands with increase in temperature relative to the end casting 53 so as to increase the effective overall length of the inner conductor 2, 3, the compensator will expand in the opposite direction relative to the end casting 53 to pull rod 6 back into a position which will maintain a constant overall length of inner conductor 2, 3 relative to the end casting 53. The shell 7 of the compensator unit may be made of any metallic material in order to obtain a desired degree of compensation, it being appreciated, of course, that materials of greater expansion with temperature will give a greater degree of compensation. Thus, we are able either to obtain an exact compensation of the expansion of the Invar rod in one direction, or else a greater or lesser degree of compensation, in order to take into account other effects than the expansion or contraction of the Invar rod per se. It should be observed that the mounting of the Invar rod is actually outside of the point of contact of the inner conductor section 2 with the end casting 53, thus enabling the material composing the shell 7 and the compensator to expand, in the manner hereinabove described, in a direction opposite to that of the inner conductor relative to the end plate 53. If desired, another material may be substituted for a small portion of the Invar rod to obtain a desired degree of expansion. At the end of the compensator unit there is provided a small device 12 which is placed on the Invar rod in any suitable manner to determine the position of the Invar rod. This device is provided with an index or calibration to enable the operator to readily observe the position of the Invar rod, and thereby determine the operating frequency.

Because of the smaller diametrical dimension of the section 2 relative to the section 3 of the inner conductor, the greater part of the heating of the inner conductor will be engendered in section 2. In order to distribute the rise in temperature of the inner conductor as evenly as possible over the entire inner conductor, and to reduce the heating of the inner conductor as much as possible, there is provided a cooling blower 58 which communicates with the end 17 of the concentric line by means of a pipe 59. It has been found that the resonant line takes an appreciable length of time for all the elements thereof to heat up to a point where the frequency is constant; in other words, equilibrium of heat engendered and dissipated is reached after a time interval depending upon such factors as the structural material of the line and the dimensions thereof. The blower 58 serves to reduce this time interval before equilibrium is reached. Air from the blower is forced through the pipe 59 and end 17 of the resonant line into a housing having a trap door 18, from which housing the air is forced through the slots of the compensator unit and into the smaller diameter section 2 of the inner conductor from which the air flows through the large diameter section 3 of the inner conductor through holes in the plate 55 and out into the space between the inner and outer conductors, from which the air is expelled through one or more apertures 60. The arrows serve to indicate the direction of flow of the circulated air. It will be understood, of course, that, where desired, the cooling blower 58 may be replaced by a suction device for sucking the air from the inner conductor, thereby reversing the direction of air flow and maintaining large diameter section 3 at a cooler temperature than in the previous case. The housing at the end 17 of the line serves the additional purposes of mechanically protecting and electrically shielding the line. In practice, the outer conductor 1 of the resonant line is grounded, and thus protects the personnel who may come in contact with the line.

In order to aid in more uniformly heating the line, the larger diameter section 3 of the inner conductor may be made of a material different from the smaller diameter section 2, such as a material having greater resistance, so that the material of section 3 will heat up much more quickly. Since a material having a greater resistance for section 3 means greater losses in the larger diameter section of the inner conductor, it will be obvious that there will be a lowering of the effective Q of the line, a condition which is inconsistent with the most satisfactory operation of the line. For this reason, it is not preferred that the section 3 be made of a material which will give a higher loss than the section 2. For lowering the amount of time to

bring the resonant line to temperature equilibrium, there is provided in the interior of smaller diameter section 2 of the inner conductor a heating coil 61 extending over the greater part of the length of the inner conductor. This coil is energized from a power source located externally of the line and so regulated by thermostat that its temperature is maintained in proper relation to that of section 2. It is preferred that this heater be effective during the time that the associated vacuum tube apparatus is disconnected from the line, so that the temperature conditions on the line be substantially the same as those existing during operation. It will thus be seen that the vacuum tube apparatus can be connected to the line for almost instantaneous operation, without change in the characteristics of the circuit, over an interval of time which ordinarily would be required to warm up the line to temperature equilibrium.

In order to prevent vibrations from being transmitted into the line and possibly changing the frequency thereof, it is preferred that the line be mounted on a plurality of shock absorbers 13, 13, as shown.

The preferred arrangement of resonant line and associated apparatus is illustrated in Fig. 3, which shows the concentric resonant line 1, 2, 3 as the frequency controlling elements of a vacuum tube oscillator 62 for use in a high power transmitter. It should be observed that the heating coil 61 located in the interior of the inner conductor 2 is connected by means of lead line 63 to a suitable source of energy through the contacts of a relay 64, in turn controlled by a push-button 65. An inspection of the circuit of relay 64 will show that when the push-button 65 is closed, the heating energy for the coil 61 is disconnected from the coil and connected to the plate or anode supply of the oscillator tube. The resonant line can thus be heated by coil 61, and maintained in proper temperature equilibrium at all times, while the oscillator or associated vacuum tube circuit is not functioning. When the plate supply is connected to the vacuum tube circuit, the load conditions on the inner conductor of the line 1 provide the proper heating for the line, and at such time the energy is disconnected from the heating coil 61 by relay 64. The line 1, 2, 3 is here shown, by way of example, as a frequency controlling element of oscillator 62, although it will be appreciated that the invention is not limited thereto, since said line can be used wherever there is need for a tuned circuit. The oscillator 62 is connected to the line in push-pull fashion in such manner as to dispense with the usual extra vacuum tube. To achieve this result, the grid is coupled to the inner section 2 by means of loop 66, while the anode is coupled through a condenser 68 to the same inner conductor in reverse fashion by means of loop 67. It will thus be seen that the line will produce in the loops 66 and 67 voltages which are of opposite phase to each other. A resistor 69 serves to provide grid bias for the vacuum tube 62, while condenser 70 serves to bypass the loops 66 and 67 to ground for radio frequency energy. Condensers 68 and 71 are regeneration control condensers which function to regulate the phase and amount of feed-back. Condenser 72 serves to balance the circuit in order to maintain symmetry. This condenser replaces the effective grid-plate capacitance of the second vacuum tube usually found in an ordinary push-pull circuit. A lecher wire system 73 serves the purpose of any suitable output circuit for the oscillator, this lecher wire system in turn being coupled to a utilization circuit such as an amplifier, not shown.

Although the wires connecting the loops 66 and 67 to the vacuum tube 62 have here been shown of substantial length, for the sake of simplifying the drawing, in practice these wires will be extremely short, and the vacuum tube will be mounted adjacent the small diameter section 2 of the line. The actual position of the tube and the construction of the wires will be such as to achieve maximum circuit efficiency.

It will be understood, of course, that the invention is not limited to the precise arrangement of parts shown and described, since various modifications may be made without departing from the spirit and scope of the appended claims. It should be distinctly understood that the features of the invention are not limited to the precise arrangement of concentric line illustrated, since the electron discharge device circuit and heating coil circuit can be used with other types of lines and tuned circuits, and are given only as illustrative of a particular and preferred embodiment of the invention. When higher power transmitters are used, the effect of the disclosed invention becomes increasingly important.

What is claimed is:

1. The combination with a concentric resonant line having an outer and a coaxial inner conductor so constructed and arranged as to form a tuned circuit, of a heating coil located within said inner conductor, said inner conductor being shorter than said outer conductor and apertured at one end, and a blower for blowing the heat generated in said resonant line through said inner conductor and out through the apertures to said outer conductor, and means for alternately rendering said heating coil or said blower operative.

2. The combination with a concentric resonant line having an outer conductor and a coaxial inner conductor so constructed and arranged as to form a tuned circuit, of a heating coil located within said inner conductor, said inner conductor being shorter than said outer conductor and apertured at both ends, and a suction device for circulating the heat generated in said resonant line through said inner conductor and out through the apertures in one end thereof, and means for alternately rendering said heating coil or said suction device operative.

3. The combination with a concentric resonant line having an outer conductor and a coaxial inner conductor so constructed and arranged as to form a tuned circuit, said inner conductor comprising two hollow sections of different diameters mechanically and electrically fastened together, the interior of said two sections communicating with each other, of a heating coil located within the smaller diameter section of said inner conductor, and a motor controlled device for circulating air through said inner conductor, and means for alternately rendering said heating coil or said device operative.

4. The combination with a concentric line having an outer and a coaxial inner conductor so constructed and arranged as to form a tuned circuit, and an electron discharge device oscillator having an anode, grid and a cathode, said grid and cathode being coupled to said line, of a heating coil located within said inner conductor, a source of heating energy for said coil, a source of anode potential for said anode, and means in-

cluding an electromagnetic relay for connecting said heating energy to said coil and simultaneously disconnecting said source of anode potential from said anode, or vice versa.

5. The combination with a concentric resonant line having an outer and a coaxial inner conductor mechanically and electrically coupled together at one end, a bellows at the other end of said inner conductor, and a rod of low temperature coefficient of expansion located within said inner conductor and linked to said bellows for maintaining the overall length of inner conductor including bellows substantially constant with changes in temperature, said rod being secured at one end to said bellows and at its other end to said first end of said line, of means for automatically compensating for variations in length of said rod, said means being located outside the electrical junction of said inner and outer conductors and mechanically linked to said rod.

6. The combination with a concentric resonant line having an outer and a coaxial inner conductor mechanically and electrically coupled together at one end, a bellows at the other end of said inner conductor, and a rod of low temperature coefficient of expansion located within said inner conductor, said rod being secured at one end to said bellows and at its other end to said first end of said line, of means for compensating for variations in length of said rod, said means being located on that side of the junction of said inner and outer conductors which is opposite that on which the bellows appears, said means including a metallic shell which expands with temperature in a direction opposite to that of said inner conductor with respect to said junction.

7. A concentric resonant line comprising an outer and a coaxial inner conductor, a metallic end plate connecting said conductors together at one end of said line, a metallic bellows at the other end of said inner conductor, a rod of low temperature coefficient of expansion within said inner conductor and connected at one end to said bellows and at its other end to a point on said line on the opposite side of said end plate relative to the location of said bellows, a compensator unit located at said point for maintaining a predetermined overall length of inner conductor with change in temperature, said unit including a metallic shell which is substantially a continuation of said inner conductor, said shell supporting said rod and being threaded on its interior, and a pair of nuts in the interior of said shell, one of said nuts being threaded on its periphery to cooperate with the threads on said shell, said one nut having an aperture in the center thereof sufficiently large to permit free movement of said rod, said other nut being threaded on its interior for cooperating with threads on said rod, said last nut being arranged to change the point of contact of said rod with said shell when said last nut is engaging said first nut, said shell being arranged to expand with temperature in a direction opposite to that of said inner conductor with respect to said end plate.

8. A line in accordance with claim 7, including a locking nut of similar construction to said first nut and also located within the interior of said shell for locking said first nut securely in position, and another nut similar in construction to said second nut for changing the point of contact of said rod with said shell in a direction opposite to that effected by said second nut.

9. In combination, a concentric resonant line having an outer and a coaxial inner conductor so constructed and arranged as to form a tuned circuit, an electron discharge device oscillator having an anode, a grid, and a cathode, a first loop of wire magnetically coupling said grid to said inner conductor, one terminal of said loop being connected to said grid while the other terminal of said loop is connected to said outer conductor through a radio frequency by-pass condenser, a second loop of wire magnetically coupling said inner conductor to said anode in reverse phase to said first loop, one terminal of said second loop being coupled to said anode through a balancing condenser and the other terminal of said second loop being coupled to said outer conductor through said radio frequency by-pass condenser, a regeneration control condenser connecting the grid to said one terminal of said second loop through said balancing condenser, and another regeneration control condenser connecting said anode to said one terminal of said second loop, such that the phase and amount of feed-back of the energy in said oscillator can be regulated, whereby said electron discharge device is coupled to said line in push-pull fashion.

10. The combination with an electron discharge device having a tuned circuit in the form of a concentric resonant line, said line having an outer and a coaxial inner conductor coupled together, of a heater coil located within said outer conductor to pre-establish a heat distribution similar to that developed by the radio frequency oscillatory energy in said tuned circuit, and means for alternatively rendering said heater coil or said electron discharge device operative.

11. The combination with an electron discharge device having a tuned circuit in the form of a concentric resonant line, said line having an outer and a coaxial inner conductor coupled together, of a heater located within said outer conductor, means for directing a flow of fluid through said inner conductor to substantially reduce time required for establishing thermal equilibrium, and means for alternatively rendering said heater coil or said electron discharge device operative.

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