Jan. 24, 1967 H. E. STEVENS ETAL 3,300,737

COAXIAL ELECTRICAL LINE ATTENUATOR

Filed March 10, 1965 2 Sheets-Sheet 1

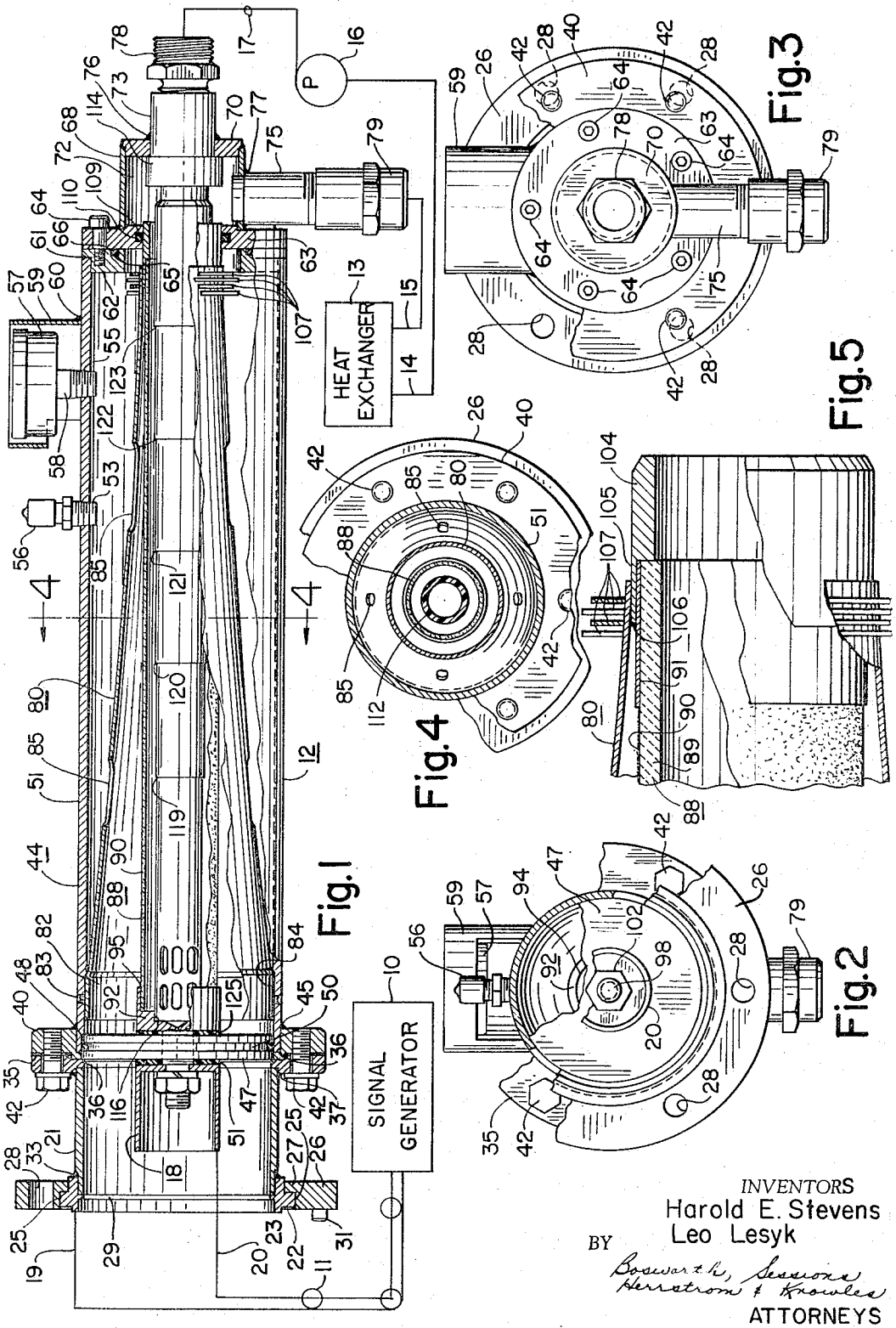


Fig. 1

Fig. 3

Fig. 4

Fig. 5

Fig. 2

INVENTORS
Harold E. Stevens
Leo Lesyk

BY Bosworth, Sessions, Herrstrom & Knowles
ATTORNEYS

Jan. 24, 1967 H. E. STEVENS ETAL 3,300,737

COAXIAL ELECTRICAL LINE ATTENUATOR

Filed March 10, 1965 2 Sheets-Sheet 2

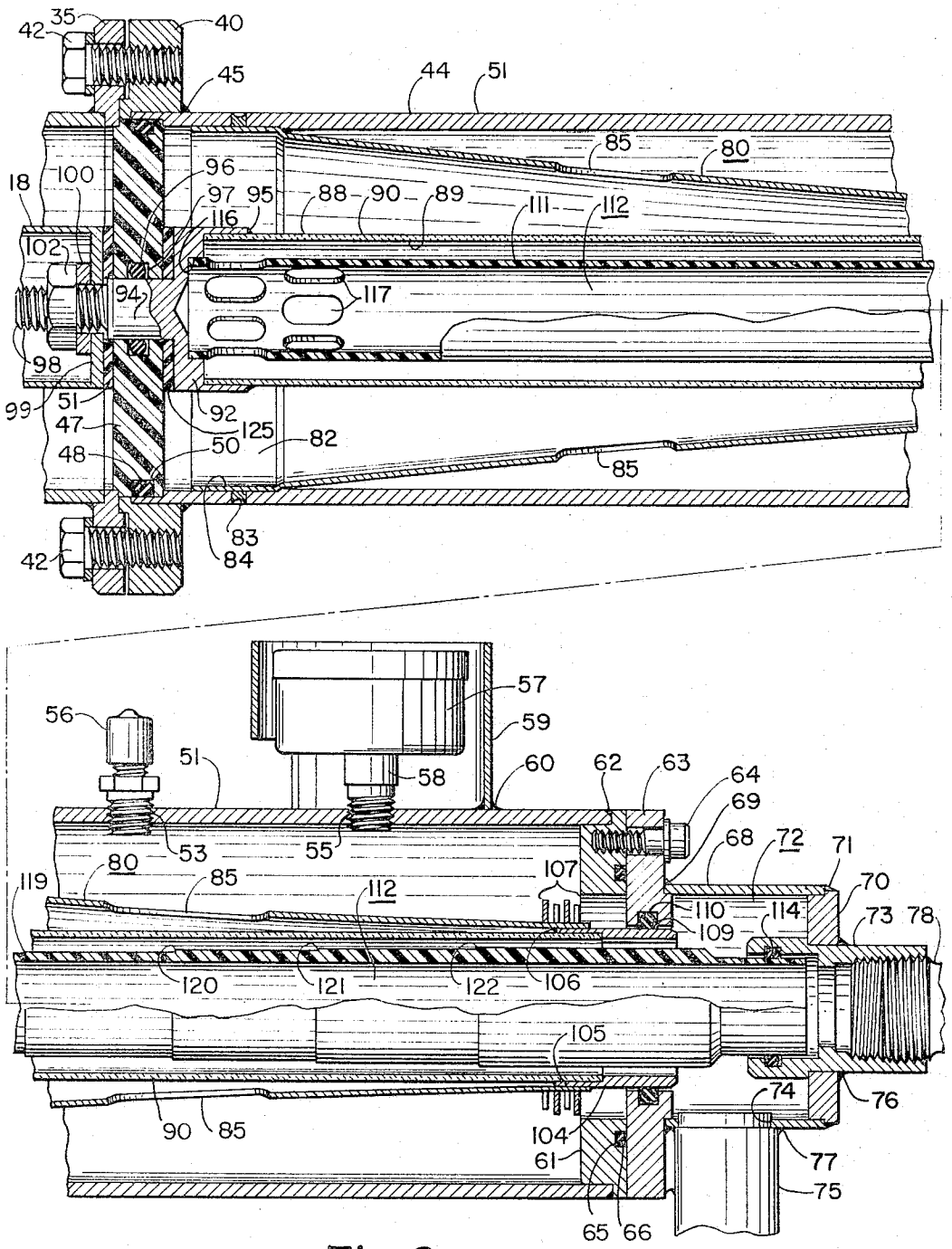


Fig. 6

INVENTORS
Harold E. Stevens
Leo Lesyk

BY Bosworth, Sessions Herrstrom & Knowles
ATTORNEYS

United States Patent Office

3,300,737

Patented Jan. 24, 1967

3,300,737

COAXIAL ELECTRICAL LINE ATTENUATOR

Harold Ellsworth Stevens, Lyndhurst, and Leo Lesyk, Cleveland, Ohio, assignors to Bird Electronic Corporation, Solon, Ohio, a corporation of Ohio

Filed Mar. 10, 1965, Ser. No. 438,486
6 Claims. (Cl. 333—22)

This invention relates to electrical devices for use in high frequency electrical apparatus and, more particularly, to an improved high frequency reflectionless termination for a coaxial transmission line.

Frequently, in testing transmitter apparatus or in measuring radio frequency power, it is necessary to terminate a coaxial transmission line in a substantially reflectionless termination, or dummy load. This termination must be capable of absorbing and dissipating this power in the form of heat. The problem of providing a coaxial line reflectionless termination is very complex when the termination must dissipate power in the order of kilowatts. It is well known in the art that a coaxial line has predetermined physical dimensions which determine the electrical characteristics which must be matched by the termination in order to prevent the undesirable reflection of radio frequency waves from the termination. To achieve maximum reflection and maximum power transfer from a transmission line to a termination, the load should have a characteristic impedance which is equal to the characteristic impedance of the line. For coaxial lines, the characteristic impedance is defined by:

$$Z_0=\frac{138.16}{\sqrt{E_r}}\log_{10}\frac{B}{A}$$

Where:

E_r=relative dielectric constant
Z_0=characteristic impedance
B=inside diameter of outer conductor
A=outside diameter of inner conductor

For maximum power transfer from a coaxial line, there should be a minimum of power reflection from the termination. Still further, any coolant material introduced into the termination must neither materially affect the voltage standing wave ratio, VSWR, nor physically affect the electrical components. These electrical requirements limit the diameter of the conductors of the terminations and therefore preclude the construction of large diameter terminations in an effort to handle extremely large amounts of heat generated in the terminations. This physical requirement and the propensity of moisture to cause arcing between high voltage conductors preclude the use of water between the conductors.

Of the known forms of terminations employed for coaxial lines, some of the most satisfactory devices employ a tapered outer conductor, or horn chamber, which is connected to the outer conductor of the coaxial line and tapers logarithmically inwardly and contacts a resistor type cylindrical inner conductor which is connected to the inner conductor of the coaxial line. Thus, because of the logarithmic taper and because the horn must be connected to the resistor, this combination of horn and resistor type inner conductor restricts the length as well as the diameter of the resistor which may be employed. One example of line termination of the tapered horn-resistor type is found in Waterfield et al., Patent No. 2,946,005. Other examples of this general type of line termination are found in Bird et al., Patent No. 2,752,572 and Bird, Patent No. 2,556,642.

Terminations suitable for use with pulse type generators must be capable of withstanding repeated thermal shock due to the sudden application and removal of power

from the transmission line. Further, for maximum power handling capacity, as well as thermal shock capacity, the termination should be provided with a coolant system including means for maintaining the resistive surface at a uniform temperature or within very small differentials throughout the surface area. Water, which is economical and has a high heat of vaporization, is one of the best coolants by which maximum power handling capacity and thermal shock capacity might be achieved, but even a small amount of moisture between conductors which are subject to high voltage may cause arcing and the resulting destruction of the termination. Accordingly, an important consideration of this invention is the prevention of condensation of the opposed surfaces of the coaxial termination conductors.

Another important consideration in the utility of a line termination is its frequency range. The broader the range over which the termination will operate, the more versatile will be its application.

Accordingly, an object of this invention is to provide an improved coaxial line reflectionless termination having a relatively broad frequency range.

Another object of this invention is to provide an improved termination for a coaxial line which is constructed to utilize the heat of vaporization of water while avoiding the disadvantages previously encountered when employing water.

Yet another object of this invention is to provide a relatively small coaxial line termination capable of handling power of the order of kilowatts.

Still another object of this invention is to provide a coaxial line termination capable of withstanding repeated thermal shock.

It is a still further object of this invention to employ in a coaxial line termination, a hollow cylindrical member having resistive material coated on its outer surface and provision for fluid flow on the interior of the member, which member is formed of dielectric material having a high thermal conductivity. Thus, the member acts as an insulator to electrical currents while acting as a metal to thermal currents.

It is also an object of this invention to provide for gas under pressure on the exterior surface of the resistor to thus prevent condensation of moisture on the surface of the resistor when the resistor is not in use.

It is a still further object of this invention to provide a coaxial line termination capable of dissipating relatively high power by employing water as a coolant in which the presence of the water in the termination produces substantially no change in the voltage standing wave ratio as compared to the same termination without water to thus assure that the termination is capable of operating over a wide frequency range, and in which good heat transfer between the resistor substrate and the water is obtained by producing turbulence in the water contacting the substrate.

It is yet another object of this invention to provide a coaxial line termination capable of dissipating power in the order of kilowatts over a wide frequency range.

Briefly, in accordance with aspects of this invention, we employ in a reflectionless coaxial transmission line termination a horn chamber serving as an outer conductor termination and as a terminating resistor housing and a resistor to be connected to the inner conductor of the transmission line, which resistor includes a resistive coating on a ceramic cylinder. Preferably, the resistor has an outer diameter substantially equal to the outer diameter of the inner conductor of the coaxial line. Advantageously, this ceramic cylinder is formed principally of a dielectric material such as beryllia, or BeO, which has a very high thermal conductivity and

is a good electrical insulator. Also advantageously, the resistor is formed of resistive material coated on the outer surface of the ceramic cylinder, or substrate, which arrangement facilitates heat transfer from the resistor. By circulating water against the interior of the ceramic cylinder by producing turbulence in the water contacting the substrate and increasing the flow rate as the temperature of the water increases, heat is removed at a very rapid rate from the resistor. Thus, it is not necessary for the water to contact the resistive coating of the resistor where it might otherwise cause arcing to other portions of the termination and where it might react with the resistive coating. Advantageously, a perforated horn is inclosed within a fluid tight housing and a dry gas is introduced to the interior of the housing to purge any moisture entrapped during assembly and is utilized to prevent condensation on the resistor when it cools between periods of operation. The dry gas prevents condensation of moisture on the film resistor which might take place if the housing were filled with air containing water vapor.

To increase the power handling capabilities of the termination, a coolant system is provided which includes a fluid coolant conduit on the interior of, and preferably coaxial with, the cylindrical resistor. This conduit has apertures in the end there of adjacent the end of the coaxial line through which apertures a coolant, such as water, is forced. This coolant flows across the interior surface of the resistor and out through the end wall of the housing without either touching the resistive surface of the resistor or entering the space between the resistor and horn-shaped outer conductor. In accordance with other aspects of this invention, the fluid coolant conduit is "stepped," or provided with sections of increasing diameter, in a direction from the inner conductor of the coaxial line outwardly toward the exterior of the housing to produce maximum heat transfer. The steps are weighted toward a smaller area in the chamber adjacent the discharge end to produce a greater velocity at this end, where the water is hottest, than the mean velocity, thus gaining a reduction of boundary temperature change.

In accordance with still other aspects of this invention, we employ, as a support for a resistive film, a ceramic material exhibits a relative high thermal conductivity, i.e., one which has a thermal conductivity, k, greater than .1 and preferably of the order of .49 calories per second per square centimeter per centimeter (traveled) per degree centigrade (A+). This latter figure corresponds to the thermal conductivity of aluminum, which is approached by good beryllia. The ceramic material, however, acts as a dielectric to electrical currents. By employing this material as a support for a resistive film, it is possible to circulate water on one surface of the material while the opposite surface of the material supports the resistive film and thus the water rapidly removes the heat generated in the film by the high frequency electrical energy.

In accordance with more specific aspects of this invention, we employ in a line termination a cylinder consisting essentially of beryllia, or beryllium oxide as it is sometimes called, which has a thermal conductivity greater than .1 and preferably in the range of .2 to .492. Beryllia having this thermal conductivity is available commercially from either National Beryllia, Haskell, New Jersey or Coors, Golden, Colorado. With this novel arrangement, it is possible to utilize water and thus economically dissipate the heat generated by the high frequency power by obviating the use of other and more expensive coolants, such as oil.

In accordance with still other aspects of this invention, we employ, in a line terminating device inclosed in a housing, a resistor formed by applying a resistive coating to one surface of a hollow ceramic member having a high thermal conductivity, means for supplying cooling

liquid solely to the interior of the resistor, and means for supplying gas under pressure between the conductors of the line terminating device. This combination prevents condensation of moisture on the resistive material when no power is applied to the terminating device.

In accordance with still other aspects of this invention, we employ, in an inclosed line terminating device, a resistor formed of a cylindrical ceramic member and a resistive coating on the outer surface of the ceramic member, which ceramic member is formed of material having a high thermal coefficient. Advantageously, we provide this termination with a cooling system including means for circulating a liquid coolant such as water on the interior surface of the ceramic member which means includes turbulence producing means for producing turbulence in the water contacting the ceramic member. This termination includes assembly housing means for maintaining dry gas under pressure around the exterior surface of the resistor. The presence of the dry gas on the exterior of the resistor prevents condensation of moisture on the resistive coating. The liquid coolant circulating system advantageously includes an annular fluid conduit member which is axially aligned with the resistor and mounted on the inside thereof and having a stepped outer surface which is stepped in a plurality of cylindrical sections of progressively increasing diameter, increasing toward the outlet of the annular passage between the fluid conduit and the resistor.

The embodiment of the invention illustrated in the accompanying drawings, forming a part of this specification, represents the best known mode of practicing the invention for effectuating the above objectives and certain other objectives having to do with details of construction and arrangements of parts which will become apparent as the description proceeds, this description being made by the use of reference numerals which indicate the parts throughout the several views.

In the drawings:

FIG. 1 is a view, in elevation, partly broken away and in section, of a line terminating device according to one illustrative embodiment of this invention, schematically illustrating the manner of connection to a radio frequency generator and to a heat exchange system;

FIG. 2 is an end view, partly in section, taken from the left hand end of FIG. 1;

FIG. 3 is an end view, taken from the right hand end of FIG. 1;

FIG. 4 is a view, in section, taken along the line 4—4 of FIG. 1;

FIG. 5 is a fragmentary view, to a larger scale, of a portion of the embodiment of FIG. 1; and

FIG. 6 is a broken view showing a portion of the device this view being similar and enlarged relative to FIG. 1 to reveal internal construction.

FIG. 1 depicts a system for terminating a coaxial line from a signal generator, which system includes a reflectionless type of line termination device **12** and means for dissipating heat generated at the line termination. This view of the load is in elevation, partly in section, with other portions of the system shown in block and schematic form. A signal generator **10** is connected by coaxial line **11** to the load or termination device **12**. The system also includes a heat exchanger **13** connected by means of pipes **14**, **15** to the load **12** and to a pump **16** which circulates coolant liquid between the load and the heat exchanger by means of a pipe **17**. The signal generator **10** provides signals at any frequency from D.C. up into the microwave region and this generator may be a portion of a transmitter. It is understood that the signal generator may be of any well known type and it may be of the pulse type, such as employed in radar, to generate pulses at a relatively low repetition rate. The line termination, according to this invention, is adapted to withstand thermal shock and is, therefore, suited to oper-

ate as a terminating device to receive the power transmitted from a radar type transmitter.

The input ends of the inner and outer conductors (to be later described in detail) which comprise the energy dissipating section of the termination or load device are connected to the coaxial line **11** through a suitable connector section which may include an inner connector **18** and an outer connector **21**. The coaxial line **11** (FIG. 1) includes an outer conductor **19** and an inner conductor **20** which are connected to such connector section of the load by conventional means. The outer conductor **19** is provided with a suitable fitting (not shown) received in an annular recess **23** in swivel follower **22**, which follower is telescoped over reduced outer end of the tubular cylindrical outer connector **21**. A swivel flange **26** is disposed about the ring **22** and includes a circular inwardly projecting radial lip **27** engaging behind annular shoulder projection **25** of the ring **22**. The swivel flange **26** has a plurality of circumferentially spaced apertures **28** through which bolts may be inserted to engage a corresponding plate, not shown, on the end of the fitting on the outer conductor **19** of the coaxial line **11** to hold the plates together. The outer connector **21** abuts a circular shoulder provided by an internal rib **29** of the swivel follower or ring **22** and is secured thereto by brazing, indicated at **33**. The swivel flange **26** includes an alignment pin **31** for engaging a suitable recess, not shown, in the fitting, also not shown, on the end of outer conductor **19**. The end of outer conductor **21** remote from the ring **22** is connected to an apertured flange ring **35**, the latter being formed with an internal rabbet to receive the connector and provide a radial locating shoulder **36** against which the connector **21** is abutted. This connection is secured by silver brazing around the periphery, as indicated at **37**. The flange ring **35** abuts a companion flange ring **40** telescoped over one end of a cylindrical housing member **44**. Silver brazing, indicated at **45**, secures the flange ring **40** to the housing member **44**. The flange rings **35**, **40** are held together by a number of bolts **42** received through aligned openings. The housing member **44** is part of a gas tight enclosure which includes an end wall **47** in the form of an insulator of dielectric material such as polytetrafluoroethylene. This insulating end wall **47** is a circular ring having oppositely directed flat parallel surfaces. Its outer periphery is held between a shallow internal radial shoulder provided by an internal rabbet in the end of the cylindrical housing member **44** and the inner peripheral portion of the flat end face of the ring flange **35**. A gas tight seal is defined by means of a rubber O-ring **48** confined in an annular recess **50** formed in the outer periphery of the plastic insulating member **47**. A ring **51** of polytetrafluorine is held between connector **18** and end wall **47**.

This termination is provided with means for maintaining a pressurized dry gas on the interior of the cylindrical housing to prevent the condensation of moisture on the surface of the resistor. This means is provided in the cylindrical housing **44** by a pair of apertures **53**, **55**. A gas conduit fitting **56** is threaded into aperture **53** and a gas pressure gauge **57** is coupled to member **44** by a pipe **58** which threadably engages aperture **55**. A dry gas, preferably nitrogen, is introduced into conduit **56** from a suitable reservoir, not shown, to maintain the interior of the housing assembly under a suitable superatmospheric gas pressure. The gauge **57** is protected by means of a gauge cover **59** which is silver brazed at **60** to the outer surface of housing cylinder **44**. Housing cylinder **44** is connected to a housing end plate **61** by silver brazing **62** to define a gas tight seal. A water chamber flange **63** abuts the housing end plate **61** and is secured thereto by means of bolts, such as bolt **64**. An O-ring seal **65** is compressed in an annular recess **66** in the abutting face of the housing end plate **61** by water chamber flange **63** to define a gas tight seal.

The coolant system includes water chamber flange **63** which is connected to a water chamber tube **68** by means of silver brazing at **69**. The end of water chamber tube **68** opposite flange **63** is defined by a water chamber plate **70** which is also brazed to water chamber tube **68** at **71**. The chamber **72**, defined by tube **68** and plates **63**, **70**, is the outer manifold chamber through which cooling liquid is exhausted from the coaxial line termination **12**. The water chamber plate **70** has an aperture which receives a water inlet fitting **73**. Water chamber tube **68** has another aperture **74** which is aligned with a water outlet fitting **75**, which fittings are secured thereto by means of brazings **76**, **77**, respectively. Fittings **73**, **75** are provided with suitable hose nipples **78**, **79**, respectively (shown in FIG. 1) which threadably engage the respective fittings and connect the respective coolant pipes **14**, **17**.

The electrical portion of the coaxial line termination includes a horn-shaped conductor **80** which acts as a termination of the outer conductor **19** of the coaxial line and has an integral cylindrical extension **82** which snugly engages the inner surface of cylindrical housing member **44** and is welded, soft-soldered, or silver brazed thereto. Solder or braze is fed at spaced points **83** around the periphery of a full ring fillet **84**, which solder feed holes are gas tight. The horn-shaped outer conductor has a plurality of apertures **85** therein for the purpose of permitting gas flow from the interior of the cylindrical housing member **44** to the interior of the horn member **80** for the purposes which will be subsequently described. The electrical portion of the coaxial line termination also includes a resistor assembly **88** which advantageously includes a ceramic dielectric cylinder **89** having a thermal conductivity, k, at least equal to .1 with a resistive coating **90** deposited, painted, or otherwise formed, on the outer surface of cylinder **89**. A metallized terminal **91** is painted or otherwise formed on each end of cylinder **89** and overlaps each end of coating **90**. Resistive coating **90** is electrically connected to the coaxial line connector section inner conductor **18** through terminal **91** and a contact member **92**, having a sleeve-like portion which encircles the end of cylinder **89** and is soldered at **95**, or otherwise joined, to resistor terminal **91** in liquid sealing relationship. The resistor contact **92** has a reduced cylindrical extension **94** which projects through the insulator **47** and compresses an O-ring **96** against an annular recess **97** in the insulator **47** to define a gas tight seal between the cylindrical extension **94** and the insulator **47**. Resistor contact **92** includes a threaded extension **98** which passes through an end plate **99** of the connector section inner conductor **18** of the coaxial line **11** and is secured thereto by means of a split washer **100** and a nut **102**.

In one embodiment, the dielectric cylinder is formed of beryllia with an outside diameter of 1¼", and inside diameter of 1⅛", and is 12" long. The resistive coating **90** covers an area 10¾" long. The resistance of this coating is of the order of 48.5 ohms to 51.5 ohms. Tests have shown that the line termination including this resistor assembly **88** are capable of successfully steadily dissipating power of the order of 50 kilowatts for several hundred hours.

As best seen in FIG. 5, the opposite end of the resistor assembly **88** from the resistor contact **92** has a contact **104** which has a sleeve portion **105** extending over the end of the ceramic cylinder **89** and soldered to the resistive terminal **91** by means of the solder indicated at **106**. The end of horn **80** adjacent contact **104** is split, such as by sawing, and pressed into engagement with contact **104** by a plurality of split compression rings **107** to provide suitable contact pressure between the end of the horn **80** and resistor contact sleeve **105** in accordance with well known practice.

The resistor contact **104** passes through a relatively large aperture in the housing end plate **61** and a relatively small aperture in the water chamber flange **63** and compresses an O-ring **109** in an annular recess **110** of

the water chamber flange to define a fluid tight seal between water chamber flange **63** and contact **104**. The gas pressure on O-ring **109** reduces the pressure differential on the O-ring and is preferably greater than the liquid pressure in chamber **72**.

The coolant system includes a coolant water tube **112** mounted in inlet water fitting **73** to compress an O-ring **114** in an annular recess **115** in inlet fitting **73** to define a fluid tight seal. The opposite end of water tube **112** is captivated by a recess **116** in the resistor contact **92**. Advantageously, tube **112** is coaxial with the ceramic tube **89**, as best seen in FIG. 4, such that the area between the two tubes is uniform in cross-section to provide a uniform path for the flow of coolant as will be subsequently described. A plurality of apertures **117** in tube **112** provides outlet passages for the coolant to permit the coolant to escape from the tube **112** into contact with the inner surface of the ceramic substrate resistor **88**. Advantageously, the outer surface of tube **112** is formed with a plurality of steps **119**, **120**, **121**, **122** and **123** by which the outer diameter of the tube **112** increases progressively in the direction of outlet manifold chamber **72** so that the flow rate of coolant increases as the coolant approaches chamber **72** where it is exhausted through the water outlet fitting **75**.

Water tube **112** is preferably made of phenolic tubing or other dielectric material capable of withstanding hot water. The five steps: **119**, **120**, **121**, **122** and **123** on the outer surface of tube **112** actually employed in the previously described operating embodiment are such that the outer diameter of the tube increases progressively from .76 inch to .92 inch in substantially equal increments and at evenly spaced intervals of 1¾ inches apart. The first step is spaced approximately 3.125 inches from the left hand end of tube **112**. The interior diameter of the tube is uniform throughout the tube length and is of the order of .68 inch and the apertures **117** are formed in two rows of six apertures each, with one row rotated circumferentially 30° from the other row to provide ample outlet area for the water. In this illustrative embodiment, the apertures are oval shaped and have a major diameter of approximately 7/16 inch. With this arrangement of elements and by maintaining water flow at a suitable rate within resistor assembly **88**, the temperature of the resistive material may be held within a surface variation of ±1° C., thus permitting maximum power dissipation for the materials employed.

The gas, which is preferably dry nitrogen or other inert gas, is introduced through the conduit **56** and circulates around through the apertures **85** of the horn **80** and contacts the resistive coating **90**, excluding air, thus to prevent the condensation of moisture on the resistive surface when no power is applied from generator **10**. Advantageously, because the gas pressure is much greater than the pressure of the water, any minute leakage which occurs in air seals will be outward. Inward leakage of air, and associated condensation at points where it is chilled below its dew point, is avoided. This leakage, if occurrent, will be indicated by gauge **57** and signal generator **10** can be turned off before damage occurs to the termination **12**.

The ceramic material formed in the tube **88** has a very high thermal conductivity, *k*, defined in terms of calories per second per square centimeter per centimeter per degree centigrade, preferably a value in the range corresponding to that of metals, such as aluminum and brass. The coefficients of thermal conductivities for aluminum and brass are .49 and .26, respectively. For example, tube **88** may be formed principally of beryllia which is beryllium oxide and preferably has a thermal conductivity in the range of .20 to .49. Because of this high thermal conductivity, the heat generated in the resistor film **90** is rapidly conducted to the inner surface of tube **89** and is transferred to the water on the interior of tube **89**.

In one illustrative embodiment of this invention, ceramic substrate resistor **88** dissipates 30 kilowatts of radio frequency power and this resistor is approximately one foot long and has an outside diameter of 1.25 inches and the resistive film is a metal resistive film which is coated on the exterior surface of the ceramic cylinder for a distance of 10¾ inches and the ends of the resistive material are connected to the contacts **92**, **104** by metallized terminals **91** suitably coated on both ends of the ceramic cylinder.

This embodiment was subjected to an accelerated life test in which it was shocked by the application and removal of power at 20% over the proposed rating of 25 kilowatts for 3,000 shock applications over a period of 50 hours. After this life test, the termination was dissembled and a close examination did not reveal any structural failures.

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 embodiments shown in the drawings 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 termination for a coaxial transmission line, the combination comprising:

a tubular ceramic dielectric member having a thermal coefficient at least equal to .2 calories per second per square centimeter per centimeter per degrees centigrade;

a film type resistor affixed on the exterior of said member;

means for connecting said resistor to the inner conductor of said line;

housing means enclosing said member in fluid sealing relationship; and

tubular conduit means for conducting a fluid to the interior of said member, said conduit means being within, substantially coextensive with, axially aligned with and spaced from said member and having a plurality of steps of progressively larger diameter in the direction of fluid flow to produce increased turbulence and velocity in the exhaust flow of fluid therebetween.

2. An attenuating device for use in a high frequency coaxial electrical system, said device comprising:

an elongated tubular outer conductor;

an elongated inner conductor within, substantially coextensive with and coaxial with the outer conductor, said conductors being separated by an annular dielectric filled space and each having a surface confronting the other across said filled space, one of the conductors comprising an elongated ceramic tube having an electrically resistive member on its surface and being formed of material having a coefficient of thermal conductivity of the order of at least about .2 calories per second per square centimeter per centimeter per degrees centigrade;

fluid flow means disposed in fixed relation to said ceramic tube; and

conduit means connected to said one conductor and adapted to be connected also to a source of fluid coolant under pressure for supplying such fluid to the one conductor, said fluid flow means being adapted to constrain the flow of fluid so supplied to flow in one direction through said tube in a receiving run and in a reverse direction in a returning run, said receiving and returning runs both being separated from said dielectric space by the ceramic tube, said fluid flow means comprising a tubular member positioned coaxially within said

ceramic tube, said tubular member having a stepped outer surface of increasing diameter which increases in the direction of said returning run.

3. An attenuating device for use in a high frequency coaxial electrical system, said device comprising:

an elongated, horn-shaped outer conductor;

an elongated inner conductor within and coaxial to said outer conductor, one of said conductors comprising an elongated ceramic tube having an electrically resistive means on one surface thereof and being formed of a material having a thermal conductivity of the order of at least .2 calories per second per square centimeter per centimeter per degrees centigrade;

fluid flow means disposed in fixed relation to said ceramic tube; and

conduit means connected to said fluid flow means and adapted to be connected also to a source of fluid coolant under pressure for supplying fluid to said one conductor, said fluid flow means being adapted to direct the flow of fluid supplied to said one conductor in one direction throughout said tube in a receiving run and in a reverse direction in a returning run said runs being concentric and within said ceramic tube, said conduit means including means spaced along said conduit means for producing turbulence in the fluid flowing in said returning run.

4. The combination according to claim 3, wherein said conduit means includes tubular member coaxially positioned within said ceramic tube and spaced therefrom and wherein said means for producing turbulence includes a stepped outer surface of progressively increasing diameter on said tubular member.

5. The combination according to claim 4 wherein the progressively increasing diameter of said tubular member increases in the direction of the returning run.

6. The combination according to claim 5 wherein said ceramic tube consists essentially of beryllium oxide.

References Cited by the Examiner

UNITED STATES PATENTS

2,262,134	11/1941	Brown	333—22
2,421,758	6/1947	Ovrebo	333—22
2,848,683	8/1958	Jones	333—22
2,894,219	7/1959	Frederico	333—22
3,044,027	7/1962	Chin et al.	333—22
3,213,392	10/1965	Hedberg	333—22
3,241,089	3/1966	Treen	333—22

FOREIGN PATENTS

1,181,935	1/1959	France.

HERMAN KARL SAALBACH, *Primary Examiner.*

R. F. HUNT, *Assistant Examiner.*