COUPLING DEVICE FOR MICRO-WAVE ENERGY

Ernest Carl Okress, Montclair, N. J., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application October 7, 1942, Serial No. 461,135

8 Claims. (Cl. 178—44)

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This invention relates to coupling devices and more particularly to a coupling device for micro-wave energy, as for instance, from the source of generation of the energy to a wave guide or other means of transmission of the energy from such source to effectuate its use.

While coupling devices per se are known in the art, difficulties have been experienced in connection therewith both as to the efficiency, as to the tuning and as to the mechanical assembly. In this latter respect it has been found difficult to construct a friction coupling device with such accuracy that the metallic parts will not either in assembly or in or use introduce strains upon the glass envelope portion and immediately or ultimately cause a crack or other rupture therein which renders the device ineffective or so grossly inefficient as to require discarding the entire coupling device.

It will be recognized by those skilled in the art that a coupling device is in effect a short length of coaxial line with a loop or other terminal for introduction into the generator and that consequently, since the generator is evacuated and the wave guide with which the device is coupled is not evacuated, a dielectric has to be interposed in the energy path for maintaining the evacuation of the generator. Various schemes have been suggested and tried, and it appears most effective to extend the coaxial pick-up rod portion of the terminal from the generator to the wave guide with said rod portion passing transversely through the wave guide and intersecting the center line of the wave guide at right angles, the portion of the rod within the wave guide constituting what may be appropriately termed an antenna. To accomplish this desideratum, a dielectric envelope, of glass, is sealed at one end to the tubular portion of the coaxial line and is sealed at its other end to a distant part of the rod portion of the coaxial line, said dielectric envelope extending with the rod through the wave guide and the two areas of sealing above mentioned being at opposite exterior portions of the wave guide. This construction necessitates that there shall be not only this mechanical attachment to the parts mentioned but, of necessity, means to establish the required antenna reactance and radiation resistance in order that the wave guide may be matched to an input having an impedance less than twice the appropriate characteristic wave guide impedance.

An object of the invention is to overcome the aforementioned difficulties and to improve the coupling device both mechanically and from an efficiency standpoint.

A further object of the invention is to obtain accurate placement of the reflecting and tuning means and at the same time avoid introduction of mechanical strain upon the glass envelope.

Another object of the invention is to provide adjustments for the reflecting and tuning means which is entirely outside the evacuated area and in operation introduces no movement of the envelope for the evacuated area or of any parts extending thereinto.

Still further objects of the invention are simplicity of parts, ease and permanence of assembly, and adaptability to known generators and wave guides.

Additional objects of the invention will appear to those skilled in the art both by direct reference thereto as the description proceeds and by implication from the context.

Referring to the accompanying drawings in which like numerals of reference indicate similar parts throughout the several views, Figure 1 is a sectional view longitudinally of my improved coupling device and of a wave guide with which it is associated;

Figures 2 and 3 are cross sections on lines II—II and III—III, respectively, of Figure 1;

Figures 4, 5 and 6 are sectional views of the character of Figure 1, but left partly in elevation, and each showing a modified construction;

Figures 7 and 8 are cross-sectional views on lines VII—VII and VIII—VIII, respectively, of Figure 6; and

Figure 9 is a view partly in longitudinal section of a further modified construction of coupling devices.

In the specific embodiment of the invention illustrated in said drawing and referring initially to the construction of Figures 1, 2 and 3, the reference numeral 10 designates a part of a known ultra-high frequency generator from which wave energy is derivable through a coaxial line means which includes a current probe or loop 11 of suitable shape situated within a cavity 12 of the generator. The interior of said generator, including said cavity, is evacuated and it is, of course, essential to maintain the vacuum throughout the useful life of said generator. Normally the current probe or loop 11 is exposed directly to the evacuated cavity.

The desideratum is to transfer energy picked up by the probe or loop to a hollow wave guide 13 situated exterior to the generator and the hollow of which is not evacuated. Wave guides in general are known to the art and constitute a means by which electromagnetic energy is propagated from one place to another before its...
ultimate transmission in free space or utilization in some other instrumentality. Usually wave guides are rectangular in cross section with one dimension greater than the other for purposes of obtaining the desired mode of oscillation and polarization of the wave that may be transmitted. The cross-sectional dimensions have a definite relation to the character of the wave being transmitted, but need not be discussed in this specification. Suffice it to say, that the terminal sections here discussed are suitable for launching the transverse electric, TE_0, mode or H_a wave. For a more extended discussion of modes and waves involved reference may be made to an article by L. J. Chu and W. L. Barrow, entitled “Electromagnetic waves in hollow metal tubes of rectangular cross section” published in Proceedings of Institute of Radio Engineers, vol. 26, No. 12, December 1938, beginning page 1520, and of especial interest, page 1532.

The coupling device per se comprises, in addition to current probe or loop 11 above mentioned, a coaxial line of which the center rod 14 is the axial portion and is a continuation of the said current probe, that portion of said rod which is within the wave guide being termed the antenna, and that part from the generator to the wave guide being termed the pick-up portion. The rod is of tungsten, copper or other suitable metal and projects from the generator to and vertically through the wave guide medially between the side walls thereof thereby intersecting the center line of said wave guide. The cooperating tubular portion of the coaxial guide is constituted by a conductive base or sleeve tube 13, and a tube 15 coaxial with a sleeve 16 which preferably is also copper, axially aligned and projecting upwardly therefrom, both the thimble and the tube having central passages 17, 18, respectively, of which one is a continuation of the other. The upper end of said tube 15 is substantially at the level of the lower horizontal wall of the wave guide but does not have any contact therewith.

Also projecting from the upper end of said thimble, preferably coaxial with the said tube 13, out of the upper end of which is sealed vacuum tight at an end margin of a long glass envelope 20 of substantially the same diameter throughout its length as said sleeve. The sleeve and glass envelope are of materials having substantially the same coefficient of expansion and by preference the glass is borosilicate glass and the sleeve is an alloy of nickel, cobalt, manganese and iron in accordance with disclosure of Patent 2,062,335 of December 1, 1936 to Howard Scott, said material being sold under the trade name of “Kovar.”

Glass envelope 20 extends upwardly through the wave guide and is sealed, as with reentrant stem 22 to the central rod 14 at a position on said rod above the wave guide, said rod in this instance extending through the seal and projecting from the upper end of the envelope. Standing upright above the wave guide to which it is attached, it serves as the metallic housing 23 coaxial with the said rod and envelope. The envelope and rod both project into said housing.

Located within said housing above the envelope and around the projecting end of rod 14 is an annular hollow piston 24 having an outer cylindrical skirt portion 25 and an inner cylindrical skirt portion 26 connected at their upper ends by an annular end wall 27. This piston 24 accordingly provides a central bore or passage 28 axially therethrough and provides between said cylindrical skirts 25 and 26 an annular downwardly opening chamber 29 the depth of which from open end 30 to end wall 27 is a coaxial quarter wave length in the electric present, which is in this instance 31.

It is appropriate to point out that central bore 28 is considerably larger than the diameter of the rod affording ample clearance to avoid contact therewith notwithstanding imperfections of manufacture, misalignment from assembly or distortions in use. Furthermore, a similar clearance or gap 31 is provided between the outside cylindrical skirt 25 and the housing 23 containing the same. These clearances are necessary in view of the fact that in operation high currents seek to traverse the space between the rod 14 and housing 23 and a sliding contact connecting those parts is generally electrically undesirable and mechanically detrimental. The chamber 29 of the piston is a coaxial quarter-wave length deep, with a high impedance at the open end 30, which acts as a mirror or perfect open coaxial line.

Such construction and adjustment for the piston 24 is obtained by a screw 32, threaded through the end of the housing 23 and shown with a knurled head 33 at its outer end for manipulation by hand. A lock nut 34 on the screw can be tightened against the housing and the screw in its knurled position. The inner end of the screw is provided with a flare 35 of inverted cup-like shape with the lower rim thereof secured to the end wall 24 of the piston. The flare 35 is of adequate depth to accommodate the upper end of the rod 14 projecting therein and the annular reactance can be obtained by adjusting the position of the piston 24 in the tube or housing 23.

The introduction of the proper radiation resistance for the antenna is accomplished by provision of an appropriate closure for one end of the said wave guide. Preferably said closure comprises a piston 36 rectangular in cross section to correspond to the shape of the wave guide and having a skirt portion 38 forming an interior chamber 35 which is a quarter wave length deep and support and adjustment for the coupling device. This piston provides an end wall 40 from which said skirt projects. On the other side of the end wall 40 from the said skirt is a reduced portion or neck 41 which connects with a rectangular head portion 42 of appropriate size to have sliding fit with the interior face of the wave guide. It will be noted from the drawing that the skirt portion 38 is of less dimension than the inside dimension of the wave guide so as to provide a gap 43 between said skirt portion and the wave guide. There exists a high impedance at the forward open end 41 since the piston chamber is a quarter wave-length deep, referred to wave guide wave length. In order to adjust this piston for altering the radiation resistance of the antenna the head 42 thereon is connected to a screw 44 rotatable with respect thereto by virtue of a flange 45 on the inner end of the screw held to the piston head 42 by an appropriate retaining washer 46.

A fixed closure 47 is screwed to the end of the wave guide as by being attached to a collar 48 which partly engirdles the end margin of the wave guide and retained thereon by suitable means, such as screws 49. Adjusting screw 44 has a suitable finger piece 50 such as the knurled knob 49 and is retained in adjusted position by a lock nut 51 adapted to be turned tightly against the end of fixed housing 47.

Electrical continuity between the upper end
of coaxial tube 16 and the adjacent wave guide bottom wall is obtained by means set forth in and forming the subject matter of co-pending application of E. C. Okress and Polykarf Kusoh, Serial No. 457,024, filed September 2, 1942, entitled "Coupling Device," and assigned to the same assignee as the present invention, and now Patent No. 2,494,500, dated January 16, 1946. Detailed description will accordingly be omitted from the present specification. Suffice it to say that tube 16 is provided with a cylindrical enlargement 52 on the inside of the envelope 20 and is directly opposed on the outside of the envelope by a metallic ring 53 the upper end of which connects with the wave guide. Surrounding the metallic ring 53 is a glass ring 54 having the same dielectric constant as the glass of the envelope. This glass ring is interposed between the metallic ring and a lower housing 55 which extends from thimble 15 to the wave guide and is concentric with said rings, envelope and sleeve 16. The glass ring, metallic ring and enlargement 52 are of a length substantially equal to a quarter coaxial wave length in the dielectric represented by the glass.

It may now be pointed out that an essential feature of the present invention resides in the provision of a piston of quarter wave length depth cut of contact from the surrounding wall of the structure in which it is used. While Figure 1 illustrates use of two such pistons both of which are adjustable at any time, it is equally within the scope of the invention to provide a piston which can be adjusted at the source of manufacture and permanently soldered in place after the adjustment has been made. A modification illustrative of this permanently adjusted structure is shown in Figure 4. Referring to this view in detail, envelope 20 with its contained coaxial rod 14c together with supporting thimble 15 and lower housing 55 conforms to the construction already described. Upper housing 22a differs from the preceding construction in that it is open at its upper end. A piston 24b is situated in the housing 23a said piston having outer and inner cylindrical skirts 25a and 26a with an upper end wall 27a. As before, a central bore or passage 28a is provided through the cylindrical inner skirt leaving an annular clearance for the rod 14c. Between the said inner and outer skirts 25a and 26a an annularly downwardly opening chamber 29a depth of which from open end 32a to end wall 27a is a quarter coaxial wave length in air.

At the upper end of wall 27a is a reduced portion or neck 56 which connects thereabove with a head 57 the size and shape of which is such that it fits within the open upper end of housing 23a. After adjustment has been made this head is soldered, as at 58, to the housing and retains that adjusted position thereafter. It is to be noted that although head 57 fits the housing there is a gap 31a separating the outer skirt 25a from contact with said housing.

Piston for radiation resistance adjustment is provided, and adjustment accomplished in a manner similar to the construction heretofore described. In this instance, piston 32a is rectangular and provides a skirt portion 36a forming a chamber 35a with a depth to the end wall 42a equal to a quarter wave length in air, referred to wave guide wave length. At the outer side of said end wall 42a is a reduced portion or neck 41a and thereby a head 42a. The head is of appropriate dimension and has a sliding fit with the wave guide whereas the skirt portion 38a is of a smaller dimension so as to leave a clearance or gap 43a between the skirt and the wave guide. After the piston is located at the desired adjusted position the place of manufacture it is permanently secured as by solder 59.

While the foregoing construction has many advantages outstanding amongst which is the fact that the open front edge of the piston constitutes a high impedance and therefore, makes it immaterial as to the structure of impedance at the rear of the piston, certain advantages are to be gained by reversing the piston and having the solid wall toward the front and the open end projecting rearward with modifications in the depth of cups however. Essential among these differences is the fact that the latter construction permits closer association of the piston to the center line of the wave guide in the instance of the piston on the axis of the probe or closer to the center line of the probe in the instance of the piston at the end of the wave guide. Also the coaxial quarter wave length rather than the wave guide wave length is used in determining the depth of the inverted rectangular cup 36b. Reversing the piston has the effect of a movable shorted line instead of a movable open line as in Figure 1. A construction including pistons 24b and 32b having the solid faces 27b and 40b thereof forward is illustrated in Figure 5. Care is taken in this construction of Figure 5 to maintain high impedance at the planes 39b and 51b of the open rear ends of the respective pistons and low impedance at the forward closed ends thereof. Parts in Figure 5 are designated by the same reference numerals as used in connection with the description of Figure 1, but with the addition of the letter b thereafter, so that repetition of description is not believed necessary here.

It is to be here noted that pistons 24b and 32b are a coaxial quarter wave length deep.

In connection with the construction shown in Figure 5 the flare 35b for reversed piston 24b extends into the chamber 25b of the piston to the middle part of end wall 27b so that it is secured. Likewise with respect to the other piston 32b, neck 41b extends axially within the chamber 32b of piston 32b to the forward end wall 40b thereof to which it is likewise attached. As in the preceding construction of Figure 1, the piston in each instance is separated from the part of the device surrounding the same. In this instance the high impedance is at the gap at the rear open end of the piston whereas the low impedance is at the forward closed end of the piston.

In Figures 6 to 8 an ultra-high frequency generator 10c is indicated with probe 10c entering cavity 12c and projecting therefrom transversely through a wave guide 13c by virtue of rod or antenna 14c formed as a continuation of said antenna. Thimble 15c having tube 16c next its inner bore, "Kovar" sleeve and tubular borosilicate glass envelope 20c are provided as before, together with enlargement 32c on the tube 16c within the envelope and metallic and glass rings 53c and 54c opposed thereto on the outside of the envelope for constituting an impedance section and electrical continuity at the longer dimension bottom wall of the wave guide. In this showing an impedance section is provided in the upper housing above the wave guide.

Describing this upper impedance section more in detail, the same comprises a metallic enlargement 52 of the coaxial quarter wave length in glass. This enlargement fits upon the rod 14c.
and is silver soldered, as at 83. The outer peripheral surface of this enlargement is next the glass envelope. Outside the envelope, of same length as and directly opposed to the said enlargement is a metallic ring 64 and next thereto is a glass ring 65 of substantially coaxial quarter wave length in glass. The glass ring fits within an upper housing 66 shown as made in two sections for enabling assembly to be accomplished more readily. The position of this electrically shorted line is readily obtained once the characteristics of the particular type of generator is established. This section obtains effect of an electrical shorting and no high frequency passes thereby. This completely avoids herefore troublesome arcing and corona occurring at the outer end of rod or antenna 14c between said antenna and housing.

At the end of the wave guide, is provided a reversed piston 36c having skirt 38c providing a chamber 38c to a forward end wall 40c such that the chamber is a quarter wave length deep in air referred to free space wave length. The piston is supported by a head 42c which fits the wave guide, a neck portion 41c extending from said head into the piston chamber and connected to the mid part of the forward end wall 40c. As in previously described constructions, the skirt 38c of the piston is spaced from the several walls of the wave guide leaving a gap 43c therebetween. The adjustment of the proper radiation resistance is achieved by the movement of piston 36c and when accomplished said piston is soldered, as at 59c in place.

The reversed piston tuning means above described may be used with other constructions of coupling devices, such as the rugged commercial structure shown in Figure 9. The piston structure is identical in Figure 9 with that in Figure 6, wherefore description is not repeated and parts may be identified by the same numerals but with substitution of letter "d" after each. Similarly the upper impedance section of Figure 9 is also like that of Figure 6 and a corresponding use of numerals is made.

In Figure 9, ruggedness of structure is obtained by utilizing an inverted cup 61 of “Kovar” at the top of the glass portion of the envelope 28d in seconded at its rim to the glass. Rod 14d is secured to the end wall of this inverted cup at the inside thereof. By virtue of the impedance section in front of the “Kovar” cup, little energy escapes thereto. Maximum rigidity and maintenance of accurate spacing of parts is obtained by use of the said inverted cup and by securing the rod thereto.

Referring to Figures 1 and 4, the forwardly facing open ended pistons 35 and 36c represent open linear, and the forward plane at 51 and 51a of each is substantially a half wave length distant from the respective rod or antenna 14 and 14c. Similarly, in the same figures, with regard to the coaxial line pistons 24 and 24a, the forward open end of each is a quarter wave length distant from the center line of the respective wave guide 13 or 13a. With the reversed or inverted skirt piston, such as shown in Figures 5 to 9, showing the shorted line assembly, the forward plane of the piston in each case is the solid wall 40b, 40c and 40d, and this is at a distance of a quarter wave length distant from the rod or antenna 14b, 14c or 14d.

With the coaxial construction, the forward plane of the piston represented by solid wall 27b, Figure 5, and the forward end of the corresponding impedance sections in the upper housings, are substantially a half wave length from the centerline of the respective wave guide 13b, 13c and 13d. Exact location of the forward planes of the several pistons is then made so as to produce the particular antenna radiation resistance and antenna reactance required at the point of termination and so are not strictly multiples of quarter wave lengths.

Since the various details of construction, as well as the precise relation and functioning of parts, are subject to variation and change without departing from the invention concept or scope of the invention, it is intended that all matter contained in the specification or illustrated in the drawing, shall be interpreted as exemplary and not in a limiting sense. It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein shown and described and all statements of the scope of the invention herein set forth as a matter of language which might be said to fall therebetween.

I claim:

1. A coupling device from an ultra high frequency generator to a wave guide, comprising an elongated sealed and evacuated envelope, a rod of which a part constitutes a pick-up portion and a part constitutes an antenna, both of said parts of the rod being within the vacuum of the envelope, said rod extending longitudinally of said envelope, said envelope and rod being transverse to and projecting through said wave guide and the wave guide having one portion for conveying energy from the region surrounding the antenna and having a directly opposite end section terminating outwardly from the antenna of the order of an odd quarter wave length therefrom, and a closure for the second mentioned portion, said closure having as part thereof a piston-like member having a closed end and an open end and forming with the enclosure portion a resonant system by which high impedance is established at the open end and low impedance at the closed end of the said member.

2. A coupling device from an ultra high frequency generator to a wave guide, comprising an elongated sealed and evacuated envelope, a rod of which a part constitutes a pick-up portion and a part constitutes an antenna, both of said parts of the rod being within the vacuum of the envelope, said rod extending longitudinally of said envelope, said envelope and rod being transverse to and projecting through said wave guide and the wave guide having one portion for conveying energy from the region surrounding the antenna and having a directly opposite end section terminating outwardly from the antenna of the order of an odd quarter wave length therefrom, and a closure for the second mentioned portion, said closure having as part thereof a piston-like member having a closed end and an open end and forming with the enclosure portion a resonant system by which high impedance is established at the open end and low impedance at the closed end of the said member.

3. A coupling device from an ultra high frequency generator to a wave guide, comprising an elongated sealed and evacuated envelope, a rod of which a part constitutes a pick-up portion and a part constitutes an antenna, both of said parts of the rod being within the vacuum of the envelope, said rod extending longitudinally of said envelope, said envelope and rod being transverse to and projecting through said wave guide and the wave guide having one portion for conveying energy from the region surrounding the antenna and having a directly opposite end section terminating outwardly from the antenna of the order of an odd quarter wave length therefrom, and a closure for the second mentioned portion, said closure having as part thereof a piston-like member having a closed end and an open end and forming with the enclosure portion a resonant system by which high impedance is established at the open end and low impedance at the closed end of the said member.
to and projecting through said wave guide and the wave guide having one portion for conveying energy from the region surrounding the antenna and having a directly opposite enclosure portion terminating outwardly from the antenna of the order of an odd quarter wave length therefrom, and a closure for the second mentioned portion, said closure having a piston as part thereof said piston having a skirt portion therearound open at one end and closed at the other and of smaller outside dimensions than the inside dimensions of the wave guide, thereby forming a peripheral gap between said skirt and wave guide, and said skirt providing an open quarter wave-length cavity therein by which impedance is minimized at said closed end across the gap.

4. A coupling device from a source of resonant frequency to a wave guide, comprising a wave guide and an elongated envelope projecting therethrough, an antenna extending longitudinally of said envelope connected to the source of resonant frequency and having an extension projecting through the end of the envelope, a metallic housing over said extension of the antenna and end of said envelope thereto coaxial with said antenna and joined to said wave guide, and a piston in said housing outside of said envelope and around said extension and out of contact from said housing and electrically coupled with low impedance to said housing for current flow, said antenna being substantially a predetermined distance from said wave guide the value of which establishes the required antenna reactance, whereby the same resonant frequency existing in the envelope is transferred to the wave guide.

5. A coupling device from a source of resonant frequency to a wave guide, comprising a wave guide and an elongated envelope projecting therethrough, an antenna extending longitudinally of said envelope connected to the source of resonant frequency and having an extension projecting through the end of the envelope, a metallic housing over said extension of the antenna and end of said envelope thereto coaxial with said antenna and joined to said wave guide, a piston in said housing outside of said envelope for providing impedance matching between said source and wave guide, said piston being out of contact from both said housing and said antenna extension, and means productive of low impedance by way of said piston from said antenna extension to said metallic housing for providing current flow from said antenna extension to the wave guide, whereby the same resonant frequency existing in the envelope is transferred to the wave guide.

6. A coupling device from a source of resonant frequency to a wave guide, comprising a wave guide, and an elongated envelope projecting therethrough, an antenna extending longitudinally of said envelope connected to the source of resonant frequency and having an extension projecting through the end of the envelope, a metallic housing over said extension of the antenna end of said envelope thereto coaxial with said antenna and joined to said wave guide, a piston in said housing outside of said envelope and out of contact from and electrically coupled with low impedance to both said housing and said antenna substantially at a common plane transverse to said housing and antenna.

7. A coupling device from a source of resonant frequency to a wave guide, comprising a wave guide and an elongated envelope projecting there-through, an antenna extending longitudinally of said envelope connected to the source of resonant frequency and having an extension projecting through the end of the envelope, a metallic housing over said extension of the antenna and end of said envelope thereto coaxial with said antenna and joined to said wave guide, and a piston in said housing outside of said envelope for providing impedance matching between said source and wave guide, said piston having an end wall and a skirt with the skirt having a longitudinal dimension of an odd quarter wave length paralleling said housing and said skirt being out of contact from said housing and providing means in conjunction therewith productive of low impedance at one end of the piston for current flow from said antenna extension to said housing.

8. A coupling device from a source of resonant frequency to a wave guide, comprising a wave guide and an elongated envelope projecting therethrough, an antenna extending longitudinally of said envelope connected to the source of resonant frequency and having an extension projecting through the end of the envelope, a metallic housing over said extension of the antenna and end of said envelope thereto coaxial with said antenna and joined to said wave guide, and a piston in said housing outside of said envelope, said piston having an end wall and a skirt with the skirt having a longitudinal dimension of an odd quarter wave length and said skirt being out of contact from said housing, said skirt having its open end toward the wave guide and its end wall at the end of the skirt away from the wave guide.

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