Oct. 28, 1952 F. L. MACALUSO 2,615,947

IMPEDANCE MATCHING APPARATUS

Filed Nov. 30, 1948 2 SHEETS—SHEET 1

Fig.1.

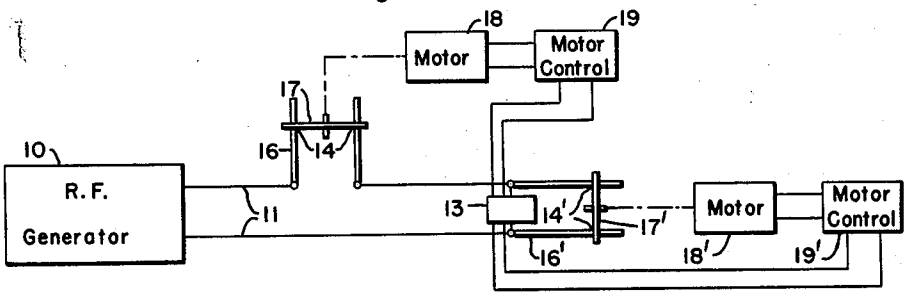



Fig.4.

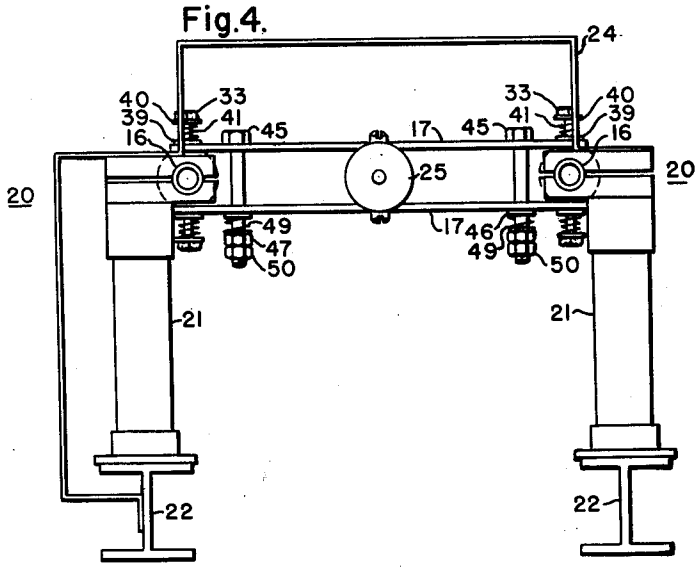
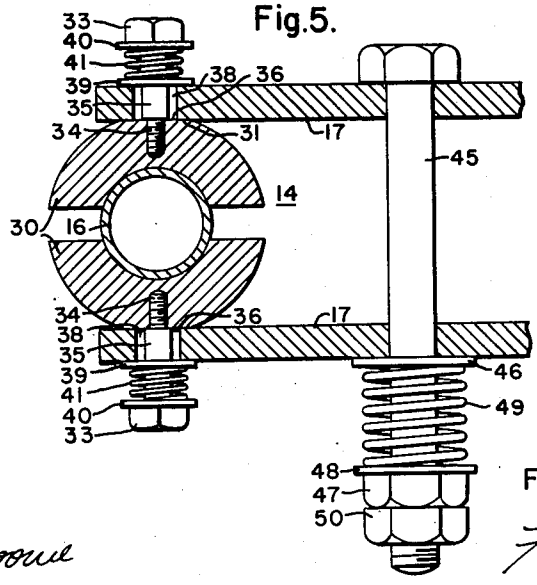



Fig.5.




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IMPEDANCE MATCHING APPARATUS

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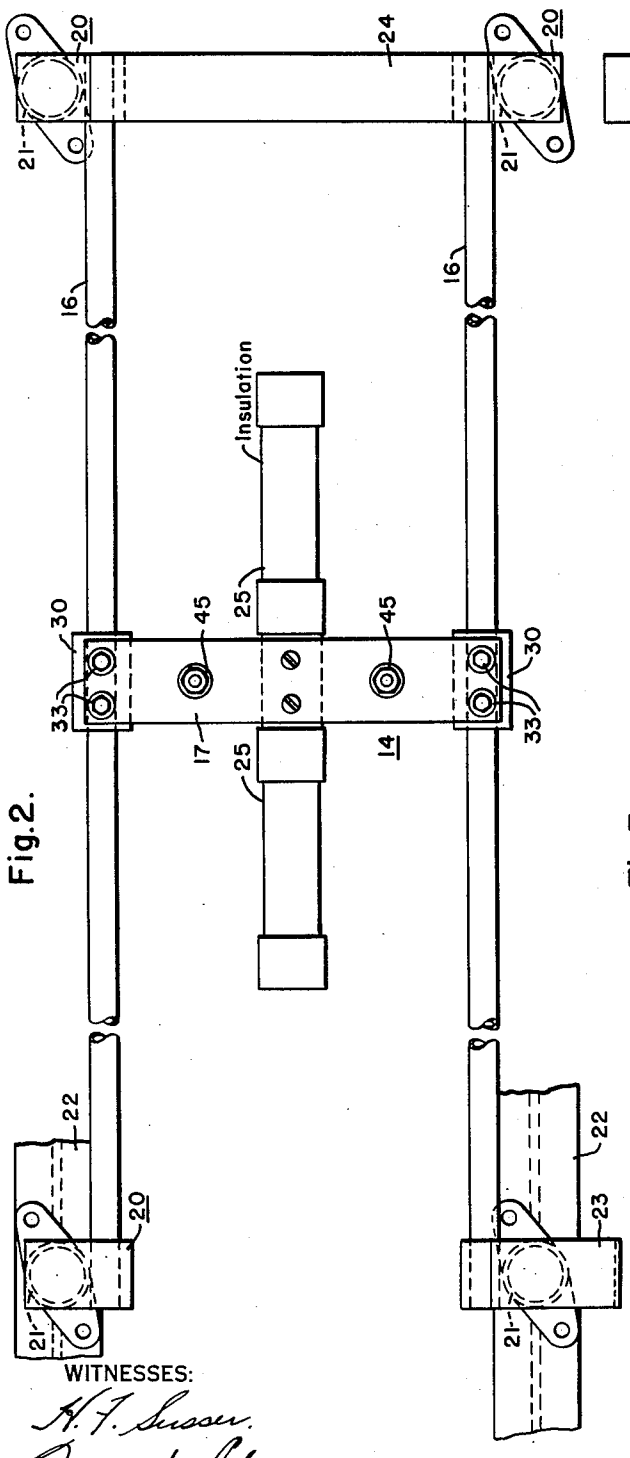



Fig.2.

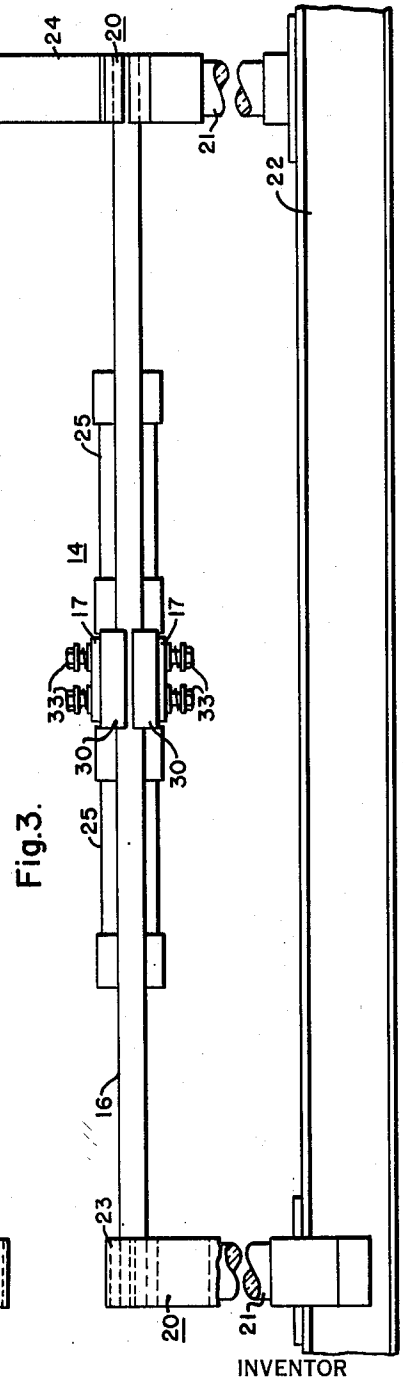



Fig.3.

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# UNITED STATES PATENT OFFICE

2,615,947

## IMPEDANCE MATCHING APPARATUS

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7 Claims. (Cl. 173—324)

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This invention relates to radio frequency generators, and more particularly to matching of impedances of the loads of such generators to transmission lines which connect the generators to the loads.

In most dielectric heating applications in which vacuum tube oscillators supply radio frequency energy to electrodes between which load articles are heated in succession, as being passed on a conveyor between the electrodes, the changes in the impedances of the articles during heating, or the differences in the impedance of different articles, causes mis-match of impedance between the transmission lines and the loads, resulting in inefficient operation, and may result in the loss of quality in some articles. This is due to the fact that the heating load is usually a low capacitive impedance whereas the vacuum tube oscillators represent a high impedance.

Transmission lines are commonly used for connecting the loads of dielectric heating systems to radio frequency generators. Tuning stubs consisting of a shorted section of a parallel two wire transmission line are used as variable inductive elements to match the impedance of the load to the line. The inductance of the tuning stubs may be varied by moving a shorting bar or slider along the length of the stubs, by means such as electric motors which respond automatically to changes in impedance. This adjustment of the positions of the sliders on the tuning stubs corrects for impedance mis-matches and enables optimum power transfer to the load articles.

A typical construction has used motor driven sliders, each consisting of a pair of semi-circular collars on the opposite sides of a metal tube, the collars being rigidly connected to cross-bars, which are drawn together by interconnecting bolts, for providing contact pressure between the collars and the tubes. A disadvantage of such a construction is that when the cross-bars are tightened to provide sufficient contact pressure, the collars bind on the tubes, due to irregularities therein, and this interferes with the adjustment of the collars by the motors. Such irregularities are due to variations in the tube diameters, departures from straightness, drawing burrs, and other imperfections in the tubes. The tubes are usually mounted on insulators which are not constructed, or installed, to very close tolerances, so that it is difficult to achieve exact parallelism between the tubes. Since the collars are rigidly attached to the cross-bars, the mounting holes

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and the assembly have to be located very accurately in order that the longitudinal axes of the two pairs of collars are exactly parallel.

This invention overcomes the disadvantages of prior tuning stub assemblies by providing sliding contactors for tuning stub tubes, which are so resiliently mounted and supported that they are movable radially of the tubes for compensating for any irregularities therein, whereby they can be moved lengthwise of the tubes, without binding, while providing the necessary contact pressure.

An object of the invention is to prevent binding between a connector slidable along a conductor, and the conductor.

Another object of the invention is to prevent binding between tuning stubs having connectors slidable along tubes.

Another object of the invention is to eliminate the necessity for close tolerances in tuning stub assemblies.

The invention will now be described with reference to the drawings of which:

Fig. 1 is a diagrammatic view of a typical circuit in which this invention is designed for use;

Fig. 2 is a side elevation of a tuning stub assembly embodying this invention;

Fig. 3 is a plan view looking downwardly upon the assembly of Fig. 2;

Fig. 4 is an end elevation of the assembly, and

Fig. 5 is an enlarged view, in cross section, of one of the tuning stubs, slidable connectors on a feeder tube, and of portions of the shorting cross-bars used.

Referring first to Fig. 1, the radio frequency generator 10, which may be a 20 kilowatt vacuum tube oscillator operating at a frequency of 13.6 megacycles, is connected by the transmission line 11 to a load 13, which may be a dielectric load to be heated by radio frequency energy. A pair of tuning stubs, one in series with the load and one in parallel with the load, are provided for matching the impedance of the load 13 to the transmission line 11. Slidable connectors 14 of the series tuning stub are in contact with the parallel conductors 16 of the stub and are connected together by a short-circuiting cross-bar 17. The cross-bar 17 is connected to an electric motor 18, which, in turn, is connected through a motor control 19 to the load 13. Slidable connectors 14' of the parallel tuning stub are in contact with the parallel conductors 16' of the stub and are connected together by a short-circuiting cross-bar 17'. The cross-bar 17' is connected to an electric motor 18' which, in turn,

is connected through a motor control 19' to the load 13.

In operation, impedance changes in the load 13 cause the motor controls 19 and 19' to operate the motors 18 and 18' to slide the connectors 14 and 14' in one direction or the other along the parallel conductors 16 and 16', until the load impedance is restored to normal.

In prior constructions, irregularities in the parallel conductors 16 and 16' forming the tuning stubs and lack of close tolerances in the manufacture and assembly of the other components of tuning stub assemblies, have caused the slidable connectors to bind, making it difficult for the automatic controls to properly position the connectors along the parallel conductors. While close tolerances in the manufacture of the tuning stubs and their components, and care in their installation will avoid some of the difficulties, this would add greatly to the cost of an installation.

The construction embodying this invention, and which will now be described in connection with Figs. 2 to 5 of the drawings, avoids the difficulties of the prior tuning stub assemblies, and can be manufactured and installed at a relatively low expense.

The parallel conductors 16 which may be straight copper tubes, are attached at their ends to the supports 20 which, in turn, are attached to the upper ends of the insulators 21, the lower ends of which are attached to the structural I-beams 22. The supports 20 for one of the tubes 16 is connected by the metal strap 23 at one end of the assembly, the left hand end facing Figs. 2 and 3 of the drawings, to one of the I-beams when it is desired to ground one side of the tuning stub. The supports 20 for both feeder tubes are interconnected at the other end of the assembly by the metal strap 24.

The inner ends of the tubular insulators 25 are attached to the bars 17 and extend parallel to the tubes equal distances therebetween. These insulators are provided for attaching the cross-bars 17 to the motor driven mechanism described in the foregoing, for adjusting the position of the cross-bar 17 along the parallel conductors.

As illustrated most clearly by Fig. 5, each connector 14 comprises the upper and lower collars 30 with inner surfaces formed as circular segments, with the diameters of the inner surfaces equal to the outer diameters of the tubes 16. The upper and lower collars are flattened at 31 at the centers of their outer surfaces.

The short circuiting cross-bars 17 contact the collars 30 at their flattened portions 31, and are secured thereby to the machine screws 33 which have their ends 34 threaded into the collars. The screws 33 have the body portions 35 which have larger diameters than the threaded ends 34, and which have the flat shoulders 36 which contact the flattened portions 31 of the collars.

The bars 17 have the circular openings 38 through which the body portions 35 of the screws 33 extend, which openings have substantially larger diameters than those of the screw body portions. The washers 39 around the screws 33, contact the outer surfaces of the bar 17, and the similar washers 40 around the screws 33 contact the inner surfaces of the heads thereof. The coil springs 41 are compressed between the washers 39 and 40, and serve to press the inner surfaces of the bars 17 tightly against the outer flattened surfaces 31 of the collars 30.

The springs 41 provide resiliency which permits vertical movement of the bars 17, relative their associated collars, when irregularities in the upper and lower outer surfaces of the tubes 11 appear during the sliding of the collars along the tubes.

The differences between the diameters of the circular openings 38 in the bars, and of the body portions 35 of the screws 33, which extend through the openings 38, and the resiliences of the spring 41 permit side movement of the collars relative to the bar 17 when irregularities in their side surfaces appear, and when the tubes depart from parallelism during the sliding of the collars along the tubes.

The springs 41 provide good contact pressure between the cross bars 17 and the collars 30 during their motion relative to each other, thus permitting the elimination of the flexible copper straps which have been used heretofore for electrically connecting the collars to the cross-bars.

The bolts 45 extend vertically through the bars 17 intermediate the tubes 16. The washers 46 extend around the bolts 45 in contact with the lower surface of the lower bar 17. The nuts 47 are threaded onto the bolts 45, and the washers 48 extend around the bolts and in contact with the inner surfaces of the nuts 47. The coiled springs 49 are compressed between the washers 46 and 48. The nuts 50 threaded onto the lower ends of the bolts are lock nuts. The bolts 45 pull the bars together for pressing the collars 30 against the tubes 16, the springs 49 providing resiliency whereby the bars 17 are able to move vertically relative to each other for additionally compensating for any irregularities in the upper and lower surfaces of the tubes 16 when the collars 30 are moved therealong.

As the collars are moved along the tubes 16 during impedance adjustments, the springs 41 on the screws 33, the springs 49 on the bolts 45, and the clearances in the openings 38 in the bars 17 around the screws 33 will permit the collars to move vertically and horizontally, and in directions therebetween, so as to ride over any irregularities in the tube surfaces without binding.

Although I have described in detail the series tuning stub, it is understood that the parallel tuning stub is constructed in identically the same manner.

I claim as my invention:

1. A transmission line for matching the impedance of a load to a radio frequency generator, comprising a pair of spaced, substantially parallel conductors, a pair of sliders formed to partially surround each of said conductors, a pair of cross-bars connecting the sliders on one of said conductors with the sliders on the other of said conductors, screws extending through said cross-bars and threaded into said sliders; said cross-bars having openings around said screws with diameters substantially larger than the diameters of the screws, coiled springs around said screws and compressed between the heads thereof and said cross-bars, and means for drawing said cross-bars together.

2. A transmission line for matching the impedance of a load to a radio frequency generator, comprising a pair of spaced, substantially parallel conductors, a pair of sliders formed to electrically contact each of said conductors, a pair of cross-bars connecting the sliders on one of said conductors with the sliders on the other of said conductors, said cross-bars being positioned in a plane substantially perpendicular to a plane containing the conductors, screws extending through said cross-bars and threaded into

said sliders, said cross-bars having openings around said screws with diameters substantially larger than the diameters of the screws, coiled springs around said screws and compressed between the heads thereof and said cross-bars, and means for drawing said cross-bars together.

3. A transmission line for matching the impedance of a load to a radio frequency generator, comprising a pair of spaced, substantially parallel conducting tubes; a pair of sliders formed as circular segments on each of said tubes, a pair of cross-bars connecting the sliders on one of said tubes with the sliders on the other of said tubes, said sliders having flattened portions contacting said cross-bars, screws extending through said cross-bars and threaded into said sliders; said cross-bars having openings around said screws with diameters substantially larger than the diameters of the screws, the portions of said screws threaded into said sliders having smaller diameters than their portions which extend in said openings in said cross-bars, and having flat shoulders contacting said flattened portions of said sliders, coiled springs around said screws and compressed between the heads thereof and said cross-bars, and means for drawing said cross-bars together.

4. A transmission line as claimed in claim 3 in which the pair of cross-bars is positioned in a plane substantially perpendicular to a plane containing said pair of conducting tubes.

5. A transmission line tuning stub comprising a pair of substantially parallel conductors, a short-circuiting member connected between said conductors, said short-circuiting member including a first and second sliding contact member respectively positioned on opposite sides of each conductor, a first cross-bar means, a first resilient coupling means connected between said first cross-bar means and each of said first sliding contact members, a second cross-bar means, a second resilient coupling means connected between the second cross-bar means and each of said second sliding contact members, each of said resilient coupling means comprising fastener members fixedly connected to the respective contact members and movable relative to the respective cross-bar means with resilient spring members adjacent each of said fastener members and operative therewith, and fastener means for drawing said first and second cross-bar means together to hold the respective sliding contacts in position on opposite sides of each conductor.

6. A transmission line tuning stub comprising a first conductor, a second conductor spaced from said first conductor and substantially parallel thereto, a short-circuiting member connected between said conductors, said short-circuiting member including a first and a second sliding contact member respectively positioned on substantially opposite sides of said first conductor, a third and a fourth sliding contact member respectively positioned on substantially opposite sides of said second conductor, a first cross-bar member, a first resilient connector means connected between the first cross-bar member and each of said first and third contact members, a second cross-bar member, a second resilient connector means connected between the second cross-bar member and each of said second and fourth contact members, each of said resilient coupling means comprising fastener members fixedly connected to the respective contact members and movable relative to the respective cross-bar means with resliient spring members adjacent each of said fastener members and operative therewith, and a resilient means for drawing together said first and second cross-bar members.

7. A transmission line tuning stub comprising a pair of substantially parallel conductors, a short-circuiting member connected between said conductors, said short-circuiting member including a first and a second sliding contact member respectively positioned on opposite sides of each of said conductors, a first cross-bar member a first resilient coupling means connected between the first cross-bar member and each of said first sliding contact members, a second cross-bar member, a second resilient coupling means connected between the second cross-bar member and each of said second sliding contact members, each of said resilient coupling means comprising fastener members fixedly connected to the respective contact members and movable relative to the respective cross-bar means with resilient spring members adjacent each of said fastener members and operative therewith, said first and second cross-bar members being positioned in a plane which is perpendicular to a plane including said conductors, and a fastener for pulling together said first and second cross-bar members.

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