April 28, 1959 J. R. BIRD ET AL 2,884,603

METHOD OF AND APPARATUS FOR CONVERTING HIGH FREQUENCY ELECTRICAL ENERGY INTO HEAT

Filed Feb. 4, 1953 2 Sheets-Sheet 1

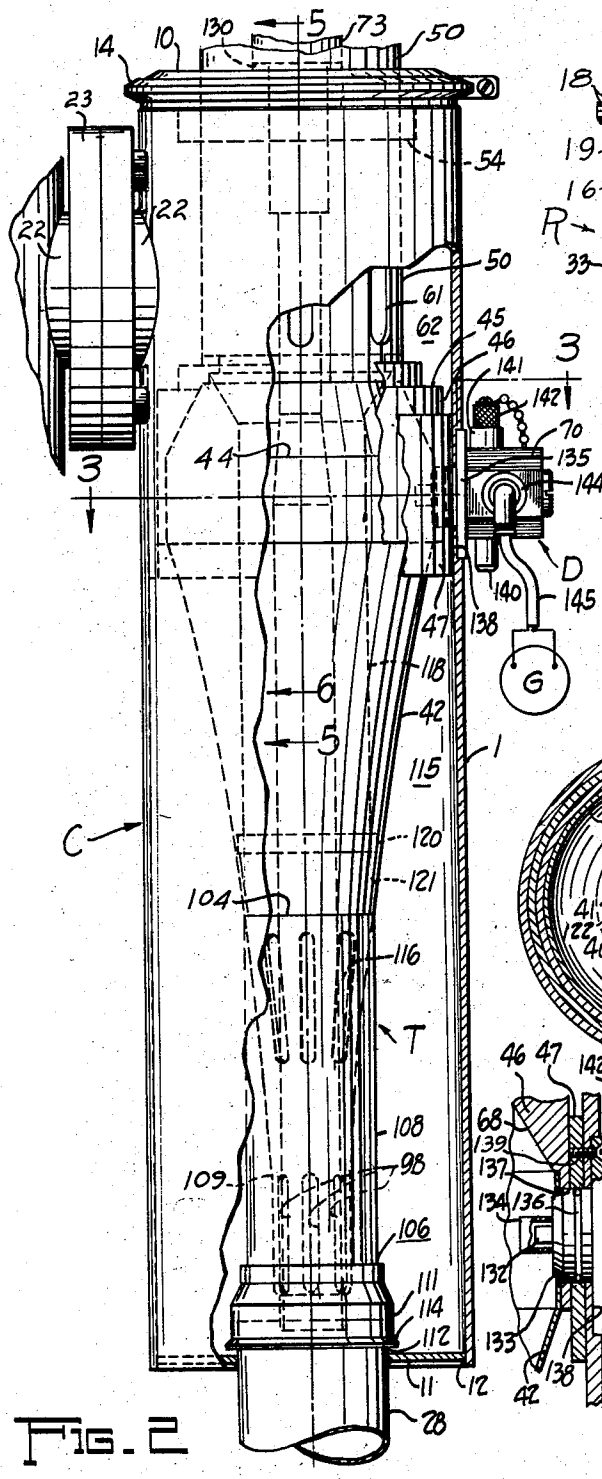


Fig. 2

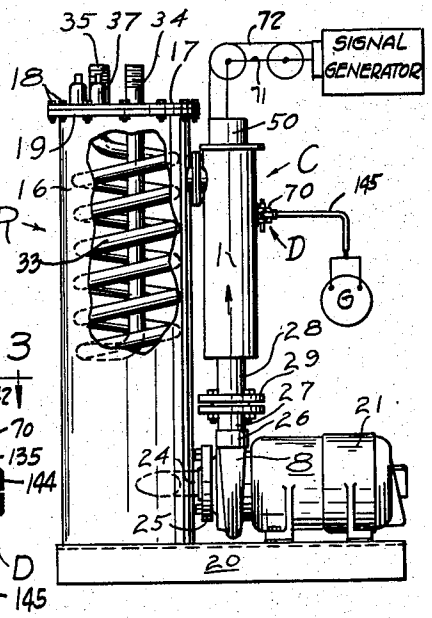


Fig. 1

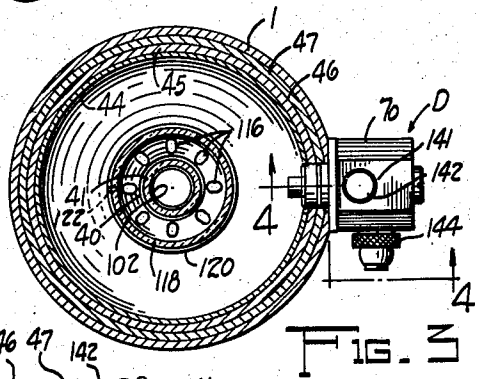


Fig. 3

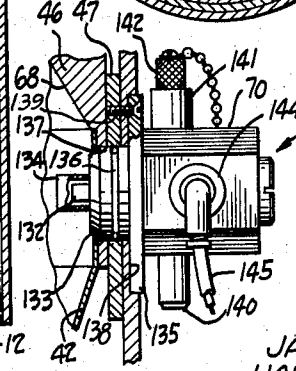


Fig. 4

INVENTORS
JAMES R. BIRD
HAROLD E. STEVENS
BY George Knowles
ATTORNEY

April 28, 1959 J. R. BIRD ET AL 2,884,603

METHOD OF AND APPARATUS FOR CONVERTING HIGH FREQUENCY ELECTRICAL ENERGY INTO HEAT

Filed Feb. 4, 1953 2 Sheets-Sheet 2

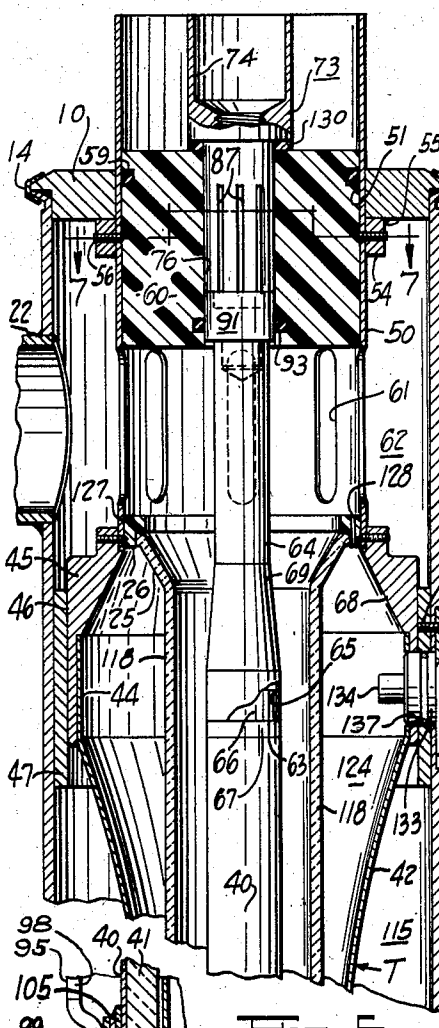


FIG. 8

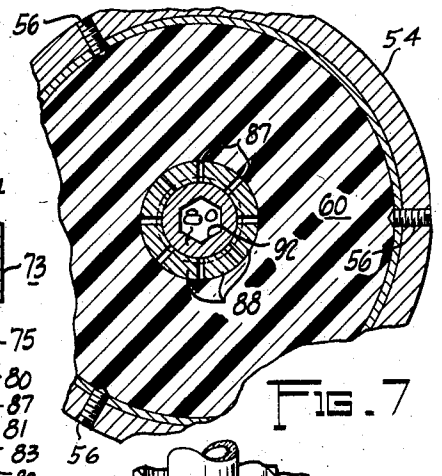


FIG. 7

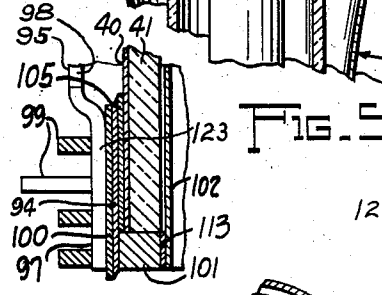


FIG. 5

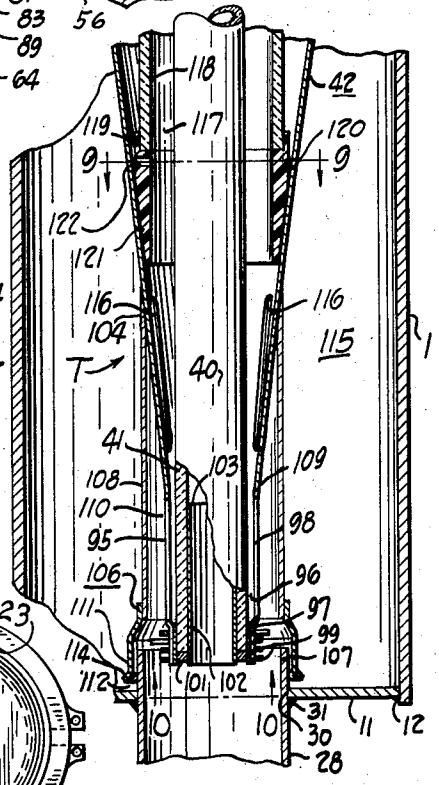


FIG. 6

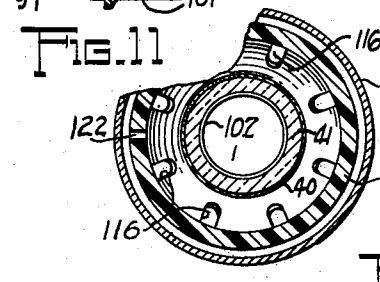


FIG. 11

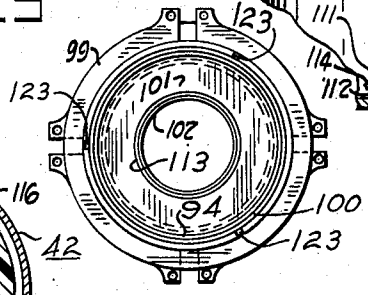


FIG. 10

FIG. 9

INVENTORS
JAMES R. BIRD
HAROLD E. STEVENS
BY George Knowles
ATTORNEY

United States Patent Office 2,884,603 Patented Apr. 28, 1959

2,884,603

METHOD OF AND APPARATUS FOR CONVERTING HIGH FREQUENCY ELECTRICAL ENERGY INTO HEAT

James R. Bird, Chagrin Falls, and Harold E. Stevens, Cleveland, Ohio, assignors to Bird Electronic Corporation, Cleveland, Ohio, a corporation of Ohio

Application February 4, 1953, Serial No. 335,118

20 Claims. (Cl. 333—22)

This invention relates to high frequency electrical devices and has particular reference to coaxial line components of the reflectionless termination type used either alone for attenuation or absorption of wave signal energy or in conjunction with suitable detector, sampling, pickup or voltage dividing devices as a measuring instrument or the like.

The transmission, absorption and measuring of high frequency electrical energy is more difficult in many respects than the corresponding treatment or handling of low frequency or direct current electrical energy because of capacitive and inductive effects, reflections and other phenomena. High frequency energy is satisfactorily transmitted on coaxial lines, however, and when the energy to be absorbed is of a relatively low order such lines have been reflectionlessly terminated successfully in accordance with well known principles. When the energy to be absorbed in the termination is of a high order, however, that is to say, above about 5 kilowatts, considerable difficulty has been encountered in providing line components such as reflectionless terminations that can withstand long periods of continuous service without failure and which conform to known theoretical considerations governing the geometry of such devices to avoid objectionable reflections. It is known, for example, that a coaxial transmission line can be terminated substantially reflectionlessly by a device which incorporates coaxial inner and outer conductors, one of which is tapered and one of which is resistive, the tapered conductor desirably taking the form of a tubular metal horn surrounding a cylindrical insulator of ceramic or like material on which is deposited or otherwise formed a film of carbon, or equivalent, the latter constituting the inner conductor of the line termination. In such arrangement the smaller end of the outer horn conductor makes direct electrical connection with resistive carbon film at one end of the inner conductor, thus completing the circuit. The curvature of the horn conductor is logarithmic, such that at any point along the length of the termination the resistance of the inner resistive film conductor between such point and the end connected to the small end of the horn is equivalent to the characteristic impedance of the termination at the point of reference.

Electrical energy fed into a line termination of the character mentioned is absorbed all along the resistive inner conductor, resulting in heating of the carbon film. At low energy levels the energy is satisfactorily dissipated into the atmosphere as by blowing air over the resistive film or by permitting air to circulate over the resistive film through the action of convection currents. It has also been proposed to employ a liquid dielectric coolant in the annular tapered dielectric space which separates the inner and outer conductors of the termination and to permit convective circulation of such coolant through the dielectric space either axially of the device or transversely thereof. Ordinary cooling methods, even those employing a circulating liquid dielectric coolant have not been entirely satisfactory in use, particularly in situations

requiring a relatively high rate of energy absorption and dissipation by the termination.

By reason of the geometry of the reflectionless device, requiring close proximity of the inner and outer conductors at one end of the device and wide separation thereof at the other end, and the need for substantially uniform heat absorption all along the length of the resistive conductor, it is not feasible merely to adopt conventional cooling, coolant circulating heat absorbing and heat transferring techniques and devices. The present invention is therefore concerned primarily with and has for one of its principal objects the provision of a new method of and apparatus for reflectionlessly terminating a coaxial transmission line and disposing of the heat energy resulting from such termination. More specifically the invention is concerned with the creation of a reflectionless termination for a coaxial line which incorporates novel cooling and heat dissipation features in combination with manufacturing, assembling and servicing advantages and which is adaptable with little change or modification for use either as a so-called "dummy" load or as a component of a volt meter or wattmeter.

To absorb high frequency electrical energy at a high rate in a reflectionless termination of the character referred to it is necessary that the resistive component or conductor of the termination be cooled rapidly and that the cooling be substantially uniform over the entire extent, surface, area or length of such resistive component, this also being an objective of the present invention.

In accordance with the method of the present invention a liquid dielectric coolant having a relatively low dielectric constant and having high heat resistance, that is to say, a liquid which is not readily volatilized and which is chemically stable at the temperatures normally encountered, is circulated at a high rate of flow over the surface of the termination resistor and, in the case of an elongated or circular sectioned resistor, preferably axially thereof. Cooling of the circulating coolant which has been heated by flowing over the hot resistive conductor is effected preferably, though not necessarily, in a zone wholly removed from the termination, this also being an objective. The coolant may, for example, be passed through a heat exchanger separate from the termination and thereafter returned to the resistor. The coolant thus completes a closed circuit in which the flow may be induced by convection but preferably is accomplished by power-driven pump means which is more effective in obtaining the high flow rate desired to secure, in effect, a scouring action of the flowing coolant over the hot carbon film resistor. Such scouring action brings the fresh coolant into intimate contact with the film surface and avoids prolonged contact between any of the coolant and the hot resistive film so that localized heating is eliminated, hot spots are prevented and a high rate of heat transfer is accomplished. The method and apparatus thus tend to maintain a maximum temperature gradient at the boundary between the heat resistant film and the coolant in contact therewith and to keep such contacting coolant in constant motion, these being additional objects and advantages of the invention.

As another objective the invention seeks to provide a coaxial line device for converting electrical wave energy into heat and in which a liquid dielectric coolant is flowed axially through the dielectric space separating the inner and outer conductors, the coolant being confined, biased or guided to flow over a path which closely adjoins or, in the case of a device having a resistive inner conductor, surrounds the resistive conductor. As a refinement of this feature of the invention the entire dielectric space separating the inner and outer conductors of the coaxial device is substantially filled with the dielectric liquid coolant in a continuous body, one portion, being an

annular outer portion of the body of liquid dielectric in the case of the device having a resistive inner conductor, being maintained in a relatively quiescent state, and another portion of such body, although continuous with or in communication with the one body, being maintained in direct contact with and heat exchange relation to the resistive conductor and being flowed rapidly over the surface of such resistive conductor. As a still further feature in refinement of this aspect of the invention, liquid dielectric coolant flowing over the resistive conductor is confined to a predetermined path of relatively small cross sectional area, preferably uniform along the length of the resistive conductor and, in the case of a device having a resistive center conductor of circular cross section, surrounding such resistive conductor.

In a specialized version of the invention wherein the coaxial device takes the form of a reflectionless termination having a cylindrical resistive inner conductor and a tapered outer conductor or horn, an annular flow path closely surrounding the resistive inner conductor and of substantially uniform section from end to end of such conductor is delineated by circular guide means in the form of a tube of dielectric material which surrounds the inner conductor in spaced relation, being disposed in the tapered dielectric space separating the resistive inner and the tapered outer conductors of the termination. Such guide means thus divides the tapered dielectric space between the conductors of the reflectionless termination into an inner flow path portion of substantially uniform section from end to end and an outer quiescent portion which tapers and is complemental in shape to the taper of the outer horn conductor. The guide means in the form of a tube is conveniently located and supported at its ends by an engagement with the outer conductor structure of the coaxial line or termination, these being features and objectives of the invention.

Another object of the invention is to provide a combination which comprises a coaxial line component or termination of the character mentioned in association with a casing or housing for holding a suitable liquid dielectric coolant, the line termination being immersed in the liquid dielectric coolant contained in the casing and being so arranged that upon flowing the liquid coolant through the casing the coolant is constrained to flow through the dielectric space of the coaxial line device or termination, preferably in an axial direction. In the arrangement preferred as an embodiment of this aspect of the invention the casing is included in a fluid coolant circuit which also includes a heat exchanger connected by suitable conduits or tubes for the serial flow of coolant as by means of a power driven pump also included in the coolant circuit. In flowing through the casing the coolant absorbs heat by direct contact with the resistive element of the coaxial line component or termination; in flowing through the heat exchanger the coolant gives up heat, say to a circulating refrigerant such as water passed through pipes or tubes immersed in a body of the circulating liquid dielectric contained in the heat exchanger receptacle. This separation of the line termination casing from the heat exchanger receptacle and the forced serial flow of coolant therethrough is an objective of the invention.

As a further objective concerned particularly with the arrangement referred to, in which the coaxial line device is in the form of a reflectionless termination having a resistive inner and a tapered or horn-shaped outer conductor, it is sought to provide improved flow of coolant through the annular dielectric space separating the termination conductors by a method and apparatus in which the coolant is admitted to the dielectric space, say through apertures in one, preferably the outer of the conductors and preferably at the smaller end of the latter and in which the coolant is withdrawn from the dielectric space at or preferably beyond the other or larger end of the outer conductor. In such coolant flow arrangement the coolant enters the dielectric space all around substantially the entire circumferential extent of the resistive film as through openings in the tapered outer conductor that are relatively close to the surface of the resistive inner conductor so as to flow axially of the latter in a sheathlike form surrounding the resistive surface as in the manner of an axially advancing cylindrical tube of liquid coolant which sweeps over all portions of the resistive film conductor at a substantially uniform rate and is free of objectionable low velocity, sluggish or quiescent coolant which might result in localized overheated "hot spots" on the resistive inner conductor. The flow in the form of a sheath thus produces substantially uniform cooling around the entire circumference of the inner conductor at all points along the length thereof.

In the specialized version of the apparatus mentioned, wherein the coaxial device is in the form of a reflectionless termination and the liquid dielectric coolant is contained in a casing which encloses or houses the termination and wherein the coolant is forced to flow over a closed circuit, the present invention also contemplates a further refinement wherein the flowing coolant is brought into the casing through an entrant tube, preferably in the bottom of the casing and is confined and directed to flow from such entrant tube directly into the dielectric space separating the inner and outer conductors of the termination, this being an objective of the invention.

It is a still further feature and objective of the invention concerned with the arrangement just mentioned to provide a combination of casing and contained termination or coaxial device wherein the latter acts as a partition or flow barrier controlling the movement of liquid dielectric coolant through the casing. In the preferred embodiment contemplated the coaxial termination device has a tapered outer conductor having a portion of maximum cross sectional area or diameter intermediate its ends which maximum section portion engages or has substantially sealing relation with the casing walls by which it is surrounded to divide the casing chamber and constrain the flowing dielectric coolant to flow through the interior of the termination. By admitting and discharging the flowing coolant to and from the annular dielectric space of the termination at only the end portions of the termination, relatively remote from the large sectioned body portion which has the sealing engagement with the casing walls, there is provided a relatively quiescent body or bodies of dielectric coolant in the casing and surrounding the termination device, the flowing liquid coolant being confined or guided for more effective cooling action over a course through the annular dielectric space of the termination, preferably over the path of relatively small cross sectional area which surrounds the inner resistive conductor, as mentioned above.

Other objects and advantages pertain to certain novel combinations of parts and features of construction, including capacitance compensation at the small end of the termination, the arrangement of the termination on a vertical axis with provision for axial withdrawal of the inner conductor structure, provision for telescopic assembly of the several component parts of the termination device and casing with advantageous locating and guiding relationships and positive securement of the inner conductor structure to resist shifting and turning in use. Such and still other objectives and advantages are apparent in the following detailed description of a preferred embodiment of the invention, its description being made in connection with the accompanying drawings forming a part of the specification.

In the drawings:

Figure 1 is an elevational view, partly diagrammatic and with parts broken away and removed, showing a high frequency electrical meter instrument which embodies the principles of the present invention and incorporates a reflectionless termination for a coaxial transmission line;

Fig. 2 is a fragmentary elevational view, partly in sec-

tion, partly diagrammatic and with parts broken away and removed, showing the casing containing line termination component of the device of Fig. 1, this view being enlarged with respect to that figure;

Fig. 3 is a transverse sectional view, with parts removed, taken substantially along the line indicated at 3—3 of Fig. 2;

Fig. 4 is a sectional detail taken substantially along the line indicated at 4—4 of Fig. 3 and enlarged with respect to that figure;

Figs. 5 and 6 are fragmentary sectional views taken longitudinally through the upper and lower portions respectively of the reflectionless termination component and the casing for such component, these views being taken respectively along lines 5—5 and 6—6 of Fig. 2 and enlarged with respect to that figure, Fig. 5 being rotated 90° into the plane of Fig. 2 from the direction of the arrows in that figure;

Fig. 7 is a sectional detail along the line indicated at 7—7 of Fig. 5, being enlarged with respect to that figure;

Fig. 8 is a longitudinal sectional detail showing an expansible section of the center conductor and the manner in which an implement is inserted axially into the movable element or expander of such section to turn such element in effecting expansion;

Fig. 9 is a transverse sectional detail taken substantially along the line indicated at 9—9 of Fig. 6 and enlarged with respect to that figure;

Fig. 10 is an axial detail view of the small diameter end of the reflectionless termination showing the spring clips for maintaining resilient contact between the resistive center conductor and the tapered metal outer conductor at the small end of the termination; and

Fig. 11 is an enlarged sectional detail, diagrammatic in character, showing the terminal contact band of thin brass soldered about the copper plated end of the resistive inner conductor at the lower or small end of the termination.

The high frequency electrical meter device illustrative of the present invention comprises a reflectionless termination T received in an elongated casing C, the latter preferably taking the form of a cylindrical metal tube 1 of brass or steel, although other cross sectional shapes can be used. The top and bottom ends of the casing are closed by circular metal plates or discs 10 and 11, respectively, the latter being permanently secured in place as by peripheral welding 12. The top or cover disc 10 is peripherally grooved and held in place as by a clamping ring 14. An interposed rubber annulus or O-ring 15 effects a fluid tight seal between the casing flange and the cover 10.

At its upper end the body tube 1 of the casing C is connected to and here supported by a heat interchanger or receptacle R, the latter being vertically elongated and comprising a cylindrical metal body tube 16 closed at the bottom by a disc similar to the disc 11 of the casing C, and at the top by a cover 17 in the form of a circular metal disc held in place by a series of circumferentially spaced peripheral bolts 18 that are received through aligned holes in the disc and in a flange 19 formed or welded in place about the upper end of body tube 16. The body tube 1 of the casing C and the body tube 16 of the receptacle R are disposed in side by side upright relation with their longitudinal axes parallel, the bottom of the receptacle R resting on and being secured to one end of a pedestal or base 20 which also serves as a support for an electrical motor 21 that in turn supports and drives a coolant circulating pump 8 mounted on the motor end bell. The pump is a conventional rotary impeller type available commercially in a motor-pump unit.

The connection between the casing C and the receptacle R is at their upper ends and comprises aligned metal coupling tubes 22 welded into aligned openings in the body tubes and attached together by flanged joint 23 sealed by a suitable ring or gasket. At the bottom end

of the casing C connection is made to the lower part of the receptacle R through the pump 8. The center or inlet of the pump is connected by a metal tube 24 to the bottom of the receptacle body 16, a flanged joint 25 being interposed to facilitate assembly and disassembly. The tangential outlet of the pump, indicated at 26, is connected by aligned tubes 27 and 28 to the lower end of the casing C, a flanged joint 29 being provided between the tubes. A liquid coolant having suitable dielectric properties fills the casing and receptacle for serial flow therethrough in a closed circuit. Mineral oils of low viscosity and high heat tolerance are suitable, as, for example, those identified in U.S. Patent 2,556,642. An especially satisfactory dielectric liquid coolant is a eutectic mixture of diphenyl and diphenyl oxide available commercially as Dowtherm A, this liquid having a dielectric constant relative to air of about $C_r=3.215$. The method and apparatus of the present invention in so far as the reflectionless termination aspects are concerned are most effective with liquid dielectric coolants of low dielectric constant, preferably under about 3.5, although an acceptable structure can be designed and satisfactory results obtained with liquids having dielectric constants of higher value, say up to about 15, although the exact limit is not sharply defined. As the dielectric constant increases, the degree of taper of the horn-shaped conductor must also increase to satisfy the known theoretical considerations governing reflectionless termination design. Thus with liquid dielectric coolants having the larger relative dielectric constants the termination design progressively becomes less practical as the dielectric constant increases because of the large size or diameter of the outer conductor necessary to accommodate the increased taper of the horn conductor.

In operating the device the motor 21 is energized to drive the pump 8, which forces the liquid dielectric coolant upwardly into the bottom of the casing C. As shown in Fig. 6, the tube 28 extends into the bottom of the casing through a circular opening 30 in the bottom closure 11, the opening being on the axis of the tubular casing to direct entering liquid coolant to flow upwardly through the center of the casing over a path through the termination T, and out the discharge tubes 22 at the top of the casing into the top of the receptacle R. In the receptacle which constitutes a heat exchanger to cool the liquid the flow of the liquid dielectric coolant is generally downwardly, liquid coolant entering the top of the receptacle from the casing C displacing liquid from the bottom of the receptacle and forcing the latter to flow out the bottom discharge tube 24 of the receptacle into the intake of the pump, thus completing the liquid coolant cycle.

As indicated in Fig. 1, the receptacle R is much larger than the casing C and has a volumetric capacity many times that of the casing to promote tempering and provide for adequate cooling of the circulating liquid. The cooling of the dielectric liquid occurs principally during its downward flow in the receptacle R, such cooling being effected by any suitable arrangement familiar to the heat exchanger art, such as heat transfer by conduction through the metal walls of the body tube 16 and dissipation into the atmosphere by radiation and convection, the heat transfer, if desired, being augmented by fins. As a further refinement of the present apparatus a cooling medium or refrigerant such as cold water from a conventional pressurized water supply system is circulated in direct heat exchange relation to the liquid dielectric in the receptacle R, the water or refrigeranat being passed through a coil or coils 33, finned if desired, disposed within the receptacle and having inlet and outlet tubes 34 and 35, respectively, projected through the top closure 17.

The inlet 34 is connected as to a city water supply system by suitable conduits and valves (not shown), one valve being an electrically operated or solenoid valve preferably of the water pilot type responsive to a ther-

mostatic switch immersed in the liquid dielectric coolant in the receptacle R and carried as by a boss **37** on the receptacle top. The switch is arranged to open the water or coolant supply valve when the temperature of the liquid dielectric coolant becomes heated to a predetermined temperature, say about 35° centigrade in the case of the diphenyl, diphenyl oxide mixture mentioned, and to close the valve when the liquid dielectric coolant is cooled to a predetermined temperature, say about 30° centigrade when using such material, the electric valve thus automatically supplying the cold water or other refrigerant so as to maintain the circulating liquid dielectric coolant within predetermined temperature limits. The energization of the pump drive motor **21** is governed manually to be turned on each time before electrical energy is fed into the device or, preferably, the pump is operated automatically to circulate the liquid dielectric coolant whenever energy or power is fed into the termination T and simultaneously with such feeding.

A further control refinement comprises a pair of series connected thermostatic switches responsive to the temperature of the dielectric coolant in the receptacle R. These switches act through suitable relays or other controls to prevent operation of the equipment with which the present instrument is associated, say, for example, a television transmitter, when such temperature is objectionably high, say above about 50° centigrade for the diphenyl, diphenyl-oxide mixture mentioned, and when such temperature is objectionably low or close to the freezing point of the liquid coolant, say below about 12° centigrade for such mixture. Still another thermostatic switch immersed in the liquid in the receptacle and responsive to the liquid temperature controls the energization of an electrical immersion heater, not shown, which is regulated in this manner to keep the temperature of the liquid coolant above the freezing point. The latter thermostatic switch may project upwardly through a port in a boss in the receptacle top **17**, the boss and the upper end of the switch assembly being enclosed in a cover **38**. The switches interlocking the signal generating equipment are mounted in other bosses under similar covers, not shown, on the top **17**.

The termination T extends downwardly into the casing C through the top opening in the latter, in fact, being carried by the top **17** in suspended relation and inserted into the casing through such top opening in assembly. The general construction and geometry of the termination T follow well known principles enunciated, for example, in United States Patents 2,552,707, dated May 15, 1951, and 2,556,642, dated June 12, 1951, and application for United States Patent Serial Number 72,782, filed January 26, 1949. There are, however, certain improvements in the combination of parts and refinements in the structure of the termination that are features and objectives of the present invention, as will appear. The termination has an inner resistive conductor in the form of a carbon film **40**, or equivalent, deposited or otherwise formed on the outer cylindrical surface of a ceramic tube **41**. Surrounding the inner resistive conductor in coaxial relation thereto is an outer tapered conductor **42** which may take the form of a metal horn spun or stamped from brass or similar thin metal. The horn is logarithmically grooved or shaped in accordance with the known principles referred to above so as to provide a characteristic impedance at any point or section which is substantially equivalent to the resistance of that portion of the resistive inner conductor **40** which lies between the point or section of reference and the small end of the termination where the inner and outer conductors are joined.

At its upper or large diameter end the tapered horn outer conductor **42** is formed with an integral cylindrical extension or connector section **44** received telescopically within a matched cylindrical socket opening through the bottom end of a body member **45** which is of circular section and may be in the form of a spinning or, as shown, a turning of brass or other metal. The conductive parts of the device are machined from brass stock, except as otherwise indicated or implied. The circular body **45** has an external surface **46**, here cylindrical, that has a freely sliding fit in the cylindrical body tube **1** of the casing or, as shown, in cylindrical reinforcing band **47** previously press fitted into the body tube of the casing to reinforce the walls of the latter. The upper open end of the circular body **45** is formed with a shallow cylindrical socket axially aligned with the socket that receives the connector **44**, one end of a cylindrical relatively thin walled metal connector tube **50** being received in the shallow socket **49** and extending upwardly therefrom through the upper portion of the casing in coaxial relation and through a central opening **51** in the top closure **10**. The connector tube **50**, of brass or copper, is secured in the shallow socket **49** as by soldering or brazing and additionally by a plurality of radial set screws **52** threaded through the termination body member **45** and the wall of the connector tube so as to bear against and become embedded in a plastic sealing ring **127** to be later described as one element of a tubular guide for the flowing liquid dielectric coolant.

A ring **54** is formed on or welded at **55** against the underside of the top closure **10** about the center opening that receives the connector tube **50**. Radial set screws **56** are threaded through the ring **55** and are received through openings in the connector tube so as to bear radially against and become interlockingly embedded in an annular block or insulator **60** of polytetrafluoroethylene or other suitable dielectric plastic material, this insulator block constituting a support for the center conductor assembly of the termination, as will appear. Rubber O-ring **59** of circular section is received in an annular groove formed in the external cylindrical surface of the insulator block **60** and engages the internal surface of the connector tube **50** in the provision of a fluid tight seal. A number of axially elongated circumferentially spaced openings or slots **61** are formed in that portion of the connector tube **50** which lies between the circular sectioned body **45** of the termination and the annular insulating block **60**, these apertures placing the interior chamber of the connector tube in communication with an upper annular casing chamber **62** which is above the circular body **45** and in communication with the heat exchanger receptacle R through the connecting tube **22**.

One end, here the lower end, of the ceramic tube **41** which carries the resistive film **40** is embraced by the small end of the outer or horn conductor **42**, while the other end, here the upper end, of the ceramic tube is connected to a center conductor connector **64** within and coaxial to the connector tube **50**. The metal center conductor **64**, which is of circular section, is formed at its lower end, which is the same diameter as the ceramic tube **41**, with an internal thin walled cylindrical socket **65** that receives reduced diameter upper end portion **66** of the ceramic tube **41**, the latter being preliminarily turned or ground down to the desired diameter and coated with silver or other conductive metal paint or plated with copper to provide a terminal band **67** which extends onto and makes annular electrical connection with the end portion **1** of the deposited carbon film coating. The joint is preferably soldered.

The circular termination body **45** is formed with an internal frustoconical surface **68** concentric to the longitudinal axis of the termination, and the center connector **64** is formed with a tapered transition portion **69** having an external frustoconical surface also concentric to the axis of the termination. The transition portion **69** is disposed inwardly of the frustoconical surface **68** of the outer conductor and in confronting relation thereto, the surfaces **68** and **69** constituting a tapered transition

section by which the diameters of the inner and outer conductor components of the termination are altered from those prevailing at the large diameter end of the horn conductor **42** to those of the connectors **50** and **64**, the latter usually corresponding in diameter to the outer and inner conductors, respectively, of the coaxial transmission line to which the termination device is to be connected.

High frequency electrical energy from a signal generator such as a television transmitter or other source, which energy is to be absorbed and converted into heat by the termination T, is conducted to the termination over inner and outer conductors **71** and **72** of a suitable coaxial transmission line, indicated diagrammatically in Fig. 1. The coaxial transmission line, conventional in character, is provided with terminal fittings by means of which the inner and outer conductors **71** and **72** are respectively connected to inner terminal **73** and the portion of the connector tube **50** which projects through the top **10** of the casing and constitutes the connector terminal for the outer conductor of the termination T.

The inner terminal **73** is of circular cross section and desirably may comprise a turning of brass or similar metal formed at its upper end with a cylindrical cup **74** which is adapted to receive a connector plug of the quick disconnect fitting (not shown) on the coaxial transmission line. This terminal is formed with a reduced diameter shank portion **75** that extends axially through center opening or bore **76** in the insulator **60**, the reduction in diameter from the outer projecting portion of the terminal **73** which contains the terminal socket **74** to the diameter of the shank portion **75** compensates for the difference in the dielectric constant of the air in which the socket portion of the terminal is located and the polytetrafluoroethylene or other insulating material in which the shank portion **75** is located, thereby maintaining substantially the same characteristic impedance axially along the length of the device.

As a result of the strong frictional grip that may be obtained between the walls **74** of the terminal cup and the center terminal plug of a coaxial line fitting attached to the present device the center conductor structure or assembly, including the center connector **64** and the ceramic tube **41** which carries the resistive film **40**, is likely to be objectionably disturbed or shifted axially unless securely anchored in place. By reason of the relatively greater area of contact between the connector tube **50** and the outside of the insulator **60** as compared to the inside bore of the insulator and the outside of the center terminal element **73** slipping and shifting normally are more likely to be encountered between the latter parts. Thus special provision is made in the form of an expanded and interlocked structure for the engagement between the inner terminal element and the surrounding insulator. To obtain a strong grip or anchorage shank **75** of the terminal element **73** is expanded radially outwardly against the walls of the bore **76** in the solid insulator **60** and an interlock established. The insulator is in turn circumferentially embraced by the cylindrical walls of the connector tube **50** and thus capable of strongly resisting the expansion of the terminal element shank **75** to maintain a lasting permanent grip of one part on another. To distend the shank **75** a pluglike expander **80** (Fig. 8) is forced axially through a center bore in the terminal element, the expander having a tapered end **81** which engages an internal shoulder **82** formed at the juncture of axial inner bore **83** and an outer threaded counterbore **84** which extends into the terminal element through the bottom of cylindrical cup **74**. Other types of expanders may, of course, be employed and the expander may be variously forced into place, a preferred arrangement being the use of the internal threads in the counterbore **84** of the terminal element **73** which cooperate with external threads **85** on the expander **80** to shift the expander axially relative to the terminal element upon relative turning so as to force the tapered end **81** against the shoulder **82**. The expander is turned as by a hex or other noncircular tool or instrument, indicated at **86**, inserted temporarily and for the purpose axially through cup **74** and into a matching socket in the expander **80**.

As a further refinement of the structural combination that holds the center conductor assembly or structure in place the terminal element shank **75** is formed with axial slots **87** which extend through the shoulder **82** in the provision of a number of tines or fingers **88**. At its end opposite the terminal cup **74** the element **73** is formed with a reduced diameter end portion **89** receivable in matching socket **90** of intermediate element **91** that has a telescoping connection with the center conductor connector **64**. The embracement of the ends of the tines **88** by the walls of the socket **90** prevents expansion of the lower end of the slotted shank **75** under the radial pressure of the expander **80** so that the expansion of the terminal element takes the form of an outward or radial bowing of each of the tines or fingers **88**, with the maximum radial distention occurring in the region of the shoulder or shoulders **82** engaged directly by the tapered end **81** of the expander. The relative movements of the parts such as the expander and the tines of the terminal element in such expansion may be small dimensionally and, in fact, are not shown in the drawings, the relatively stiff plastic block **60** strongly resisting distortion. Rubber O-ring **93** is received in an annular recessed groove formed in the wall of the bore **76** in the plastic insulator and engages the cylindrical external surface of the intermediate element **91** to seal the bore **76**.

The insulator **60**, which, as previously mentioned, is preferably a relatively stiff plastic material such as polytetrafluoroethylene, while incompressible, or substantially so, is sufficiently deformable so that under the expanding pressures exerted by the bowed tines **88** it tends to flow slightly into the slots **87**, thereby providing an interlock mechanical in nature between the terminal element **73** and the insulator which resists turning of the terminal element relative to the insulator. The outward bowing of the tines **88**, which may of course result in slight axial swelling of the plastic insulator **60**, also provides an interlock mechanical in nature between the terminal element **73** and the insulator which resists relative axial shifting of the parts. Thus inner terminal element **73** is both frictionally gripped and mechanically interlocked by and with the surrounding annular plastic insulator **60** in such a manner as effectively to prevent both relative turning and objectionable axial displacement or shifting of the center conductor structure of the device under such forces as are encountered in normal use or incidental to connecting and disconnecting a coaxial line.

Besides effecting a strong grip and interlock between the insulator and the terminal element **73** by expansion of the latter, the expanding pressure is transmitted radially through the walls of the insulator **60** to the embracing cylindrical walls of the connector tube **50**, which thus maintains a tight grip on the insulator to resist relative turning and axial shifting of the parts. To further insure against axial shifting and turning of the insulator in the connector tube **50** an interlock is provided in the form of the radial set screws **56** threaded through aligned openings in the connector tube **50** and in the surrounding ring **54**, the openings being suitably tapped to receive the set screws. As shown in Fig. 7, the set screws bite into the periphery of the insulator **60**.

At the small end of the termination T the tapered outer or horn-shaped conductor **42** may be curved logarithmically into tangential contact with the deposited resistive film coating **40** of the center conductor or, and this is the preferred arrangement, may include a relatively short integral cylindrical end section or portion

95 to provide an annular radially shallow clearance space 96 of uniform circular section surrounding the resistive film 40 of the center conductor at the small end of the termination. This annular clearance is more effective for the flow of liquid coolant than the extremely thin tapered clearance space resulting from tangential contact between the curved horn and the cylindrical film resistor as called for by theoretical considerations governing the design of reflectionless terminations for coaxial lines. To compensate for the departure from such theoretical considerations resulting from use of the cylindrical end section 95 a capacitance compensating inductive metal tube 102 is disposed inside the end of the resistive conductor tube 41 and electrically connected to the small end of the conductor horn 42. The present device incorporates certain features of construction and combinations of parts that are improvements on a similar and earlier cylindrical end section—compensating tube arrangement described and claimed in copending application Serial No. 72,782 for High Frequency Electrical Device referred to above.

Contact is made between the horn conductor 42 and the resistive inner conductor 40 by a reduced diameter cylindrical end 97 which is integral with and extends as an axial continuation or extension of the cylindrical portion 95. The small cylindrical end portion or section 95 of the horn conductor 42 is formed with apertures such as axially elongated slots 98 for admitting liquid coolant to the dielectric space between the termination conductors, as will be described later. These slots extend the full length of the cylindrical portion 95 and are spaced uniformly about the circumference of such cylindrical portion. At least one of the slots 98 is continuous through the reduced diameter cylindrical end portion 97 to permit expansion and contraction of the latter in yieldingly gripping the end of the inner conductor. Electrical connection may be made directly between the carbon film coating 40, comprising the inner conductor, and the cylindrically curved inner surface of the extreme end or terminal portion 97 of the metal horn conductor 42, suitable yielding clamping means such as a plurality of axially spaced parallel split spring rings 99 contracting resiliently about the cylindrical end portion 97, the latter having axial slot extensions 123 continuous with some of the slots 98. The cylindrical terminal end of the horn conductor is thus held or compressed conformatively against the inner conductor for good electrical contact with the latter.

As a preferred arrangement for connecting the compensating tube 102 to the horn 42 and one which obtains certain advantages in the way of protection for the carbon film 40 by preventing scraping and burning thereof, the present device employs a terminal element or band 100. This conductive metal band may take the form of a strip of thin sheet brass, having a thickness, say, of about .005 inch and commonly known as shim stock, wrapped about the end portion of the carbon film 40 on the ceramic tube 41 and permanently secured in place by an underlying film 94 (Fig. 11) of solder. The solder bonds to a conductive film or coating 105 of copper electroplated or otherwise formed as a cylindrical band on the end portion of the carbon film. The brass terminal band 100 extends axially beyond the end of the ceramic tube 41 and receives or embraces a ring 101 of brass or other metal which is located and abutted protectively against the end of the ceramic tube and which, in turn, embraces the conductive capacitance compensating tube 102 of brass or other similar metal received or telescoped within the end of the ceramic tube 41. The ring 101 is soldered to the metal terminal element or band 100 and at 113 to the tube 102, these joints being made, if desired, at the same time the terminal band 100 is soldered to the copper plating 105 on the film conductor 40.

The metal capacitance compensating tube 102 is of such length that its upper or innermost end 103 is disposed approximately at the radial plane defined by the juncture indicated at 109 between the cylindrical end portion 95 and the tapered portion of the outer horn conductor 42. Capacitance between the conductive metal sleeve 102 and the film conductor 40 compensates for loss in capacitive coupling between the tapered horn conductor 42 and the resistive film conductor 40 resulting from using the cylindrical portion 95 at the small end of the horn conductor instead of continuing the logarithmic curvature of the tapered horn into tangential contact with the cylindrical surface of the resistive film conductor as called for by the theoretical considerations previously referred to which govern the design of reflectionless terminations.

The termination T is aligned axially with the entrant tube 28 through which the circulating liquid dielectric coolant is introduced into the casing C, the inflowing liquid being thus directed to flow axially against the small end of the termination. To guide and confine the flow of the liquid a funnel 106 embraces both the end of the termination and inlet end 107 of the entrant tube 28. The funnel has a stem portion 108 received about the small end of the horn conductor 42, the funnel stem being soldered to and making substantially annular sealing contact with the external surface of the horn conductor at a circular line 104 above or spaced toward the large end of the termination from upper ends of the axial slots 98 and 116 which admit the liquid dielectric coolant into annular space 96 between the horn conductor and the inner resistive film conductor 40. The interior of the cylindrical stem portion 108 of the funnel is of larger diameter than that portion of the external surface of the horn conductor 42 surrounded thereby to define annular clearance space 110 extending the full length of the axial conductor slots 98 and 116. This space provides a passage for axial flow of entering liquid coolant in the form of a tubular sheath so that such coolant may enter the annular dielectric space 96 along the full length of each of the slots 98 and 116.

At its other or lower end the funnel 106 is formed with a bell end 111 which surrounds the end 107 of the entrant tube 28 in embracing but slightly spaced relation, the annular clearance thus provided being indicated at 112. The bell end 111 is formed with a flared lip 114 which acts as a pilot to guide the funnel over the tube end 107 in assembling the parts into the telescoped relation shown. The inflowing liquid, confined as by the entrant funnel 106, is constrained to flow into the annular dielectric space between the resistive inner film conductor 40 and the tapered outer conductor 42 at the small end of the termination. The liquid coolant flows thence axially over a path of substantially uniform cross sectional area toward and through the large end of the termination. This arrangement provides a new mode of operation in which complete and effective cooling is provided for the film resistor 40 substantially uniformly along its length and about its circumference by liquid dielectric coolant maintained at a high rate of flow substantially uniformly along the length and about the circumference of the hot surface of the resistor.

In a termination employing the cylindrical end portion 95 at the small end of the outer conductor the inflowing circulating liquid enters the dielectric space through the slots 98 in the small end and flows thence axially into the wider or larger cross sectional area portions of the dielectric space. As the cross sectional area of the dielectric space 96 progressively increases in the direction of coolant flow, the coolant stream, in the form of a tubular sheath is augmented by flowing coolant entering the space 96 through the auxiliary slots 116 in the tapered part of the horn conductor, the augmenting coolant commingling with the coolant stream from the cylindrical portion of the dielectric space.

The liquid dielectric coolant surrounding the tapered

outer or horn conductor 42 is in a quiescent state, or substantially so, the flow through lower outer portion 115 of the casing chamber being relatively small or nonexistent and resulting from permissible leakage between the body 45 of the termination and the casing walls or reinforcing ring 47.

Equalization of pressure between the interior or dielectric space of the termination and the outer casing chamber 115 is obtained through the annular clearance 112 between the funnel 106 and the end 107 of the tube 28.

In circulation of the liquid dielectric coolant about its circuit the flow through the casing C is confined substantially to the annular dielectric space separating the inner and outer conductors of the termination even though the casing is completely filled with and the termination is immersed in the liquid dielectric coolant and even though the annular dielectric space between the coaxial conductors of the termination is in communication at 112 with the surrounding casing chambers 62 and 115. This control of the liquid dielectric coolant is obtained through structural features by which the casing and the line termination are so interfitted and combined with one another, with the receptacle R, and with the liquid circulating means comprising the pump 8 and the conduits or tubes 22, 24, 27 and 28. The termination body 45 constitutes, in effect, a partition or barrier across the path of the circulating liquid and the liquid entrance and exit openings of the casing are located near the corresponding entrance and exit axial slots 98, 116 and 61 in the outer conductor of the termination to constrain the flow of the coolant within the casing substantially to the annular dielectric space between the coaxial conductors of the termination and over a path primarily axial which is at least as long as the full length of the resistive film conductor 40, or substantially so.

In flowing axially through the annular dielectric space of the termination the liquid dielectric coolant is desirably maintained in a path closely surrounding the resistive inner film conductor 40 so as to maintain the form of a tubular sheath and a relatively high flow velocity over the surface of such resistor. Various flow confining and baffling or biasing arrangements can be employed to accomplish this objective, a preferred device comprising a tubular guide 118 which surrounds the inner conductor in coaxial relation. An annular passage 119 of substantially uniform circular cross section is thus delineated throughout the major portion of the length of the resistive film conductor 40. Since the coolant flow confining guide 118 is disposed in the dielectric space of the termination T and in the electrical field of the line, it is formed of a suitable dielectric material such as a plastic like polytetrafluoroethylene or, as here shown, of glass, preferably the familiar heat resistant Pyrex glass or equivalent having the desired low coefficient of thermal expansion. At its end adjacent the small end of the termination T the glass guide 118 is telescoped into a counterrbore 119 of a plastic collar or thimble 120 of plastic dielectric material such as polytetrafluoroethylene. This thimble, open at both ends, is formed at its end opposite the counterbore 119 with a tapered external surface 121 which fits the internal tapered contour of the outer conductor 42 over an annular area of contact between the parts. An opening or passage 122 through the wall of the thimble 120 permits pressure equalizing flow between the annular path 117 for the flowing coolant and annular chamber portion 124 surrounding the tubular guide 118 and located between such guide and the tapered outer conductor horn 42.

At its other or upper end the tubular glass guide 118 is formed with an integral flared end or trumpet-shaped portion 125 which surrounds the tapered transition portion 69 of the inner conductor 64 and with the latter defines an annular passage of progressively increasing cross sectional area for the upward flowing dielectric coolant. The peripheral edge of the flared end 125 of the coolant guide may fit the interior of the tube 50 but preferably is received in an annular rabbet 126 of a locating and sealing ring 127 formed of suitable plastic material such as polytetrafluoroethylene. The periphery of the sealing ring has a snug fit with the internal cylindrical surface of the connector tube 50, which thus locates the upper or flared end of the glass guide in coaxial relation to the termination conductors. The ring 127 also constitutes a seal between the periphery of the flared end 125 of the glass guide and the outer conductor of the coaxial line, which seal, however, need not be completely fluid tight since a relatively small flow of the dielectric liquid coolant through the tapered portion 124 of the annular dielectric space is not objectionable and in practice is desirable for the purpose of eliminating bubbles of air or other gas that might otherwise collect in the dielectric space of the line and interfere with the operation of the device or create objectionable electrical characteristics.

To insure a small fluid flow through the tapered chamber 124 that surrounds the guide 118 the sealing ring 127 is formed with an axial passage or aperture 128 which thus connects the tapered dielectric chamber portion 124 with the annular dielectric space between the center conductor connector 64 and the connector tube 50. The connecting passage or opening 128 in the plastic ring 127 and the like passage 122 in the plastic thimble 120 are respectively located substantially at the extreme upper and extreme lower ends of the tapered dielectric chamber portion 124 to result in a limited flow of liquid dielectric coolant through such apertures or openings into and out of the tapered portion of the dielectric space of the termination that has a scavenging effect which carries occluded air or other gas. Gas bubbles and the like that may be present in the tapered portion of the dielectric space are thus carried along with the flowing liquid dielectric coolant into the annular dielectric space within the connector tube 50, out the openings 61 in such connector tube, into and through the annular casing chamber 62, and thence into the receptacle R where the gas or air is accumulated or, if desired, vented to the atmosphere through a suitably valved top opening. The annular dielectric block sealing the upper end of the connector tube 50 extends downwardly at least to the tops (as shown) or even below the upper ends of the slots 61 and also below the top of the port or opening in the pipe or tube through which the coolant is discharged from the casing C into the receptacle R to prevent entrapment of air or gas in the dielectric space at the upper end of the termination.

The maximum diameter and cross sectional area of the guide tube 118, and of the plastic sealing rings 120 and 127 when the latter are employed, is less than the diameter and cross sectional area of the interior opening or passage of the connector tube 50 so that in assembling the guide tube 118 (and the thimble 120 and sealing ring 127 in the event such latter are employed) with the outer conductor structure of the termination, the guide tube may be inserted axially into place through the open terminal end of the connector tube 50 prior to insertion therein of the annular insulator block 60 and the inner conductor assembly. In commercial production of the device it is proposed that the circular body 45, the connector tube 50 and the tapered horn conductor 42 be assembled together in the telescoped relation shown while outside of the casing body tube 1. The dielectric material guide tube 118 is also moved into place prior to assembly into the line of the inner conductor components and while the outer conductor components are outside the casing tube 1. The annular insulator block 60 is assembled about the inner terminal element 73 by sliding it axially over the inner conductor tube 41 to the desired location about the shank 75 of the inner terminal element 73, the block being located in such assembly by a plastic dielectric washer 130 interposed between the block and the shoulder provided by the relatively large

diameter head end of the inner terminal element **73**. This washer, of polytetrafluoroethylene or the like, spaces the diameter change of the inner conductor axially from the plane of the dielectric change in compensation of the fringe effects of capacitance and bending of the electrical field at and adjacent the site of the dielectric change. The center conductor structure of the termination, comprising the ceramic tube **41** with its terminal band **100** and capacitance compensating tube **102**, the connector **64** and the terminal **73**, together with the dielectric insulating block **60** placed about the latter as above, is then assembled with the outer conductor structure by relative axial telescoping movement to the position shown in Figs. 2, 5 and 6.

Prior to the insertion of the termination T or the outer conductor **42** thereof into the casing C the funnel element **106** is assembled onto the small end of the outer conductor by telescoping such element into place and soldering or brazing the end of the stem portion **106** to the external surface of the outer conductor **42**. The spring clamping rings **99** are assembled about the axially split cylindrical end **97** of the outer conductor either before or after the inner conductor structure has been moved into place. Because of the constriction of the split cylindrical end **97** resulting from the circumferential clamping action of the spring rings **99** it is preferable to insert the inner conductor structure before the spring rings are clamped about end **97**. The clamping force of such end about the terminal band **100** on the inner conductor is insufficient, however, to prevent axial slipping or shifting movement of the inner conductor structure relative to the outer conductor structure. In thus telescopically assembling the tubular guide component for the circulating coolant and the inner conductor structure with the outer conductor structure prior to the insertion of the latter into the casing body **1**, the parts may be easily and accurately placed by telescopic movement in the desired predetermined relative positions as by means of suitable assembly jigs. In such initial assembly outside the casing C the set screws **52** and **56** may also be advanced or adjusted into engagement with the plastic sealing ring **127** of the guide tube **118** and with the annular dielectric block **60** to secure these plastic components in place. The top closure **10**, including the ring **54**, is placed about the connector tube **50**, secured as by brazing or welding and the holes for the set screws **56** drilled and tapped in a preliminary sub-assembly procedure. Thus the termination T, including the inner and outer conductor structures or assemblies and the guide tube **118**, and with the casing tube closure **10** attached to the connector tube **50**, is insertable by axial movement as a unit into the casing C, the engagement between the upper rim of the casing body tube **1** and the periphery of the top closure **10** serving to locate the line assembly in the casing. During the movement into position of the insertable line unit the bell end **111** of the funnel element **106** serves as a pilot to guide the lower or small end of the termination T into axial alignment with the discharge or inlet end **107** of the entrant tube **28**, the funnel element being rigidly secured to the outer conductor **42** as by the soldered joint mentioned.

The permissible axial slipping or shifting of one conductor structure relative to the other, mentioned above, is a desirable feature not only because of the accommodation of manufacturing variations which permits greater tolerances and the ability of the device to expand and contract differently upon temperature changes encountered in practice but because of further advantages incident to service and repair in the field. It may occur, for example, that one of the inner conductor components such as the resistive film **40** or the ceramic tube **41** becomes damaged in use or the instrument may appear to be functioning improperly so that it becomes desirable to inspect the interior of the line or the inner conductor to determine the existence of a defect in or injury to one of the component parts or elements.

The structure of the present invention provides for optional removal and replacement of the inner conductor assembly without disturbing the outer conductor assembly and without even draining or removing the liquid dielectric coolant from the casing C. To effect such removal, the main coaxial transmission line comprising the inner and outer conductors **71** and **72** previously mentioned in connection with Fig. 1 is first disconnected from the terminal end of the connector tube **50** and the socket or cup **74** of the inner terminal element **73** so as to disconnect the device or instrument from the signal generator. Thereafter the interlock and grip of the insulating block **60** on the shank **75** of the terminal element **73** is released or relieved by backing off the expander **80** which is turned relative to the terminal element by an implement such as a hex wrench **86** inserted axially through the cup **74** of the terminal element and into nonrotative interfitting engagement with the expander. The tines **88** being of resilient spring material such as brass, of which the terminal element **73** is formed, spring back to their normal unstressed shape, as shown by full lines of Fig. 8, when relieved of the expanding support provided by the expander **80**, thereby reducing the size of the terminal element shank and withdrawing it from interlocking engagement with the walls of the bore **76** in the insulator block **60**. The interlock and grip between the insulator block **60** and the terminal element shank **75** being thus released, the inner conductor assembly is no longer held against relative turning or relative axial movement by the insulating block **60** and can be withdrawn bodily from within the outer conductor assembly, the inner conductor structure or assembly being lifted vertically in this operation. The bore **76** in the insulating block **60** is, of course, slightly larger in diameter than the withdrawn parts such as the resistive coating **40** on the cylindrical ceramic tube **41** and the brass terminal band or element **100** on the lower end of the inner conductor so that these parts may be withdrawn axially through the insulating block **60** in lifting the inner conductor assembly up and out through the top of the connector tube **50** while the insulating block **60** remains permanently assembled and secured in the latter through the interlocking action of the set screws **56**. Upon replacement of the same or a duplicate substitute inner conductor assembly the brass terminal band **100** bears the frictional load imposed by the split clamping end **97** of the horn conductor which, under the resilient squeezing action of the spring rings **99** and by reason of the inherent resilience of the brass or other metal stock from which the horn is formed, must be slightly distended by the terminal band **100** to admit the latter in the automatic establishment of electrical connection between the ends of the conductors at the remote or lower end of the termination.

The termination T can be used to absorb the energy from a high frequency electrical signal generator such as a television transmitter, functioning in such use as a so-called "dummy" load, the reflectionless nature of the resistive termination and its ability to absorb power at a high rate making it particularly desirable and acceptable for such purpose. As a more specialized use the termination device may be combined with a suitable signal responsive system including a detector connected and arranged, say, to sample the wave signal from the transmitter in accordance with the principles set forth in the copending applications for patents referred to above particularly Serial No. 116,318, filed September 17, 1949 An instrument such as a voltmeter or wattmeter is thus provided to indicate voltage or power present at or being fed into the termination. When such an instrument is desired employing, say, a current sampler or voltage sampler, a pickup device or detector D, like the unit assembly D described in copending application Serial No

99,474, filed June 16, 1949, which is part of a voltage divider, is combined with the termination T so that the parts function together in accordance with the principles described in the applications referred to.

When effecting the present combination of the detector or current sampling device D with the termination T certain advantageous results have been obtained, in that the detector D in the form of a so-called combined capacitance voltage divider and crystal cartridge assembly is mounted on the casing C rather than on the tapering transition section of the coaxial line. The present mounting permits removal and replacement of the inner conductor assembly described above without disturbing the detector or voltage divider unit D and also locates the axis of pickup probe 132 closely adjacent the plane of the juncture between the resistive film conductor 40 and the plated on or metal paint contact band 67 with attendant improvement in accuracy of the instrument. The internal structure of the detector cartridge unit D is essentially the same as that of the corresponding unit in the patent application referred to and detailed disclosure is omitted here to avoid duplication. The unit includes a chambered body member 70 of brass or similar metal which corresponds to the body 70 in the patent application of reference. In the present arrangement, however, the body 70 is formed with or has secured thereto a cylindrical pilot extension 133 which surrounds and is coaxial to the body opening through which probe 132 and plastic cap 134 project from the internal chamber of the detector body 70. A flat mounting plate 135 is formed with a central aperture which receives the cylindrical extension 133 of the body and is abutted against a shoulder of the latter, being secured to the body and to the cylindrical extension 133 as by brazing or soldering.

A circular opening 137 to receive the pilot extension 133 is formed through the wall of the casing 1, through the reinforcing band or ring 47, and through the telescoped body 45 and connector section 44 of the termination outer conductor. This opening through the juxtaposed parts is of such size as to provide a sliding fit with the pilot extension 133 received therein, the pilot thus keying the parts together and preventing both rotative and axial movement of the termination T relative to the casing C and making full circular electrical contact with the conductive surface of the outer conductor. Rubber O-ring 136 is received in a circular groove formed in the external cylindrical surface of the extension 133 and engages the wall of the circular opening through the casing to seal such opening and prevent loss of liquid dielectric coolant therethrough. A flat spot face 138 on the outside of the casing body 1 about the opening 137 receives the mounting plate 135, the latter being attached to the casing as by screws 139 threaded into tapped holes that extend into the reinforcing ring 47. Within the body 70 is the tree structure described in the patent application referred to. It includes the adjustable length probe 132 which is insulated from the body and covered or enclosed by the plastic cylindrical cup 134, the latter sealing the opening into the chamber of the detector body 70 to prevent liquid dielectric coolant in the casing C from entering the interior of the detector or sampling unit D. The condenser element of the detector unit tree structure (not shown) extends into a cylindrical metal cap or lateral extension 140 on the body 70, this extension being diametrically opposite tubular extension or sleeve 141 formed on or secured in the body 70 to receive and mount in removable and interchangeable relation a crystal rectifier unit 142. The condenser element 140 and the crystal unit 142 are on a common axis which parallels the axis of the casing C and a connector terminal 144 of the detector unit D is provided on one side of the body 70 for connecting the detector or voltage sampling assembly D through a cable 145 to a sensing element G in the form of a D'Arsonval galvanometer or the like.

The present invention thus provides a novel method of and apparatus for converting high frequency electrical energy into heat and dissipating such energy, the specialized aspects of the invention providing a method and apparatus for terminating a coaxial transmission line substantially without reflection and for absorbing electrical energy at a relatively high rate. In its applications to instruments for use with coaxial transmission lines and the like the invention provides a unique arrangement by means of which high frequency energy may be detected or sampled substantially in the plane of the entering end of a reflectionless termination.

In effecting absorption of the high frequency energy the invention utilizes a liquid dielectric coolant directed over the resistive surface of a coaxial line component at a high velocity sufficient to have a scrubbing action on the surface of the resistor which prevents volatilization of the liquid coolant by prolonged contact with the hot resistor surface.

In accordance with the patent statutes the principles of the present invention may be utilized in various ways, numerous modifications and alterations being contemplated, substitution of parts and changes in construction being resorted to as desired, it being understood that the embodiment shown in the drawings and described above and the particular method set forth are given merely for purposes of explanation and illustration without intending to limit the scope of the claims to the specific details disclosed.

What we claim and desire to secure by Letters Patent of the United States is:

1. In a high frequency electrical device of the type in which a pair of conductors, one of them tapered and one of them resistive, are arranged coaxially with an annular dielectric space therebetween, a liquid dielectric coolant in the space between the conductors, means communicating with the annular dielectric space at axially spaced points along the length of said annular dielectric space and providing a path external to the annular space for the flow of liquid dielectric coolant over a closed circuit, and guide means of dielectric material extending longitudinally through the dielectric space, said guide means having a passage defining surface disposed in spaced generally parallel confronting relation to the surface of the resistive conductor to provide therebetween a passage which along the length of the resistive conductor and between said spaced points is of less cross sectional area than the dielectric space and is closely adjacent the surface of the resistive conductor, said path providing means being adapted at one of said points of communication with the dielectric space to introduce liquid dielectric coolant primarily into the passage between the guide means and the resistive conductor to obtain flow of liquid coolant primarily longitudinally of the resistive conductor and to confine liquid dielectric coolant flowing over the passage part of said circuit to a predetermined portion of said annular dielectric space disposed between such guide means and the resistive conductor whereby flowing liquid coolant so confined and guided convectively cools the resistive conductor when the latter is heated by absorbed electrical energy.

2. In a high frequency electrical device of the type in which a pair of conductors, one of them tapered and one of them resistive, are arranged coaxially with an annular dielectric space therebetween, a liquid dielectric coolant in the space between the conductors, means communicating with the annular dielectric space at axially spaced points along the length of said annular dielectric space and providing a path external to the annular space for the flow of liquid dielectric coolant over a closed circuit, and a guide tube of dielectric material coaxial to the conductors and surrounding one of them, said guide tube extending through the annular dielectric space and having a passage defining surface disposed in spaced generally parallel confronting relation to the surface of the resistive conductor providing with the resistive con-

ductor a confined passage for liquid dielectric coolant, said passage along the length of the resistive conductor and between said spaced points being of less cross sectional area than the dielectric space and closely adjacent the surface of the resistive conductor, said path providing means being adapted at one of said points of communication with the dielectric space to introduce liquid dielectric coolant primarily into the passage between the guide tube and the resistive conductor to obtain flow of liquid coolant primarily longitudinally of the resistive conductor, whereby flowing liquid dielectric coolant cools the resistive conductor when the latter is heated by absorbed electrical energy.

3. In a high frequency electrical device of the character described, a casing, a liquid dielectric coolant in the casing, an inner conductor and an outer conductor arranged coaxially, the inner conductor comprising an elongated relatively resistive member, the outer conductor comprising an elongated tube surrounding the inner conductor in generally spaced relation, the outer conductor tube being tapered along its length and with the inner conductor defining an annular dielectric space which progressively diminishes in radial extent toward one end of the inner conductor, the conductors being disposed within the casing and immersed in the liquid dielectric coolant, means for effecting a flow of the coolant axially of the conductors, and guide means of dielectric material within the annular dielectric space surrounding the inner conductor and constraining the flow of coolant to an elongated path located wholly in and of less cross sectional area than the annular space between the conductors, said elongated coolant path surrounding and being closely adjacent the surface of the resistive inner conductor and of substantially uniform annular section along its length whereby the flowing coolant is guided over the resistive inner conductor convectively to cool the latter when it is heated by absorbed electrical energy.

4. A high frequency electrical device comprising an elongated inner substantially cylindrical resistive conductor, an outer elongated and longitudinally tapered conductor surrounding the inner conductor in coaxial generally spaced relation, a tubular guide of dielectric material surrounding the resistive conductor and separated from the latter by an annular space, the guide extending longitudinally through the space between the inner and outer conductors, one end of the guide being substantially in sealing engagement with the tapered conductor intermediate the ends of the latter, one of the conductors being apertured to admit liquid dielectric coolant into the space between the conductors at a region adjacent the smaller end of the outer conductor, the annular space between the tubular guide and the resistive conductor constituting a passage for liquid dielectric coolant so admitted to cool the resistive conductor, and means for receiving liquid dielectric coolant from the other end of the tubular guide, conducting the received liquid over a closed path, and returning the liquid to the annular dielectric space through the apertured conductor.

5. In a high frequency electrical device of the character described, a casing, a liquid dielectric coolant in the casing, a coaxial electrical line section in the casing and immersed in the coolant, said line section comprising an inner conductor and an outer conductor surrounding the inner conductor in generally spaced relation, the outer conductor having a body portion intermediate its ends sealingly engaging the casing and end portions separated from one another by and of less cross sectional area than the body portion, said end portions being spaced from the casing in the provision of chambers in the casing separated from one another by the line section body, said end portions being apertured to place the space between the line section conductors in communication with the casing chambers whereby coolant in one casing chamber is continuous with coolant in another casing chamber through said space in the provision of a coolant path for the liquid dielectric and over which the latter is constrained to flow through such space in heat exchanging relation to the line section conductors, and means including a heat exchanger having liquid receiving and returning connections to the casing chambers providing a return path for coolant outside the said space between the line conductors, whereby to complete a coolant circuit from one casing chamber, through the space between the line conductors to the other casing chamber, and return to said one casing chamber over the return path.

6. A high frequency line terminating device comprising an elongated casing and an elongated receptacle disposed in side by side relation with their long axes substantially parallel, means connecting the casing and the receptacle together at axially spaced points for the serial flow therethrough of a liquid, a liquid dielectric coolant in the casing and receptacle, a high frequency termination immersed in the liquid in the casing, said termination comprising inner and outer spaced coaxial conductors one of which is resistive and one of which is apertured for the flow of the liquid into the space between the conductors in direct heat exchanging relation to the resistive conductor, pump means in one of the connections between the casing and the receptacle to induce said serial flow of the liquid, the connection through which liquid enters the casing being substantially on the axis of the termination and disposed to direct such entering liquid to flow primarily axially into the casing and against one end of the termination, and means associated with the receptacle for cooling liquid flowing therethrough whereby heat absorbed from the resistive conductor in the casing is carried into the receptacle and liquid dielectric coolant withdrawn from one end of the casing at a relatively high temperature is returned to the other end of the casing at a relatively low temperature.

7. A high frequency line terminating device comprising a vertically elongated casing and a vertically elongated receptacle disposed in side by side relation and connected together at vertically spaced points for the serial flow therethrough of a liquid, a liquid dielectric coolant in the casing and receptacle, a high frequency termination immersed in the liquid in the casing, said termination comprising inner and outer spaced coaxial conductors one of which is resistive and one of which is tapered and apertured for the flow of the liquid into the space between the conductors in direct heat exchanging relation to the resistive conductor, the termination being located between the vertically spaced points of connection of the liquid flow means to the casing and having its axis vertical and the smaller end of its tapered conductor directed downwardly whereby the portion of the resistive conductor at the smaller end of the tapered conductor is disposed adjacent liquid coolant entering the casing at the lower of the connection points, and means associated with the receptacle for cooling liquid flowing therethrough whereby heat absorbed from the resistive conductor in the casing is carried into the receptacle and liquid dielectric coolant withdrawn from one end of the casing at a relatively high temperature is returned to the other end of the casing at a relatively low temperature.

8. In a high frequency electrical device of the character described, resistive inner and tapered outer conductors arranged in a coaxial line, the conductors being separated by an annular dielectric space which is of relatively small radial thickness at one end of the inner conductor and which increases in radial thickness progressively toward the other end of the inner conductor, guide means of dielectric material extending longitudinally through the space between the conductors, a liquid dielectric coolant, conduit and circulation inducing means for containing the coolant, said last-named means being connected to the outer conductor and having a liquid passage providing with such outer conductor a closed fluid circuit for circulation therethrough of the coolant,

the outer conductor being apertured adjacent one end to place the passage of the conduit and circulation inducing means in communication with the annular dielectric space between the conductors, and the guide means being adapted to constrain the circulating liquid dielectric coolant to flow axially through the annular dielectric space over a path in which the coolant is in direct heat exchanging relation to the resistive conductor and which at any point over the major part of the length of the resistive conductor is of less transverse extent than such dielectric space at the same point.

9. A high frequency electrical device comprising inner and outer conductors arranged as a coaxial line having resistive and connective sections and a transitive section between and joining the resistive and connective sections, the resistive section including an elongated inner resistive conductor portion and coextensive in length with the resistive portion an elongated longitudinally tapered outer conductor portion separated from such resistive portion by an annular dielectric space, the connective and transitive sections each comprising inner and outer conductor portions, the tapered conductor portion having one end adjacent the transitive section of greater cross sectional area than the outer conductor portion of the connector section, and conduit means making connection with the annular space between the line conductors at axially spaced points and providing with the line a closed fluid circuit which includes said annular space for the circulation of liquid dielectric coolant cyclically in direct heat exchanging relation to the inner resistive conductor portion in convectively removing heat resulting from absorption of electrical energy in the resistive conductor portion, one point of connection of the conduit means being at the small end of the tapered outer conductor portion with the connection of the conduit means to the annular space at such one point being symmetric about the axis of the line, and another such point being at the connector section and spaced axially from the resistive portion in the direction away from said one point connection whereby the circulating coolant flows substantially wholly axially over the entire length of the resistive conductor portion and axially through the transitive section of the line in substantially straight line continuous movement.

10. A high frequency electrical device comprising inner and outer conductors arranged as a coaxial line having resistive and connective sections and a transitive section between and joining the resistive and connective sections, the resistive section including an elongated inner resistive conductor portion and coextensive in length with the resistive portion an elongated longitudinally tapered outer conductor portion separated from such resistive portion by an annular dielectric space, the connective and transitive sections each comprising inner and outer conductor portions, the tapered conductor portion having one end adjacent the transitive section of greater cross sectional area than the outer conductor portion of the connector section, conduit means making connection with the annular space between the line conductors at axially spaced points and providing with the line a closed fluid circuit which includes said annular space for the circulation of liquid dielectric coolant cyclically in direct heat exchanging relation to the inner resistive conductor portion in convectively removing heat resulting from absorption of electrical energy in the resistive conductor portion, one point of connection of the conduit means being at the small end of the tapered outer conductor portion and another such point being at the connector section whereby the circulating coolant flows axially over the entire length of the resistive conductor portion and axially through the transitive section of the line in substantially straight line continuous movement and a dielectric tube surrounding the resistive conductor portion and disposed within the tapered conductor portion, said tube defining a sheathlike coolant path closely surrounding the resistive conductor portion and included in the closed fluid circuit.

11. A high frequency electrical device comprising inner and outer conductors arranged as a coaxial line having resistive and connective sections and a transitive section between and joining the resistive and connective sections, the resistive section including an elongated inner resistive conductor portion and coextensive in length with the resistive portion an elongated longitudinally tapered outer conductor portion separated from such resistive portion by an annular dielectric space, the connective and transitive sections each comprising inner and outer conductor portions, the tapered conductor portion having one end adjacent the transitive section of greater cross sectional area than the outer conductor portion of the connector section, conduit means making connection with the annular space between the line conductors at axially spaced points and providing with the line a closed fluid circuit which includes said annular space for the circulation of liquid dielectric coolant cyclically in direct heat exchanging relation to the inner resistive conductor portion in convectively removing heat resulting from absorption of electrical energy in the resistive conductor portion, one point of connection of the conduit means being at the small end of the tapered outer conductor portion and another such point being at the connector section whereby the circulating coolant flows axially over the entire length of the resistive conductor portion and axially through the transitive section of the line in substantially straight line continuous movement, and a dielectric tube surrounding the resistive conductor portion and disposed within the tapered conductor portion, said tube defining a sheathlike coolant path closely surrounding the resistive conductor portion and included in the closed fluid circuit, said dielectric tube being continuous through both the resistive and transitive sections of the line.

12. A high frequency electrical device comprising inner and outer conductors arranged as a coaxial line having resistive and connective sections and a transitive section between and joining the resistive and connective sections, the resistive sections including an elongated inner resistive conductor portion and coextensive in length with the resistive portion an elongated longitudinally tapered outer conductor portion separated from such resistive portion by an annular dielectric space, the connective and transitive sections each comprising inner and outer conductor portions, the tapered conductor portion having one end adjacent the transitive section of greater cross sectional area than the outer conductor portion of the connector section, conduit means making connection with the annular space between the line conductors at axially spaced points and providing with the line a closed fluid circuit which includes said annular space for the circulation of liquid dielectric coolant cyclically in direct heat exchanging relation to the inner resistive conductor portion in convectively removing heat resulting from absorption of electrical energy in the resistive conductor portion, one point of connection of the conduit means being at the small end of the tapered outer conductor portion and another such point being at the connector section whereby the circulating coolant flows axially over the entire length of the resistive conductor portion and axially through the transitive section of the line in substantially straight line continuous movement, and a dielectric tube surrounding the resistive conductor portion and defining a coolant path of relatively small cross sectional area, said small area path being included in the closed fluid circuit, said tube having one portion of substantially uniform section disposed within the tapered conductor portion and a tapered tube portion the end of which engages the outer conductor of the line to be supported thereby.

13. A high frequency electrical device comprising an elongated inner substantially cylindrical resistive con-

ductor, an outer elongated and longitudinally tapered conductor surrounding the inner conductor in coaxial generally spaced relation, the outer conductor being apertured at one end, conduit means making connection with the space between the coaxial conductors through an outer conductor aperture at said one end and at a point axially spaced from such end and providing with the space between the conductors a closed fluid circuit for the circulation of liquid dielectric coolant in direct heat exchanging relation to the inner resistive conductor in convectively removing heat resulting from absorption of electrical energy in the resistive conductor, and a dielectric tube surrounding the resistive conductor in spaced relation and defining a coolant path of relatively small cross sectional area included in the fluid circuit, one end of the tube being substantially in sealing relation to the outer conductor at a point intermediate the aperture and the spaced connection point of the conduit means.

14. In a high frequency electrical device of the character described, a casing, a liquid dielectric coolant in the casing, an inner conductor and an outer conductor arranged coaxially, the inner conductor comprising an elongated relatively resistive member, the outer conductor comprising an elongated tube surrounding the inner conductor in generally spaced relation, the outer conductor tube being tapered along its length and with the inner conductor defining an annular dielectric space which progressively diminishes in radial extent toward one end of the inner conductor, the conductors being disposed within the casing and immersed in the liquid dielectric coolant, conduit and circulation inducing means connected to the casing and having a liquid passage providing with the casing a closed fluid circuit for the circulation of the liquid dielectric coolant through the casing, and guide means within the casing, said guide means including one tube telescoped over the smaller end of the outer conductor and at one end sealed to the latter and including another tube of dielectric material extending longitudinally through the annular dielectric space and surrounding the inner resistive conductor in generally spaced coaxial relation, said guide means constraining the circulating liquid to a sheathlike path closely surrounding the inner conductor, said liquid path being a portion only of the space within the casing, other portions of the casing space being substantially filled with liquid dielectric coolant which remains relatively quiescent during the circulation of the liquid over said path.

15. A high frequency line terminating device comprising an elongated casing and an elongated receptacle disposed in side by side relation with their long axes substantially parallel, means connecting the casing and the receptacle together at axially spaced points for the serial flow therethrough of a liquid, a liquid dielectric coolant in the casing and receptacle, a high frequency termination immersed in the liquid in the casing, said termination comprising inner and outer spaced coaxial conductors one of which is resistive and one of which is apertured for the flow of the liquid into the space between the conductors in direct heat exchanging relation to the resistive conductor, the termination also including a connective section comprising coaxial inner and outer connector elements for connection of the termination conductors to the inner and outer conductors of a coaxial electrical line, said connective section projecting from the casing, the termination being mounted in and supported by the casing for facile removal and replacement as a unit independently of the liquid connecting means, means associated with the receptacle for cooling liquid flowing therethrough whereby heat absorbed from the resistive conductor in the casing is carried into the receptacle and liquid dielectric coolant withdrawn from one end of the casing at a relatively high temperature is returned to the other end of the casing at a relatively low temperature, and pump means in one of the connections between the casing and the receptacle to induce said serial flow of the liquid.

16. A high frequency line terminating device comprising an elongated casing and an elongated receptacle disposed in side by side relation with their long axes substantially parallel, means connecting the casing and the receptacle together at axially spaced points for the serial flow therethrough of a liquid, a liquid dielectric coolant in the casing and receptacle, a high frequency termination immersed in the liquid in the casing, said termination comprising inner and outer spaced coaxial conductors one of which is resistive and one of which is apertured for the flow of the liquid into the space between the conductors in direct heat exchanging relation to the resistive conductor, pump means in one of the connections between the casing and the receptacle to induce said serial flow of the liquid, the connection through which liquid enters the casing being disposed to direct such entering liquid to flow primarily axially into the casing, guide means within the casing and disposed to receive axially directed entering liquid and conduct the same over a predetermined path in the casing to the apertured conductor, said guide means substantially confining the entering liquid in said predetermined path and preventing commingling of the entering liquid with other liquid in the casing, said predetermined path registering with the aperture of the apertured conductor for the flow of such entering liquid directly into said space between the conductors from said predetermined path, and means associated with the receptacle for cooling liquid flowing therethrough whereby heat aborbed from the resistive conductor in the casing is carried into the receptacle and liquid dielectric coolant withdrawn from one end of the casing at a relatively high temperature is returned to the other end of the casing at a relatively low temperature.

17. A high frequency line terminating device comprising an elongated casing and an elongated receptacle disposed in side by side relation with their long axes substantially parallel, means connecting the casing and the receptacle together at axially spaced points for the serial flow therethrough of a liquid, a liquid dielectric coolant in the casing and receptacle, a high frequency termination immersed in the liquid in the casing, said termination comprising inner and outer spaced coaxial conductors one of which is resistive and one of which is apertured for the flow of the liquid into the space between the conductors in direct heat exchanging relation to the resistive conductor, pump means in one of the connections between the casing and the receptacle to induce said serial flow of the liquid, the connection through which liquid enters the casing being substantially on the axis of the termination and disposed to direct such entering liquid to flow primarily axially into the casing at one end of the latter and directly against one end of the termination, the termination also including a connective section comprising coaxial inner and outer connector elements for connection of the termination conductors to the inner and outer conductors of a coaxial electrical line, said connective section projecting from the other end of the casing, the termination being mounted in and supported by the casing for facile axial withdrawal and insertion as a unit from and into the casing through the other end of the latter independently of the liquid connecting means, and means associated with the receptacle for cooling liquid flowing therethrough whereby heat absorbed from the resistive conductor in the casing is carried into the receptacle and liquid dielectric coolant withdrawn from one end of the casing at a relatively high temperature is returned to the other end of the casing at a relatively low temperature.

18. A high frequency line terminating device comprising a vertically elongated casing and a vertically elongated receptacle disposed in side by side relation and connected together at vertically spaced points for the serial flow therethrough of a liquid, a liquid dielectric coolant in

the casing and receptacle, a high frequency termination immersed in the liquid in the casing, said termination comprising inner and outer spaced coaxial conductors one of which is resistive and one of which is apertured for the flow of the liquid into the space between the conductors in direct heat exchanging relation to the resistive conductor, the termination also including a connective section comprising coaxial inner and outer connector elements for connection of the termination conductors to the inner and outer conductors of a coaxial electrical line, the connection through which liquid enters the casing being substantially on the axis of the termination and disposed to direct such entering liquid to flow primarily upwardly and axially into the casing the bottom end of the latter and directly against one end of the termination, said connective section projecting from the top end of the casing, the termination being mounted in and supported by the casing for facile upward withdrawal and downward insertion as a unit from and into the casing through said top end of the latter independently of the liquid connecting means to permit such withdrawal of the termination unit for service and repair without removing the liquid dielectric coolant from the casing, and means associated with the receptacle for cooling liquid flowing therethrough whereby heat absorbed from the resistive conductor in the casing is carried into the receptacle and liquid dielectric coolant withdrawn from one end of the casing at a relatively high temperature is returned to the other end of the casing at a relatively low temperature.

19. In a high frequency electrical attenuating device of the character described, an elongated resistive inner conductor comprising a thin film surface resistor, an elongated outer conductor having a conductive surface surrounding the inner conductor and separated from the film surface resistor of the latter by a dielectric space in the provision of a dissipative coaxial line in which the inner conductor film resistor is heated by absorbed electrical energy, tubular guide means of dielectric material extending longitudinally through the dielectric space in spaced surrounding coaxial relation to the inner conductor, the guide means delineating a portion only of said dielectric space as an elongated passage surrounding the inner conductor, another portion of the dielectric space being outside of the passage portion and separated from the latter by the guide means, liquid dielectric coolant in the dielectric space, and means providing a cooling path for dielectric liquid external to the dielectric space, said last named means being adapted to introduce liquid into the elongated passage adjacent one end of the inner conductor, to withdraw liquid from such passage adjacent the other end of the inner conductor, and cooperatively with the guide means to confine the effective flow of the liquid dielectric coolant through the dielectric space substantially wholly to the elongated passage portion.

20. In a device for absorbing high frequency energy from a coaxial electrical line, a termination comprising elongated inner and outer conductors disposed in coaxial relation, the inner conductor comprising a member having a cylindrically shaped resistive surface film, the outer conductor comprising a tapered horn surrounding the inner conductor in coaxial relation and having large and small ends, said small end being electrically connected to the resistive film at one end of the inner conductor, the horn otherwise being insulated from the resistive film by an elongated dielectric space of circular section which envelopes the resistive film, means for electrically connecting the resistive film at the other end of the inner conductor and the large end of the outer conductor horn to the inner and outer conductors, respectively, of such a line, the resistive film of the termination being adapted to absorb and become heated by electrical energy received through the line conductors, a body of liquid dielectric coolant, a power driven liquid pump, a heat exchanger, and means confining the liquid and connecting the pump and the heat exchanger in a closed series liquid circuit which includes the annular dielectric space between the horn and the resistive film of the termination for continuous circulation of the liquid dielectric over and withdrawal of heat from the resistive film, said liquid confining and circuit connecting means being adapted to carry and guide liquid being forced toward the dielectric space along a path coaxial to the termination conductors to enter the dielectric space surrounding the resistive film substantially wholly axially and with a flow pattern symmetric about the longitudinal axis of the termination conductors from a point axially beyond one end of the resistive film, and said liquid confining and circuit connecting means being further adapted to effect withdrawal of liquid dielectric from said dielectric space at the other end of the resistive film substantially wholly axially and with a flow pattern symmetric about said axis to a point axially beyond such other end of the resistive film, whereby to provide essentially axial flow of the liquid coolant between said points beyond the ends of the resistive film and symmetric flow at a uniform rate over and about all portions of such film and in sheathlike form along a path surrounding the resistive film.

References Cited in the file of this patent

UNITED STATES PATENTS

309,246	Patterson	Dec. 16, 1884
2,050,885	Hafecost	Aug. 11, 1936
2,146,076	Kogel	Feb. 7, 1939
2,159,782	Conklin	May 3, 1939
2,328,373	Bogardus	Aug. 31, 1943
2,438,915	Hansen	Apr. 6, 1948
2,450,467	Clark	Oct. 5, 1948
2,463,428	Rieke	Mar. 1, 1949
2,486,285	Hurst	Oct. 25, 1949
2,548,457	Wilson	Apr. 10, 1951
2,560,536	Althouse	July 17, 1951
2,561,184	Dehn	July 17, 1951
2,627,550	Rose	Feb. 3, 1953
2,752,572	Bird	June 26, 1956