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J. R. BIRD ET AL
COAXIAL LINE LOAD DEVICE

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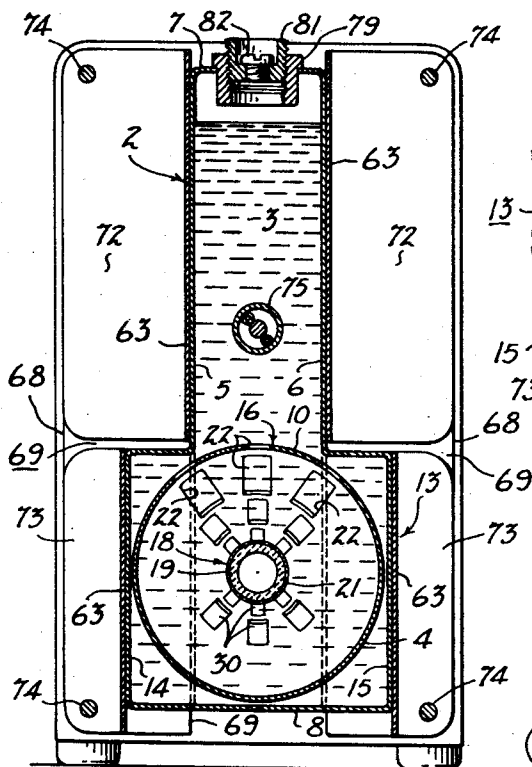


Fig. 3

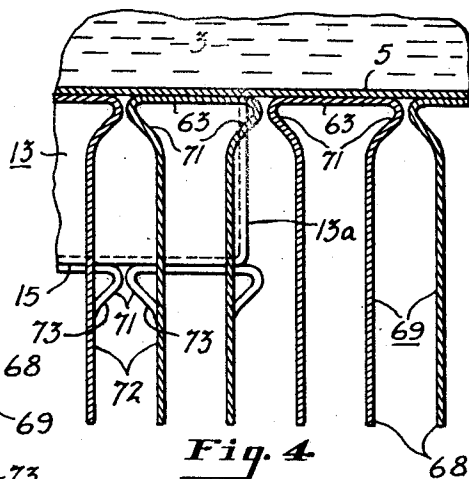


Fig. 4

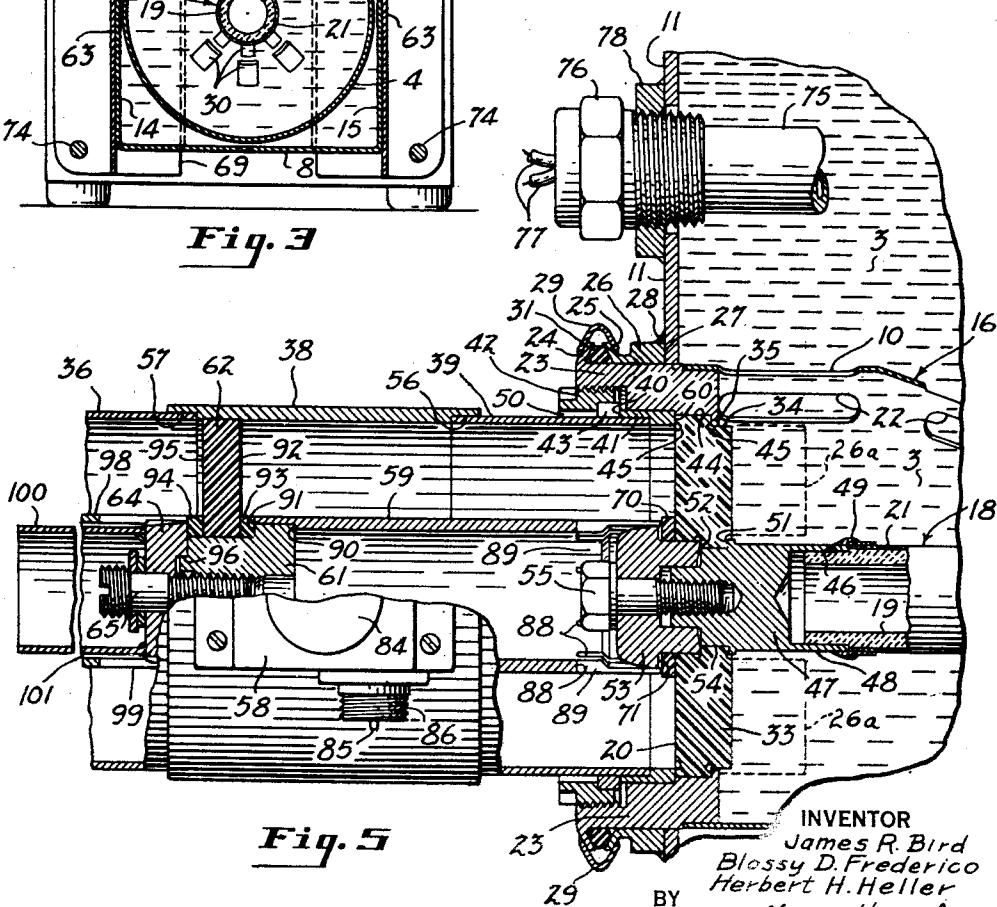


Fig. 5

INVENTOR
James R. Bird
Blossy D. Frederico
Herbert H. Heller
BY
George Knowles
ATTORNEY

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COAXIAL LINE LOAD DEVICE

James R. Bird, Chagrin Falls, Blossy D. Frederico, Cleveland, and Herbert H. Heller, Cleveland Heights, Ohio, assignors to Bird Electronic Corporation, Cleveland, Ohio, a corporation of Ohio

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14 Claims. (Cl. 333—22)

This invention relates to resistive terminations commonly known as dummy loads for high frequency coaxial lines. Such devices are used, for example, in substitution for an antenna while testing or adjusting very high frequency transmitters such as those used in television and frequency modulation broadcasting.

A load customarily is designed for use with a coaxial line of a specific characteristic or surge impedance and preferably is arranged to have an input impedance which, over a large range of frequencies, is equal to that characteristic impedance. In U.S. Patent 2,556,642 to James R. Bird there is disclosed a coaxial reflectionless load device suitable for use in high frequency electrical circuits. That device comprises an attenuating line section including an outer sleeve conductor tapered inwardly to its rear end and an inner conductor coaxially mounted within the sleeve and joined thereto at its rear end. The inner conductor is resistive in character, being in the form of a thin resistive coating on a ceramic core. The taper of the outer conductor is preferably exponential so that the device exhibits a pure ohmic characteristic, that is, the characteristic impedance of the line at any point is equal to the resistance of the line measured between the conductors at such point. The attenuating line section is enclosed in a suitable housing filled with a liquid dielectric and the tapered outer conductor is perforated or slotted to allow the liquid dielectric, serving also as a coolant, to be in continuous contact or heat exchanging relation with the inner conductor. The housing containing the bath of liquid dielectric may be cooled by radiant or convective loss of heat to the atmosphere, or, where high power absorption and dissipation is desired, by a circulated refrigerant. To that end, a suitable heat exchanging element or conduit for the refrigerant may be immersed in the liquid dielectric above the attenuating line section, and a cooling liquid such as water circulated through the conduit from a suitable source.

It will be appreciated that the necessity for providing a source of cooling liquid, for instance hose connections to a water tap and to a drain, may be inconvenient and occasionally impractical to accomplish. A load having a high input rate and capable of dissipating its heat to the atmosphere without need for fluid connections is much to be preferred. Accordingly it is an object of the present invention to provide, for a high frequency coaxial line, an improved load structure having a high input capacity, a load capable of dissipating heat to the atmosphere at a high rate or having a high power absorbing factor without excessive temperature rise and without need for a cooling medium to be circulated in heat exchange relation to the dielectric of the load or other auxiliary cooling means. More particularly it is sought to obtain improved convective flow of the liquid dielectric cooling medium in coaxial load devices employing such a medium to the end that the resistive film conductor of the load is more effectively and uniformly cooled in the avoidance of objectionable hot spots which change the electrical characteristics of such a device and,

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more seriously, result in short effective life or early failure of the device.

Related to the convective flow feature is another objective of the invention having to do with the dissipation of heat from the coolant filled housing to the atmosphere. While metal finning is a recognized expedient the present invention provides fins of an improved form which not only exhibit high heat transfer characteristics but also strengthen the housing structure in a unique manner and facilitate production and assembly by reason of their simplicity.

Another object of the invention is to provide a load device having a high heat dissipating rate while yet being of a compact size and generally rectangular in shape for ease of handling and for convenience of mounting in associated equipment when desired.

Yet another object of the invention is to provide a fluid tight insulating coupling for very high frequency equipment within a housing containing fluid whereby connection may be made to an external coaxial line with low losses and with little disturbance of the line characteristics and in a manner precluding loss of fluid from the housing.

In accordance with the invention, the tapered attenuating line section is immersed in a liquid dielectric coolant contained in a metal housing so shaped as to promote improved convective flow of the coolant. The housing is made to a generally rectangular form. The length of the housing is greater than its height, its height is several times greater than its width and its width is intermediate the maximum and minimum diameters of the tapered outer sleeve or horn conductor of the dissipative line. The attenuating line section is projected into the housing interior through an opening adjacent the bottom of one end wall of the housing and is supported by such housing wall. Thus the line section is located close to the bottom wall of the housing and with its axis substantially parallel thereto. The lower region of the housing has a laterally enlarged portion adjacent the supporting end wall and this portion has a width which is slightly greater than the maximum diameter portion of the sleeve or tapered horn conductor which it accommodates. Perforations or slots centrally located in the top and bottom surfaces of the sleeve cooperate with the narrow width feature of the housing to promote convective circulation of the fluid within the housing at a relatively high rate and solely by thermosiphon action for effective removal of heat from the attenuating line section, particularly from the inner conductor thereof.

In a specialized version representing the best mode of practicing the invention, the housing has vertically extending lateral fins attached to or formed along its sides for effective dissipation of the heat. The fins are proportioned in size with respect to the main and the laterally enlarged portions of the housing to achieve a uniform rectangular external configuration.

According to another and more specialized feature of the invention, the dielectric space of the attenuating line section is sealed into the housing through a plug or washer made of a low loss dielectric material such as polytetrafluoroethylene or a compound known commercially as Teflon. The seals to the washer are made of narrow sections with undercut sealing surfaces whereby to achieve a tight seal, despite the cold-flow characteristics of the material.

For further objects and advantages and for a better understanding of the invention attention is now directed to an illustrative embodiment representing the best mode of practicing the invention, as set forth in the following description and as shown in the accompanying drawings forming a part of this specification. The features be-

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lieved to be novel will be more particularly pointed out in the appended claims.

In the drawings wherein like numerals throughout the several views denote like parts:

Figs. 1 and 2 are side and plan elevation views respectively of a coaxial plan load device embodying the invention.

Fig. 3 is a vertical section through Fig. 2 along the lines 3—3 taken in the direction indicated by the arrows.

Fig. 4 is a plan sectional detail along the lines 4—4 indicated in Fig. 2.

Fig. 5 is a fragmentary side sectional elevation along the lines 5—5 in Fig. 1 and seen in the direction indicated by the arrows.

Referring to the drawings and more particularly to Figs. 1 and 2, there is shown a load device 1 comprising a generally rectangular housing 2 which serves as a reservoir or tank for liquid dielectric 3 in which an attenuating line section 4 of the tapered horn type is immersed. The liquid dielectric coolant may be such as set forth in copending application for United States patent Serial No. 335,118, filed February 4, 1953 or available commercially as Dowtherm "A." The housing may be made of sheet material such as steel, copper, brass, aluminum or the like. Material of good heat conductivity is desirable and in general brass or copper are preferred because of the ease of soldering and brazing thereto. The housing may be formed of a sheet of brass bent with 90° corners to form main side walls 5, 6 and top and bottom walls 7 and 8, abutted edges being welded in a medial seam at 9 in the center of the top wall 7. End walls 11, 12 are of a width greater than the spacing of the side walls 5, 6 and are fastened by welding in the corners to make a fluid-tight enclosure.

In the lower region of the front part of the housing there is provided a laterally enlarged portion 13 of generally square cross section and with a width or spacing between supplemental side walls 14, 15 just great enough to accommodate the maximum diameter portion of the attenuating line section 4. The width or spacing between the main side walls 5 and 6 on the other hand is intermediate the maximum and minimum diameters of the tapered horn outer conductor of the attenuating line section 4. The length of the housing 2, namely the distance between front and rear end walls 11, 12 respectively is greater than the height, namely the distance between the top and bottom walls 7 and 8. The height is several times greater than the width, namely the spacing between the main side walls 5, 6. Enlarged portion 13 has rear wall 13a located intermediate the ends of the attenuating line section 4.

The attenuating line section 4 is accommodated in the lower part of the housing close to the bottom wall 8 and with its axis substantially parallel thereto. The attenuating line section comprises a hollow horn or shell 16 (Fig. 5) which is of tubular form tapering inwardly to its rear end 17. This horn surrounds the inner or resistive conductor 18 in coaxial relation and is preferably tapered exponentially as described in greater detail in the Bird patent previously referred to. The inner conductor may comprise a ceramic tube 19 coated with a layer of a resistive coating 21 sufficiently thin to eliminate skin effect in relation to currents flowing thereto throughout the range of frequencies for which the device is designed. The coating 21 may be in the form of carbon, tungsten, platinum or other metal applied by vacuum vaporization, sputtering, painting in colloid dispersion, electrolytic deposition, or other known methods. The outer tapered conductor 16 is perforated to allow the circulation of the liquid dielectric 3 therethrough; these perforations may be in the form of longitudinal slots, preferably all along the top surface but only adjacent the small end in the bottom surface of the horn shaped conductor as illustrated in Figs. 3 and 5 at 22 and 30 respectively.

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The outer tapered conductor 16 is formed at its large diameter end with an integral cylinder portion 10 fastened peripherally to a mounting ring 23 over which it is telescoped and which may be made of brass or other relatively soft metal. The fastening may be by soldering or, if desired, by mechanical means such as screws placed around the periphery of the ring. The ring 23 has a rearwardly inclined outer flange 24 at its forward end, this flange being juxtaposed to a forwardly inclined outwardly directed radial flange 25 at the forward end of a fastening ring 26. The fastening ring 26 is externally milled or otherwise cut away at its inner end to obtain a squared or other non circular cross section received matingly and non rotatively within the matching opening in the upright front wall 11 of the housing. The milling also provides a radial shoulder 27 on the mounting ring which is disposed flatwise against the outside of the housing and is fastened hermetically thereto, preferably by welding or brazing as indicated at 28. The milling or cutting away of the inner end of the mounting ring 26 at circumferentially spaced regions to provide the non-circular shape mentioned results in a plurality of circumferentially spaced arcuate segments 26a which are integral with the body of the mounting ring, project through the housing opening into the housing interior and embrace the cylindrical portion 10 of the conductor 16. In the embodiment of the invention presently contemplated there are four of the segments 26a, two of them being shown in broken lines in Fig. 5. These segments guide the attenuating line section in assembly and support it over a substantial portion of its length to prevent wobbling of the line in the housing. As shown also in Fig. 5, the segments 26a are displaced from the openings 22 in the upper cylindrical portion of the outer conductor to avoid interference with the convective flow of the coolant. The body portion of the mounting ring 23 makes a snug sliding fit within the embracing fastening ring 26 and the two are held together by means of a constricting clamping ring 29. The clamping ring is V-shaped in cross section to engage the inclined radial flange portions 24 and 25 and draw them together. An O ring 31 made of soft resilient compressible material, not affected by the dielectric fluid within the housing, for instance, a rubber-like sealing gasket material, is located between the flange portions 24 and 25. As the clamping ring is tightened circumferentially as by means of screw 32 (Fig. 2), the O ring washer is compressed and a hermetic seal is achieved.

The outer tapered conductor 16 and the inner conductor 18 are located in spaced relation at their front end by means of an insulating washer 33 made of low loss dielectric material such as the compound polytetrafluoroethylene known commercially as "Teflon." The rear outer edge of the spacer 33 is circumferentially rabbeted at 34 to provide a shoulder, which shoulder abuts against an inwardly directed thin shallow flange 35 on the rear end of the mounting ring 23. The mating faces of the circumferential flange 35 and the radial shoulder of the insulator 33 or one of them, are inclined slightly off the radial in the direction obtaining an undercutting of the shoulder on the partition washer 33 in order to produce a locking effect when the insulator is squeezed axially in the manner now to be described.

The structure of the outer conductor for coupling the load device to the end of a transmission line comprises a tubular cylindrical member or portion 36 having at its outer or free end the usual very high frequency bolting flange 37 (Fig. 1), an intermediate branch line coupling member or portion 38 in the form of a cylindrical tube and a thermal insulating member or portion 39 also in the form of a cylindrical tube. The inner end of the cylindrical tube member 39 is provided with a contact ring 41 preferably made of brass and brazed thereto. The ring 41 is rabbeted internally to receive the end of the tube member 39 in a sliding fit in assembly, the

abutment of the tube against the bottom of the rabbet serving to locate the tube in predetermined position in the ring. The forward or outer end of the mounting ring 23 is counterbored and internally threaded to receive a spanner type ring screw 42 provided at its inner end with an internal circumferential rabbet in which is accommodated a split washer or ring spacer 43, preferably made of hard metal as steel. The internal diameter of the ring 42 is greater than the external diameter of the thin thermal barrier member 39 in the provision of an annular clearance 50 therebetween. When the ring screw 42 is tightened, the spacer ring 43 is forced axially against radial end face 40 of the contact ring 41 which, being fast to the external conductor of the coupling structure locks the line in position. Inner end face 60 of the contact ring 41 engages the circumferentially extending outer edge portion of the insulating washer 33 and causes outer periphery 44 of the partition washer to be squeezed between the inward flange 35 on the mounting ring 23 and the rear or inner face 60 of the contact ring. The end face 60 is chamfered or inclined oppositely to the inclined face of the mounting ring flange 35. The partition washer is formed on its outer face 20 and at the juncture of the surfaces defining the rabbet 34 with grooves 45 extending circumferentially about the partition washer and located in underlying relation to the edge corners of the inclined faces on the flange 35 and the ring end 60. Thus the peripheral portion 44 of the partition washer located radially outwardly of or beyond the stress relieving break grooves 45 is not only squeezed but is also locked in dovetail fashion so that a fluid tight seal is maintained notwithstanding the cold-flow characteristics of the material of which the dielectric partition washer or spacer 33 is composed.

The inner conductive structure which connects to the resistive conductor 18 is sealed through the insulating partition 33 in the following fashion. The end of the ceramic core 19 is formed with a reduced diameter portion 46 and a thin conductive band of plated-on metal such as silver is applied over the end portion of the resistive coating 21 and extends over the reduced diameter portion 46. The rear end of a circular sectional conductive plug 47, which may be made of brass, as by turning in a lathe, is formed with a tubular end extension 48 which is received telescopically and makes a snug fit over the reduced diameter portion 46 of the inner conductor, the overlapping portions being secured together by a conductive cement. Further to assure good electrical conductivity at the joint, a band of solder 49 is placed to overlap tubular extension 48 and the plated-on metal contact band of the inner conductor 18. The diameter of the plug 47 is the same as that of the inner conductor 18 whereby to effect a smooth unbroken surface between the parts that constitute the inner conductor of the attenuating line section. The plug 47 is provided with an external undercut or inclined circumferential shoulder 51. This shoulder is formed by machining a reduced diameter portion on the plug, by providing a flange, or, as shown, by both a reduced diameter portion and a shallow radial flange. Inclined end face 52 of an external mounting cap or ring 53 cooperates with the plug shoulder 51 to compress axially an internal radially projecting and circumferentially continuous lip portion 54 of the insulating spacer or partition 33. The parts are drawn together axially by tightening bolt 55 which passes through a central opening in the cap 53 and is threaded axially into the end of the plug 47. This end of the plug is reduced in diameter to provide a pilot which is received telescopically within a socket drilled into the cap 53, thereby establishing axial alignment of the parts. The socketed end of the cap has a reduced diameter end received snugly and locatingly within the counterbore in the partition member 33 which is adjacent the annular lip 54 and a deformable Teflon washer or ring 70 embraces the cap and is confined between the front face

20 of the partition 33 and annular shoulder 71 on the cap 53. The internal annular lip 54 is formed with undercut and circumferentially grooved side walls whereby to relieve the strain in the material when the lip is under axial compression between the inclined annular compression surfaces of the shoulder 51 and the cap end face 52. The lip 54 thus is squeezed in dovetail fashion whereby to provide a locking effect. This results in a hermetical seal which is long lasting in spite of the cold-flow characteristics of the insulating material.

It is desirable that the branch line coupling portion 38 be thermally insulated from the mounting ring 23, the attenuating line section 4, and the liquid dielectric and other components associated with the housing 2. To this end, the intermediate portion 39 of the outer conductor is made of material of relatively low thermal conductivity, such as stainless steel of the type, say, AISI type 302, and is relatively thin or shell like in cross section. By reason of its high strength the 18% chromium, 8% nickel, iron alloy comprising the conductor portion 39 can be made extremely thin, of the order, say, of about .025 inch to about .060 inch at a diameter of 3 inches. Shown is nominal 18 gauge tube about .048 inch thick. The tubular outer member comprising the coupling line section 38 has internally rabbeted ends providing short cylindrical sockets or undercuts 56 and 57 which receive the ends of the tubular outer members comprising conductor sections 39 and 36 respectively. The overlapping portions of the members are fastened together by suitable means such as brazing and there is thus provided a smooth unbroken interior surface of uniform diameter whereby to maintain the characteristic impedance unchanged throughout the coupling structure.

The branch coupling portion 38 is provided with a lateral aperture over which is secured a mounting block 58 formed with a socket 80 to receive a voltage or other coupling device 84 for sampling the voltage or energy at the input of the load device.

The outer conductor tube 38 of the branch coupling line section is provided with a detector mounting block 58 secured as by screws and brazing. The mounting block 58 is formed with a cylindrical socket 80 that opens through a mating aperture in the outer conductor of the line so as to provide access to the annular dielectric space surrounding the center conductor. The mounting block 58 is adapted to receive a suitable voltage or other detecting or coupling device for sampling the line voltage or energy at the input end of the attenuating line section load device. The coupling device, here indicated at 84, may be any of the known types of pickups, reference being made to copending application Serial Number 344,542, filed March 25, 1953, on "Directional Wattmeter" for a disclosure of a removable and replaceable cartridge type pickup device that can be inserted into the socket 80 of the mounting block 58 for sampling the electrical energy. When using the removable cartridge type pickup device of the character referred to it may be convenient to make the electrical connections to the components of the pickup inside the mounting block 58. In such case the leads are brought out through the side of the block to a center terminal 85 (Fig. 5) and a threaded outer terminal boss 86 to which a galvanometer or other suitable indicator (not shown) may be connected as by means of a coaxial cable having an appropriate end fitting for attachment to the boss 86.

Inner conductor 59 of the coupling line section is in the form of a cylindrical brass or other resilient metal tube. At its inner end this tube is formed with axial slots 88 in the provision of a multiplicity of axially directed fingers 89 that resiliently embrace the tapered head end of the mounting cap 53. Desirably the inner end of the conductor tube 59 is bored or internally relieved to reduce the thickness of the spring contact fingers 89. At its outer end the inner conductor tube 59 is supported on the large diameter end of a stepped plug 61 having a

reduced or small diameter portion received through and supported in the center hole of a circular insulating disc 62 of polytetrafluoroethylene or similar plastic material. The end of the conductor tube 59 which is received over the large diameter inner end of the plug 61 is counter-bored in the provision of a circumferentially extending locating shoulder 90 which abuts the end of the plug 61 about the periphery of the latter and insures that in assembly the outer end of the conductor tube 59 is flush with circular plug shoulder 91 defining the step between the large and small diameter portions of the plug 61. Interposed between the shoulder 91 and the inside face 92 of the insulating and supporting disc 62 is a plastic insulating ring 93, which may also be formed of polytetrafluoroethylene or the like. Both the insulating ring 93 and a similar ring 94 disposed against outside face 95 of the disc 62 are of the same external diameter as the inner conductor tube 59 to obtain the desired electrical characteristics in the transmission line in view of the stepped construction and the change in dielectric from air to solid plastic insulation and back to air, involving as it does attendant changes in dielectric constant. To hold the insulating and supporting disc 62 and the insulating rings 93 and 94 in assembled relation on the reduced diameter portion of the plug 61, a circular metal cap 64 is held against the outer end of the plug as by a stud 65 that extends through a center bore hole in the cap and is threaded into an axially extending tapped hole in the plug 61. Desirably a shallow axial counterbore is formed in the cap 64 about the stud hole in the provision of an annular socket 96 that receives snugly an axially directed pilot extension on the outer end of the plug 61 to locate the parts in predetermined coaxial relation in assembly.

As previously mentioned, suitable provision is made for attachment of the coupling line section to the end of a coaxial electrical transmission line. In the arrangement shown the outer tubular conductor 38 of the coupling line assembly projects axially beyond the supporting insulating disc 62 and such projecting or outer end is bored or otherwise relieved internally at 57 to receive one end of the outer tubular conductor 36 of the standard line coupling device. The tubular metal tube 36 is brazed or otherwise secured in the relieved end 57 of the tubular conductor portion 38 and the outer end of the conductor tube 36 carries or is secured in the usual attaching ring 37 of the conventional union.

The inner conductor of the coupling line assembly includes a tubular conductor 98 of brass or similar resilient metal having axial slots in its inner end portion in the provision of resilient fingers 99 that slide over and yieldingly embrace the tapered periphery of the cap 64. In this respect the connection of the inner tubular conductor 98 to the cap 64 is similar to the connection of the tubular inner conductor 59 of the branch coupling line section to the cap 53. The fingers 89 of the conductor 59 and the fingers 99 of the conductor 98 are locatingly abutted axially against the insulating plastic washers 70 and 95, respectively. By reason of the frustoconical or tapered shape of the caps 53 and 64 the electrical connection between each of the fingers and the cap is effected adjacent the inner axially directed circular face of the cap which defines the stepdown to the reduced diameter portion of the center conductor extending through corresponding insulating partition. Furthermore, the tapered or frustoconical shape of the center conductor caps 53 and 64 facilitates assembly, in that the ends of the center conductor tubes 59 and 98 are easily located over the smaller ends of the caps and then slid axially into place with attachment slight radial distention of the resilient fingers 89 and 99.

In the case of one of the conductor end caps, here the cap 64, provision is made for piloting into place the tubular conductor that is to be received over the cap. This supplemental pilot means takes the form of a metal

tube 100 that is secured in endwise relation against the outer face of the cap and in coaxial relation thereto. The pilot tube 100 has an outer diameter preferably less than the internal diameter of the inner conductor tube 98, providing an annular clearance 101 between the tube so that the fingered end of the conductor tube 98 is readily disposed over the pilot tube 100 during the initial stage of the assembly. The connections from the main transmission line to the present load device are thus made by bolting the end flange of the transmission line, indicated at 66 (Fig. 1) to the cooperating flange 37 of the coupling assembly outer conductor 36. The end of the inner conductor of the main line is simultaneously connected as by the bullet connector shown to the inner conductor tube 98.

It will be appreciated that energy flowing into the attenuating line section is converted into heat within the resistive portion of the line, the resistive portion comprising the extremely thin coating 21 on the inner conductor 19. This coating has a very low thermal capacity and it is essential, in order to prevent the development of hot spots which would damage the coating, that there be continuous, substantially uniform and certain circulation of coating fluid about the inner conductor. The tall narrow shape of the housing 2 has been found to be particularly effective in promoting convective currents of the fluid 3 therein by thermosiphon action. As the fluid comes into contact with the inner conductor it is heated and tends to rise through the axially elongated top slots 22 distributed throughout the length of the upper portion of the outer tapered horn conductor 16. At the same time, cooler fluid enters the longitudinally tapered annular dielectric space of the attenuating line section through the axially elongated bottom slots or openings 30 located in the bottom portion of the tapered horn conductor 16 primarily in the rear or small diameter part. There are no openings in the side portions of the horn conductor so that all cooling fluid entering the annular dielectric space surrounding the resistive center conductor to replace that flowing out the top slots 22 by reason of the convective movement must gain access through the bottom slots 30. In the arrangement shown wherein the bottom slots are located primarily in the small end of the horn conductor, actually in that portion of the tapered horn which surrounds about two thirds or less of the resistive portion of the center conductor adjacent the shorted end of the latter, there is induced into the convective flow an horizontal component which beneficially causes the cooling liquid dielectric to flow axially or longitudinally of the resistive center conductor. This restriction of the cooling fluid entrance openings to the small end of the horn or the equivalent use of large entrance openings at the small end and small entrance openings at the large end results in a balancing of the cooling effect on the elongated resistive conductor in the elimination of objectionable hot spots detrimental to the thin film coating. The fluid thus advances both upwardly and towards the front of the attenuating section as it flows about and is heated by contact with the inner conductor 18. Thus, as seen by reference to Fig. 2, there occurs a generally clockwise circulation of the fluid in the housing, such circulation being indicated by the curved arrows 67. Explained in another way, the fluid flows forwardly along the narrow bottom portion of the housing, rearwardly along the narrow top portion. In the front portion, above the large end of the attenuating line section the flow is generally upward, while in the rear portion the flow is generally downward.

In order to cool the housing and the fluid contained therein, lateral fins or vanes 68 are fastened to the side walls 5 and 6 of the housing. These vanes are formed of channel members 69 formed of brass or other suitable metal having high heat conductivity. They are disposed side by side and spaced so that the distance between the adjacent walls of adjoining channel members is approxi-

mately equal to the distance between the two walls of one channel member. The base portions of the channel members where they are attached to the side walls 5 and 6 of the housing are laterally enlarged or spread with extended parallel shoulders 71 in the provision of relatively wide channel webs 63 so as to give large surfaces of attachment to the housing side walls and also large surface areas for the conduction of heat into the fins. The attachment of the fins to the walls is done by brazing or spot welding, if desired, with the webs 63 disposed flatwise against the housing walls.

In the rear region of the housing having the relatively closely spaced side walls 5, 6 the fins 69 extend the entire height of the housing. In the forward upper region where the side walls 5, 6 extend downwardly only as far as the laterally enlarged portion 13 of the housing defined by the more widely spaced side walls 14, 15 there are provided upper short fins 72 of the same width as the fins 69 but of lesser height, these short fins being co-extensive in height with the forward portions of the walls 5, 6 to which they are attached and thus reaching substantially from the enlarged portion 13 to the top of the housing.

On the sides 14, 15 of the enlarged housing portion 13, there are provided narrow or shallow fins 73 which are vertically aligned with the upper fins 72 and extend laterally to the spaced parallel planes defined by the outer edges of the other fins 69 and 72. Thus the fins on the sides of the housing have a generally rectangular external configuration whereby the load is more conveniently handled and stacked when desired and more readily incorporated in standard racks or cabinets for this type of equipment. Tie-rods 74 extend the full length of the housing from the front plate 11 to the rear plate 12, passing through holes in the four outer corners of the fins and serving to stiffen the structure and to prevent injury to the fins from accidental damage.

In the illustrated embodiment of the invention as a precaution against inadvertent overloading there is provided a thermocouple unit connected to a conventional electrical safety cut out switch, not shown. The thermal unit is located within a blind tube 75 which is fastened to a threaded bushing or plug 76 threaded into a ring 78 welded to the front housing wall 11. The thermocouple tube 75 is thereby located within the housing and immersed in the liquid dielectric coolant 3 directly above the attenuating line section. Lead wires 77 to the thermocouple extend to the safety device or, if desired to an indicating meter.

The unit is filled with the liquid dielectric coolant through bushing 79 in the top wall 7 of the housing. The bushing is internally threaded to receive a plug 81 and the plug in turn is provided with a safety vent screw 82 which is loosened when the device is in use in order to prevent the possibility of explosion through building up of pressure should the input wattage into the attenuator be increased beyond its safe capacity.

The dielectric fluid within the housing is preferably one having a low dielectric constant, dielectric constants of the order of about three and below being satisfactory. It is preferable not to use dielectrics having constants above five because of the relatively large physical size of the outer conductor which would then be required in order to achieve the desired characteristic impedance equal to that of the transmission line. It is also desirable to use a fluid dielectric having substantially the same dielectric constant as the insulating partition 33 in order to avoid the reflective effect of a sudden change in dielectric characteristics. For an insulator 33 made of a compound known commercially as "Teflon" having a dielectric constant of the order of about 2.05, suitable liquid dielectrics are Dowtherm "A" and common mineral oil such as that sold commercially for medicinal purposes and known as "Nujol" having a dielectric constant of about 2.15. These liquids function effectively as coolants

by reason of their relatively high specific heat capacity and low viscosity which facilitate convective flow through the housing and thereby insure rapid removal of heat from the inner conductor.

The flow of the liquid dielectric through the attenuating line section causes it to become heated and that heat is communicated to the walls of the housing from whence it is conducted into the lateral fins. The fins lose heat to the atmosphere through radiation and also by flow of ambient air through the narrow vertical spaces between them. A dull black paint applied to the outside of the casing and fins promotes the loss of heat therefrom and increases the power dissipating capacity of the device.

While a certain specific embodiment of the invention has been illustrated and described in detail, the same is intended as illustrative and not as limitative of the invention. The specific size and portions of the parts may be varied considerably without departing from the invention and it is accordingly intended, in the appended claims to cover any such modifications coming within the true scope of the invention.

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

1. A heat dissipating termination for a high frequency coaxial line comprising an attenuating line section having front and rear ends and including an outer elongated circular sectioned sleeve conductor tapering from a relatively large diameter at its front end to a relatively small diameter at its rear end and an inner conductor coaxially mounted within and generally spaced from said sleeve and joined thereto at its rear end, a fluid tight housing enclosing said line section, said housing being of generally rectangular form in side elevation with a height substantially greater than its width, and, throughout the major portion of its extent, a width intermediate the maximum and minimum diameters of said sleeve at its front and rear ends respectively, a laterally enlarged portion in said housing in the front part thereof having a width sufficient to accommodate the large diameter front end of said sleeve, said attenuating line section being located close to the bottom wall of said housing with its axis substantially parallel thereto, a dielectric fluid substantially filling said housing and the space between said outer and inner conductor, said sleeve having perforations in its top and bottom surfaces cooperating with the narrow width feature of said housing to promote convective circulation of fluid in the housing for effective removal of heat from said attenuating line section.

2. A heat dissipating termination for a high frequency coaxial line comprising an attenuating line section having front and rear ends and including an outer elongated circular sectioned sleeve conductor tapering inwardly from a relatively large diameter at its front end to a relatively small diameter at its rear end and an inner conductor coaxially mounted within and generally spaced from said sleeve and joined thereto at its rear end, a fluid tight housing enclosing said line section, said housing being of generally rectangular form in side elevation with a length greater than its height, a height several times greater than its width, and, throughout the major portion of its extent, a width intermediate the maximum and minimum diameters of said sleeve at its front and rear ends respectively, a laterally enlarged portion in said housing in the lower region of the front part thereof, said portion having a width sufficient to accommodate the large diameter front end of said sleeve, said attenuating line section being located close to the bottom wall of said housing with its axis substantially parallel thereto, a dielectric fluid substantially filling said housing and the space between said outer sleeve and inner conductor, said sleeve having perforations in its top and bottom surfaces cooperating with the narrow width feature of said housing to promote convective circulation of fluid in the housing for effective removal of heat from said attenuating line section.

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3. A heat dissipating termination for a high frequency coaxial line comprising an attenuating line section having front and rear ends and including an outer elongated circular sectioned sleeve conductor tapering inwardly from a relatively large diameter at its front end to a relatively small diameter at its rear end and an inner conductor coaxially mounted within and generally spaced from said sleeve and joined thereto at its rear end, a fluid tight housing enclosing said line section, said housing being of generally rectangular form in side elevation with a length greater than its height, a height greater than its width, and, throughout the major portion of its extent, a width intermediate the maximum and minimum diameters of said sleeve at its front and rear ends respectively, a laterally enlarged portion in said housing in the lower region of the front part thereof, said portion having a width just slightly greater than the maximum diameter of said sleeve and being approximately square in cross section, said attenuating line section being located close to the bottom wall of said housing with its axis substantially parallel thereto, a dielectric fluid substantially filling said housing and the space between said outer sleeve and inner conductor, said sleeve having perforations in its top and bottom surfaces cooperating with the narrow width feature of said housing to promote convective circulation of fluid in the housing for effective removal of heat from said attenuating line section, and radiating fins fastened externally to said housing for dissipating said heat, said fins comprising a group of relatively narrow fins disposed on the outside of the enlarged portion of the housing and groups of relatively wide fins disposed on the outside of other portions of the housing.

4. A heat dissipating termination for a high frequency coaxial line comprising an attenuating line section having front and rear ends and including an outer elongated circular sectioned sleeve conductor tapering inwardly from a relatively large diameter at its front end to a relatively small diameter at its rear end and an inner conductor coaxially mounted within and generally spaced from said sleeve and joined thereto at its rear end, a fluid tight housing enclosing said line section, said housing being of generally rectangular form in side elevation with a length greater than its height, a height greater than its width, and, throughout the major portion of its extent, a width intermediate the maximum and minimum diameter of said sleeve at its front and rear ends respectively, a laterally enlarged portion in said housing in the lower region thereof adjacent a front end wall, said portion having a width just slightly greater than the maximum diameter of said sleeve and being approximately square in cross section, said attenuating line section being supported from said front end wall and located close to the bottom wall of said housing with its axis substantially parallel thereto, a dielectric fluid substantially filling said housing and the space between said outer sleeve and inner conductor, said sleeve having perforations in its top and bottom surfaces cooperating with the narrow width feature of said housing to promote convective circulation of fluid in the housing for effective removal of heat from said attenuating line section, and radiating fins extending from the side walls of said housing for dissipating said heat, said fins comprising vertically extending channel members proportioned in width with relatively narrow fins on said enlarged portion of the housing to define a generally rectangular external configuration for said termination.

5. A heat dissipating termination for a high frequency coaxial line comprising an attenuating line section having front and rear ends and including an outer elongated circular sectioned sleeve conductor tapering inwardly from a relatively large diameter at its front end to a relatively small diameter at its rear end and an inner conductor coaxially mounted within and generally spaced from said sleeve and joined thereto at its rear end, a fluid tight housing enclosing said line section, said housing being of generally rectangular form in side elevation with a

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length greater than its height, a height greater than its width, and, throughout the major portion of its extent, a width intermediate the maximum and minimum diameters of said sleeve at its front and rear ends respectively, a laterally enlarged portion in said housing in the front part thereof having a width sufficient to accommodate the front end of said sleeve, said attenuating line section being located close to the bottom wall of said housing with its axis substantially parallel thereto, a dielectric fluid substantially filling said housing and the space between said outer sleeve and inner conductor, said sleeve having longitudinal slot-like perforations in its top and bottom surfaces cooperating with the narrow width feature of said housing to promote convective circulation of fluid in the housing for effective removal of heat from said attenuating line section, said slots being disposed to provide a progressively greater open area in the upper surface of the sleeve towards the front end thereof whereby to achieve a rear front horizontal component of fluid flow through the sleeve for effective cooling of said inner conductor.

6. A coaxial line attenuator comprising an inner conductor and a tubular outer conductor surrounding the inner conductor in spaced coaxial relation as a resistive line section assembly, one of the conductors being resistive, one of the conductors being apertured for the circulation of liquid dielectric coolant through the space between the conductors, housing means for receiving the conductors and containing liquid dielectric coolant, a connector section for connecting said inner and outer conductors of the resistive assembly to the inner and outer conductors of a coaxial transmission line, said connector section comprising an inner conductor and an outer conductor coaxially arranged with respect to one another and to the resistive assembly, said connector section conductors being separated from one another by an annular dielectric space, means mounting both the resistive assembly and the connector section to the housing means to be supported by the latter in fixed predetermined rigid relation with the resistive assembly within and the connector section without such housing means, a dielectric partition separating the space between the conductors of the resistive assembly and the dielectric space of the connector section to exclude liquid dielectric coolant in the dielectric space of the resistive assembly from the dielectric space of the connector section, the outer conductor of the connector section including a branch coupling element comprising a tube of relatively high heat conductivity metal and a barrier element comprising a relatively thin sectioned tube of relatively low heat conductivity metal, the barrier element being outside the housing means and the partition and interposed between the outer conductor of the resistive assembly and the branch coupling element to minimize heat transfer therebetween and between the housing means and the branch coupling element, and the branch coupling element being formed with means to receive and support a pickup unit in coupled relation to the inner conductor of the connector section.

7. A coaxial line attenuator comprising an inner conductor and a tubular outer conductor surrounding the inner conductor in spaced coaxial relation as a resistive line section assembly, one of the conductors being resistive, one of the conductors being apertured for the circulation of liquid dielectric coolant through the space between the conductors, housing means for receiving the conductors and containing liquid dielectric coolant, said housing means comprising a wall formed with an opening through which the conductors are admitted in assembly, a connector section for connecting said inner and outer conductors of the resistive assembly to the inner and outer conductors of a coaxial transmission line, said connector section comprising an inner conductor and an outer conductor coaxially arranged with respect to one another and to the resistive assembly, said connector

section conductors being separated from one another by an annular dielectric space, means mounting both the resistive assembly and the connector section to the housing means to be supported by the latter in fixed predetermined rigid relation with the resistive assembly within and the connector section without such housing means, said mounting means being adapted for facile removal and replacement of the connector section and the resistive assembly as a unit relative to the housing means with the resistive assembly moving axially through the opening in said wall of the housing means during such removal and replacement, a dielectric partition separating the dielectric space of the connector section from the dielectric space of the resistive assembly and disposed across the wall opening of the housing means to prevent the escape of liquid dielectric coolant in the housing means through the dielectric space of the connector section, the outer conductor of the connector section including a branch coupling element comprising a tube of relatively high heat conductivity metal and a barrier element comprising a relatively thin sectioned tube of relatively low heat conductivity metal, the barrier element being outside the housing means and the partition and interposed between the outer conductor of the resistive assembly and the branch coupling element to minimize heat transfer therebetween and between the housing means and the branch coupling element, and the branch coupling element being formed with means to receive and support a pickup unit in coupled relation to the inner conductor of the connector section.

8. A coaxial line attenuator comprising an inner conductor and a tubular outer conductor surrounding the inner conductor in spaced coaxial relation as a resistive line section assembly, one of the conductors being resistive, one of the conductors being apertured for the circulation of liquid dielectric coolant through the space between the conductors, housing means for receiving the conductors and containing liquid dielectric coolant, said housing means comprising a wall formed with an opening through which the conductors are admitted in assembly, a connector section for connecting said inner and outer conductors of the resistive assembly to the inner and outer conductors of a coaxial transmission line, said connector section comprising an inner conductor and an outer conductor coaxially arranged with respect to one another and to the resistive assembly, said connector section conductors being separated from one another by an annular dielectric space, a dielectric partition separating the space between the conductors of the resistive assembly and the dielectric space of the connector section to exclude liquid dielectric coolant in the dielectric space of the resistive assembly from the dielectric space of the connector section, means mounting the resistive assembly and the connector section in end to end relation in the wall opening of the housing means with their axis substantially normal to the plane of such opening and with the partition disposed across such opening to prevent the escape of liquid dielectric coolant in the housing means through the dielectric space of the connector section, the resistive assembly and the connector section each being connected solely at one end to the mounting means and projecting as cantilevers in opposite directions from the wall of the housing means, the outer conductor of the connector section including a branch coupling element comprising a tube of relatively high heat conductivity metal and a barrier element comprising a relatively thin sectioned tube of relatively low heat conductivity metal, the barrier element being outside the housing means and the partition and interposed between the outer conductor of the resistive assembly and the branch coupling element to minimize heat transfer therebetween and between the housing means and the branch coupling element, and the branch coupling element being formed with means to receive and support a pickup unit in coupled relation to the inner conductor of the connector section.

9. A coaxial line attenuator comprising an inner conductor and a tubular outer conductor surrounding the inner conductor in spaced coaxial relation as a resistive line section assembly, one of the conductors being resistive, one of the conductors being apertured for the circulation of liquid dielectric coolant through the space between the conductors, housing means for receiving the conductors and containing liquid dielectric coolant, said housing means comprising a wall formed with an opening through which the conductors are admitted in assembly, a connector section for connecting said inner and outer conductors of the resistive assembly to the inner and outer conductors of a coaxial transmission line, said connector section comprising an inner conductor and an outer conductor coaxially arranged with respect to one another and to the resistive assembly, said connector section conductors being separated from one another by an annular dielectric space, a dielectric partition separating the space between the conductors of the resistive assembly and the dielectric space of the connector section to exclude liquid dielectric coolant in the dielectric space of the resistive assembly from the dielectric space of the connector section, a ring member, means securing the ring member to the wall of the housing means for facile removal and replacement, the ring member having a center opening registered with the wall opening, means securing one end of each of the outer conductors to the ring member with the resistive assembly and the connector section in end to end relation and extending in opposite directions from the plane of the center opening, a dielectric partition across the center opening and separating the dielectric space of the connector section from the dielectric space of the resistive assembly to prevent the escape of liquid dielectric coolant in the housing means through the dielectric space of the connector section, the outer conductor of the connector section including a branch coupling element comprising a tube of relatively high heat conductivity metal and a barrier element comprising a relatively thin sectioned tube of relatively low heat conductivity metal, the barrier element being outside the housing means and the partition and interposed between the outer conductor of the resistive assembly and the branch coupling element to minimize heat transfer therebetween and between the housing means and the branch coupling element, and the branch coupling element being formed with means to receive and support a pickup unit in coupled relation to the inner conductor of the connector section.

10. A coaxial line attenuator comprising an elongated inner resistive conductor and a tapered outer conductor surrounding the resistive conductor in spaced relation, one end of the resistive conductor being electrically connected to the small end of the outer conductor, the outer conductor being apertured for the circulation of liquid dielectric coolant through the space between the conductors, housing means for receiving the conductors and containing liquid dielectric coolant, a body of such coolant in the housing and immersing the conductors, said housing means being formed to define a wide chamber portion at one of its ends and a narrow chamber portion at the other of its ends, said wide chamber portion being of less length than the resistive conductor, said housing means including an upright wall, means secured to the large end of the outer conductor mounting the conductors on said wall and constituting the sole supporting connection between the housing means and the conductors, said conductors extending horizontally from said wall through the wide chamber portion and into the narrow chamber portion, said narrow chamber portion being of less width than the large end of the outer conductor, and the housing means being formed to define a coolant path continuous with the wide chamber portion at a point above the conductors and adjacent the large end of the outer conductor, continuous with the narrow chamber portion at a point spaced beyond the small end of the outer conductor,

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and throughout its length between said points of less width than the wide chamber portion.

11. In combination in a high frequency electrical coaxial transmission line system, a termination in the form of a heat dissipating line section having inner and outer conductors disposed in coaxial relation, a coupling in the form of a line section having inner and outer conductors disposed in coaxial relation, the outer conductor of the coupling line section comprising a relatively thick sectioned tube of one electrically conductive material and a relatively thin sectioned tube of another electrically conductive material disposed in end to end coaxial relation, said thin tube being of metal of low heat conductivity relative to the electrically conductive material of the thick tube and being interposed and electrically connected between the thick tube and the outer conductor of the termination line section to constitute a barrier to the conduction of heat axially along the coupling line section.

12. The combination claimed in claim 11 in which the thin sectioned tube is of stainless steel of the type comprising an alloy of iron with chromium and nickel.

13. In a high frequency electrical attenuator, housing means containing a body of liquid dielectric coolant and, supported by the housing means and immersed in the liquid coolant, a coaxial line comprising an elongated inner resistive conductor and a tubular outer conductor surrounding and concentric to the resistive conductor and separated therefrom by an annular dielectric space; the tubular conductor being apertured for the circulation of the liquid dielectric coolant through the annular space by thermosiphon action and being tapered between a portion of relatively large cross sectional area and, spaced axially from the latter, a portion of relatively small cross sectional area; the housing including a relatively wide portion receiving the relatively large portion of the tubular conductor and a relatively narrow portion receiving the relatively small portion of the said tubular conductor, the wide and narrow housing portions defining chambers of different widths continuous with one another for the circulation therethrough of the liquid coolant by thermosiphon action, the large portion of the outer conductor having a transverse dimension greater than the corresponding dimension of the narrow chamber, the line extending through the wide chamber and into the narrow chamber with the large portion of the tubular conductor

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disposed in the wide chamber, and the narrow chamber being generally longer axially of the line and taller transversely of the line than the wide chamber.

14. In a high frequency electrical attenuator, housing means containing a body of liquid dielectric coolant and, supported by the housing means and immersed in the liquid coolant, a coaxial line comprising an elongated inner resistive conductor and a tubular outer conductor surrounding and concentric to the resistive conductor and separated therefrom by an annular dielectric space; the tubular conductor being apertured for the circulation of the liquid dielectric coolant through the annular space by thermosiphon action and being tapered between a portion of relatively large cross sectional area and, spaced axially from the latter, a portion of relatively small cross sectional area; the housing including a relatively wide portion receiving the relatively large portion of the tubular conductor and a relatively narrow portion receiving the relatively small portion of the said tubular conductor, the wide and narrow housing portions defining chambers of different widths continuous with one another for the circulation therethrough of the liquid coolant by thermosiphon action, and said chamber of the narrow housing portion being continuous with the chamber of the wide housing portion along the major part of the length of such wide portion parallel to the axis of the line and also across one end of the wide portion along a line transverse to such axis in the provision of a closed path for the cyclic convective flow of coolant through the chambers and the dielectric space of the line.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,958,830

November 1, 1960

James R. Bird et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, line 70, for "attachment" read -- attendant --; column 12, line 19, after "rear" insert -- to --; line 32, for "conductorss" read -- conductors --; column 13, line 47, for "sepaarted" read -- separated --; column 14, line 71, for "coalant" read -- coolant --.

Signed and sealed this 31st day of December 1963.

(SEAL)

Attest:

ERNEST W. SWIDER

EDWIN L. REYNOLDS

Attesting Officer

Acting Commissioner of Patents

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