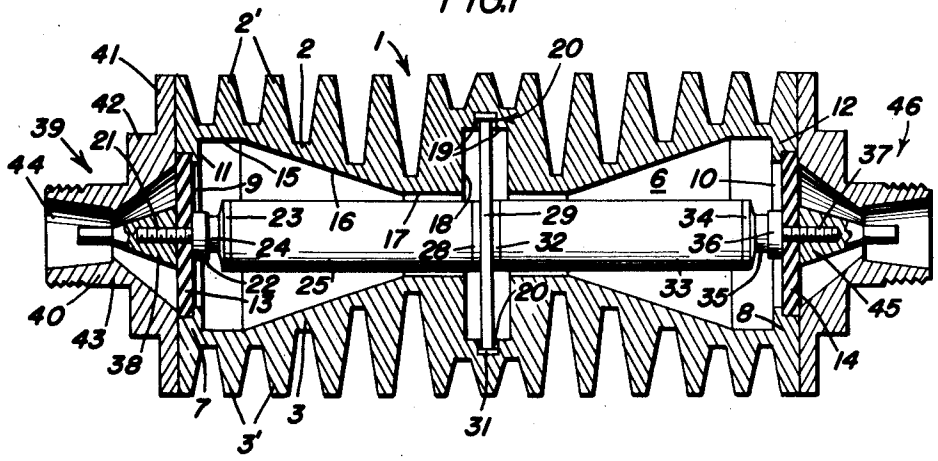
June 28, 1960 E. A. DORSETT 2,943,283

DOUBLE-GROUND PLANE ATTENUATOR

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FIG. 1



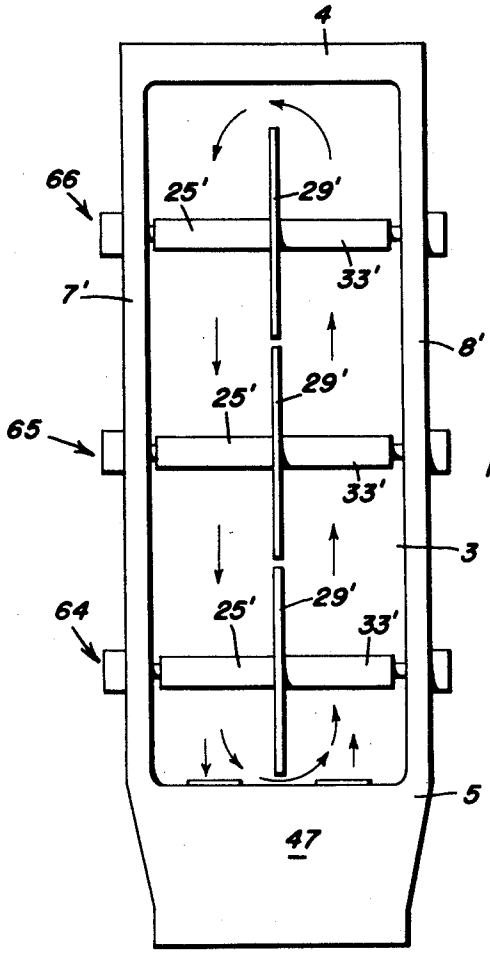


FIG. 3

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June 28, 1960 E. A. DORSETT 2,943,283

DOUBLE-GROUND PLANE ATTENUATOR

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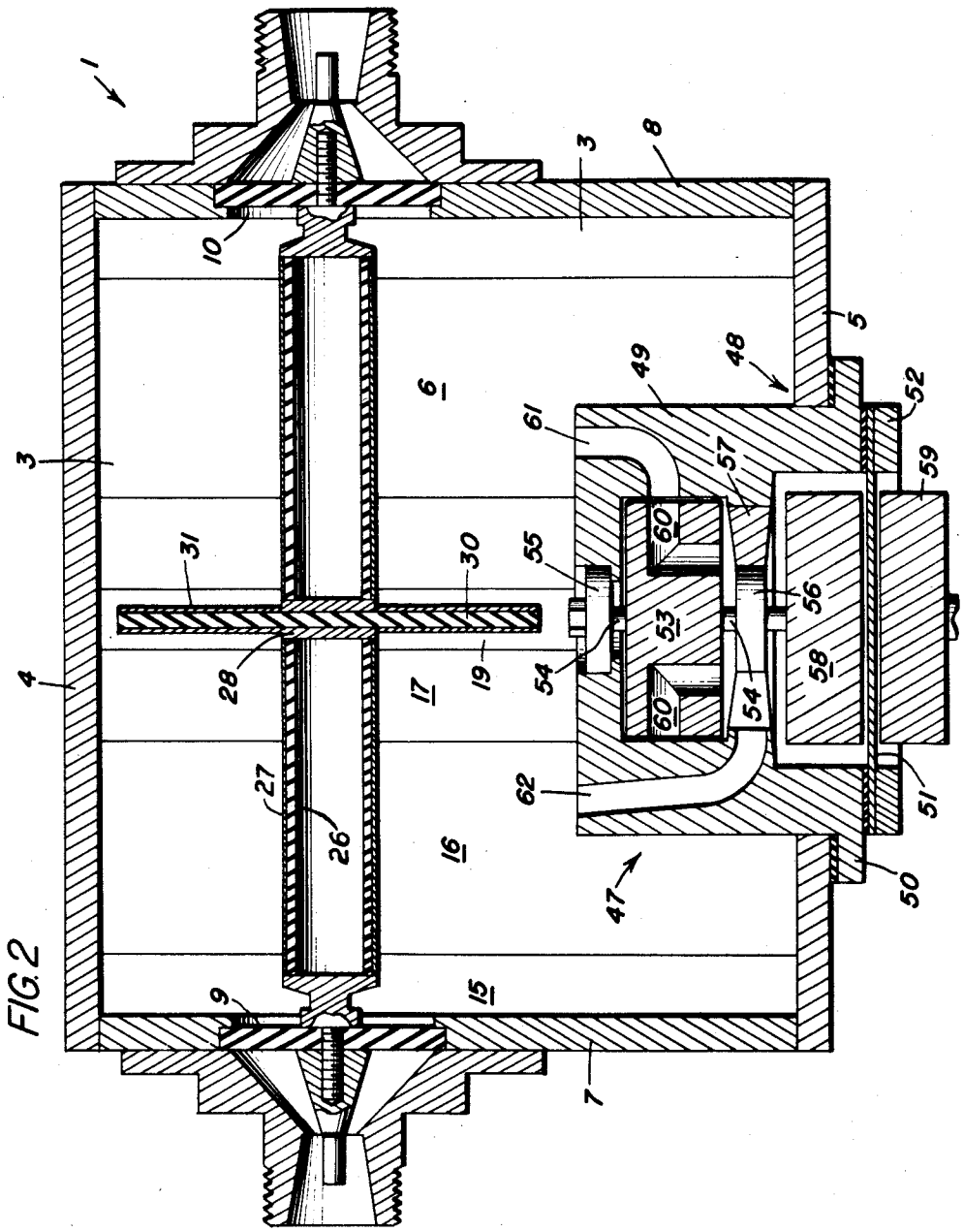


FIG 2

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United States Patent Office 2,943,283 Patented June 28, 1960

2,943,283

DOUBLE-GROUND PLANE ATTENUATOR

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Filed June 10, 1957, Ser. No. 664,815

8 Claims. (Cl. 333—81)

The present invention relates to liquid-cooled attenuators of high frequency electrical energy and more particularly to a liquid-cooled, double-ground-plane transmission line attenuator for employment with coaxial cables.

An attenuator of electrical energy employed to dissipate appreciable power must utilize resistive elements that are either large in size or, if small, are cooled by artificial means such as forced air or forced liquid flow. In order to build a practical attenuator the resistive elements thereof must be considered as lumped constant elements rather than as distributed parameter elements, which requires that the resistive elements be physically small compared to the wave length of the operating frequency of the system in which the attenuator is employed.

The present invention is concerned with an attenuator of considerable power handling capability to be employed in systems operating in the R.F. range of frequencies, which are normally transmitted via coaxial cables. At the frequencies involved the resistive dissipative elements of the attenuator must be relatively small to be considered as lumped constants and since the invention is concerned with dissipation of considerable amounts of power, artificial cooling of the resistive elements is mandatory.

The prior art attenuators for utilization at radio frequencies comprises a coaxial cable having a resistive center conductor cooled by a moving liquid dielectric, such as oil, which conveyed the heat of the center conductor to the outer conductor and through the outer conductor to the surrounding air. Considerable difficulty is encountered in obtaining a flow of coolant through a coaxial cable that is adequate to achieve the desired cooling of the centered conductor. Further the means for effecting movement of the coolant must be disposed externally of the cable and therefore entry and exit connection for the coolant must be made in the outer conductor of the coaxial cable which produces undesired alterations in the electrical transmission characteristics of the cable.

In accordance with the present invention a double-ground-plane transmission line having resistive elements is employed as an attenuator for R.F. energy. A double-ground-plane transmission line comprises two wide parallel conductors having a center conductor disposed therebetween. The width of the center conductor is sufficiently small, compared to the width of the two parallel conductors, that the parallel conductors appear infinite and R.F. leakage at the open edges of the line is minimized. Since the sides of a double-ground-plane line may be open, a cooling liquid may be freely circulated over the resistive elements and the circulating equipment may be positioned externally of the walls of the line so as to have no effect upon the transmission properties of the line. The parallel planes of a double-ground-plane line are both grounded and may be connected together both electrically and physically by conductive walls parallel to the center conductor, so long as the walls are displaced

from the center conductor by the distance required to make the ground planes appear infinite at the operating frequencies. If these requirements are met the side walls lie outside of the region of influence of the R.F. field and do not appreciably effect the transmission characteristic of the line.

In accordance with one embodiment of the attenuator of the present invention, the ground planes of a double-ground-plane line comprise a first pair of opposed side walls of an enclosure and the walls interconnecting the ground planes comprise a second pair of opposed side walls of an enclosure. The enclosure has a pair of end walls each having a coaxial cable connector centrally located therein. Connected between the center conductors of the two connectors is a cylindrical resistive element shunted at its longitudinal center to the ground planes through a further resistive element. The resistive elements comprise a "T-pad" attenuator for dissipating energy applied to the double-ground-plane line. The enclosure is filled with dielectric oil or other suitable insulating liquid and is circulated by means of a pump disposed wholly within the enclosure and secured to one of the side walls of the second pair of side walls, that is, the walls interconnecting the ground planes. The ground planes may be made sufficiently wide that the projection of the pump into the enclosure is not so great that the pump extends into a region where it can affect the R.F. field of the line. The pump must be quite small so as not to extend too far into the enclosure and also so that it can be placed in the space between the ground planes, the height of this space being dictated by the transmission characteristics of the line. In order to meet the dimensional requirements, the capacity of the pump is limited and a by-pass is provided around the pump so the pump need only establish a small rapid flow of liquid which will induce flow of the major portion of the liquid through the enclosure, including the by-pass around the pump.

In a second embodiment of the invention, several attenuators are disposed in a single housing and are cooled by liquid circulation established by a single pump. The characteristic of double-ground-plane lines which permit the pump to be disposed in the enclosure in the first embodiment of the invention also permit several lines to be appropriately located in a single housing without appreciable interaction between the various lines.

It is an object of the present invention to employ a liquid-cooled, double-ground-plane transmission line attenuator at radio frequencies.

It is another object of the present invention to connect a double-ground-plane line attenuator in a coaxial cable for attenuation of R.F. energy.

It is yet another object of the present invention to provide a liquid-cooled, double-ground-plane line attenuator employing resistive elements arranged as a "T-pad."

It is still another object of the present invention to provide a double-ground-plane attenuator for connection in a coaxial line, wherein a pump is sealed within the attenuator for circulating a cooling liquid to dissipate heat generated therein.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a cross-sectional view of the side elevation of the attenuator of the present invention;

Figure 2 is a cross-sectional view taken perpendicular to the plane of Figure 1; and

Figure 3 is a schematic showing of a multiple attenuator unit.

Referring now more particularly to Figures 1 and 2

of the accompanying drawings the double-ground-plane line attenuator of the present invention includes a housing generally designated by the reference numeral **1** having a first pair of opposed side walls **2** and **3** and a second pair of opposed side walls **4** and **5** perpendicular to the walls **2** and **3**, the walls **2—5** defining a cavity **6** having a rectangular transverse cross-section. The housing **1** further includes a pair of end walls **7** and **8** perpendicular to and integral with the side walls **2** and **3**. The end walls **7** and **8** are provided with aligned circular apertures **9** and **10**, respectively, which are positioned centrally of the end walls **7** and **8** in the vertical dimension as viewed in Figure 1 and are positioned somewhat closer to the side wall **4** than the side wall **5** as viewed in Figure 2 of the accompanying drawing.

The aperture **9** in end wall **7** has a region of reduced diameter adjacent the inner surface of the wall **7** to provide a peripheral flange **11**, while the aperture **10** has a region of reduced diameter adjacent the inner surface of the wall **8** to provide a peripheral flange **12**. Circular discs **13** and **14** of dielectric material are disposed respectively in the apertures **9** and **10**, the inner surfaces of the discs **13** and **14** being seated against the flanges **11** and **12**, respectively, and the outer surfaces being flush with the outer surfaces of the walls **7** and **8**, respectively. The discs **13** and **14** function as dielectric windows which permit the passage of R.F. energy therethrough into and out of the housing **1**.

The inner surfaces of the side walls **2** and **3** are mirror images of one another about a horizontal center plane passing through the centers of the discs **13** and **14** while the two halves of the inner surface of the side wall **2** between end walls **7** and **8** are mirror images of one another as viewed in Figure 1 of the accompanying drawings. The surface configuration of the left hand half of the inner surface of the side wall **2** is now described which for the reasons set forth immediately above completely defines the shape of the inner surfaces of the walls **2** and **3**. The inner surface of the left hand half of the wall **2** extends inwardly from the flange **11** for a short distance to define a horizontal surface **15** which terminates in a flat surface **16** sloping toward the center of the enclosure **1** at a constant angle. The surface **16** terminates in a flat surface **17** which extends to within a short distance of the longitudinal center of the housing **1**. The surface **17** intersects a vertical surface **18** which extends upwardly for a vertical distance approximately equal to the length of the vertical projection of the surface **16**. The surface **18** terminates in a horizontal surface **19** which extends an equal distance on either side of the horizontal center of the housing **1**. The surface **19** is provided with a rectangular groove **20** for purposes to be described subsequently. The walls **2** and **3** therefore provide a cavity **6** which is a constant height for a short distance inwardly of the end walls **7** and **8** and then decreases uniformly in height as the longitudinal center of the housing **1** is approached. Regions of constant height are again provided between the surfaces **17**, and a central portion of greatly increased height is provided by the surfaces **18** and **19** and extends equal distances on both sides of the longitudinal center of the housing **1**.

Proceeding with the description of the attenuator, conductive screw **21** extends through the dielectric disc **13** and is connected to a conductive circular disc **22** having one surface abutting the inner surface of the dielectric disc **13**. The disc **22** is connected to a conductive circular disc **23** through a conductive solid cylinder **24**. The disc **23** abuts an open end of a hollow resistive element **25** having a diameter which is small compared to the width of the side walls **2** and **3**. As viewed in Figure 2 of the accompanying drawings the elements **25** consist of a hollow glass cylinder **26** having a resistive coating **27** disposed on its outer periphery and on its ends. The other end of the resistive element **26** abuts a conductive disc **28**, the diameters of the discs **23** and **28** being equal to the diameter of the hollow cylindrical resistive element **26**. The conductive disc **28** contacts one surface of a vertical flat, rectangular resistive element **29** which consists of a glass plate **30** having a resistive coating **31** on its flat, vertical surfaces and on its upper and lower edges. The vertical dimension of the element **29** is such that it extends into the grooves **20** in the side walls **2** and **3** and contacts the bottom of the grooves **20** to provide an electrical contact between the resistive coating **31** and the walls **2** and **3**. The horizontal dimension of the resistive element **29** is determined, in conjunction with the resistivity of the coating **31**, by the desired resistance of the element and the heat dissipating surface area required. The only specific limitation on the horizontal width of the element **29** is that it must not contact the walls **4** and **5** so that cooling medium may be freely circulated in the housing **1**.

The right side of the element **29** is contacted by a conductive disc **32** which abuts one end of a hollow resistive element **33**, the other end of which is connected through conductive disc **34**, conductive cylinder **35** and conductive disc **36** to a conductive screw **37** that extends through the center of the dielectric disc **24**. The elements **32**, **33**, **34**, **35**, **36** and **37** are identical to the elements **21**, **22**, **24**, **23**, **25**, and **26**, respectively, and all of these elements are coaxial with an axis passing through the centers of the dielectric discs **13** and **14**, this axis also passing through the center of the resistive element **29**. The cavity **6** defined by the walls **2—8** of the housing **1** is adapted to be filled with a dielectric liquid such as oil which is circulated within the housing, by means to be described subsequently, in order to convey heat generated in the resistive elements **25**, **29** and **33** to the metallic walls **2—8**. The walls **2** and **3** are provided with a plurality of cooling fins **2'** and **3'**, respectively, on their external surfaces in order to facilitate dissipation of the heat in the surrounding air. Although only the walls **2** and **3** are illustrated as having cooling fins it is to be understood that all or any of the walls of the housing **1** may be provided with such members.

The portion of the screw **21** which extends through the dielectric disc **13** threadedly engages a center conductor **38** of a coaxial cable connector **39**. The central conductor **38** has a truncated conical portion, the base of which has the same diameter as the elements **25** and **33** and is seated against the dielectric disc **13** and the top of which terminates in a cylindrical portion of such a diameter as to be receivable in the female center conductor of a mating coaxial line connector. An outer conductor **40** of the connector **39** comprises a circular base plate **41** which seats against the end wall **7** of the housing **1** and may be suitably secured thereto as by bolts, not illustrated. Extending horizontally from the plate **41** is a circular portion **42** which terminates in a centrally-disposed, externally-threaded, cylindrical member **43** which may be engaged by an internally threaded member of a co-operating coaxial cable connector, not illustrated. The outer conductor **40** is provided with a central aperture **44** which tapers gradually inwardly from the left hand extremity of the connector to a region adjacent the intersection of the conical and cylindrical portions, of the inner conductor **38** and thereafter increases in diameter to the internal diameter of the flange **11** in the end wall **7**. The screw **37** which passes through the dielectric disc **14** in the end wall **8** of the housing **1** engages a central conductor **45** of a coaxial connector **46** which is substantially identical to the connector **39**.

The resistive elements **25** and **33** and the side walls **2** and **3** of the housing **1** constitute a double-ground-plane transmission line wherein the diameters of the elements **25** and **33** are of such a small size with respect to the width of the side walls **2** and **3** that the ground planes constituted by the side walls **2** and **3** appear infinite so

far as an R.F. field is concerned and leakage of energy is minimized.

Attenuation of the signals applied to the attenuator of the present invention is accomplished by a "T-pad" section comprising the cylindrical resistive elements **25** and **33** and the flat plate resistive element **29**, the elements **25** and **33** constituting the cross arm of the "T-pad" and the element **29** constituting the grounded leg thereof. In operation, R.F. energy applied to one of the connectors **39** or **46** and abstracted from the other connector is attenuated by the series resistance of the resistive elements **25** and **33** and by the shunt resistance path to ground through the element **29**.

In order to avoid discontinuities in the transmission paths from a coaxial cable to the attenuator and from the attenuator to a coaxial cable, the inner and outer diameters of the conductors of the coaxial cable must be matched to the spacing between the walls **2** and **3** and the diameter of the resistive elements **25** and **33**, respectively. Further, the resistance of the double-ground-plane line must be matched to the characteristic impedance of the coaxial lines and the effects of discontinuities resulting from the passing from an air to a liquid dielectric must be minimized. The conical portion of the center conductors **38** and **45** of the connectors **39** and **46** provide a constant impedance taper which matches the diameter of the coaxial lines to the double-ground-plane line. The taper of the internal apertures of the connectors **39** and **46** serve to match the internal diameters of the outer conductors of the coaxial cables to the spacing between the walls **2** and **3** of the attenuator and the impedance of the attenuator is matched to the characteristic impedance of the coaxial cable by means of a linearly tapering impedance transform provided by the sloping inner surfaces **16** of the side walls **2** and **3**. In addition, the effects of the discontinuities resulting in passing from an air to a liquid dielectric are minimized by undercutting the center conductor of the double-ground-plane line, the appropriate undercuts being effected by selecting elements **22** and **24** and **35** and **36** having appropriate diameters with respect to one another and with respect to the elements **25** and **33**. Although specific arrangements are illustrated and described for minimizing discontinuities in the transmission paths between the attenuator and associated coaxial lines it is not intended to limit the invention thereto since other well-known techniques may be employed.

The present invention is primarily concerned with providing effective cooling of the electrical energy dissipating elements **25**, **29** and **33** of the attenuator so that relatively small resistive elements may be employed to dissipate an appreciable amount of power. It is necessary that the resistive elements be maintained small with respect to the wave length of the operating frequency so that they may be considered as lumped constants and since the attenuator of the present invention is to be employed primarily at R.F. and higher frequencies, the resistive elements are physically small.

As previously indicated, the housing **1** is filled with oil which is to be circulated within the housing in order to conduct heat from the elements **25**, **29** and **33** to the side walls **2**—**8** of the housing **1**. The oil in the housing **1** is circulated by means of a centrifugal pump **47** secured in a circular aperture **48** in the side wall **5** and disposed wholly within the housing **1**. The pump **47** is disposed a considerable distance from the elements **25** and **33** compared to their diameters and consequently lies in a region of low field intensity so that the conductive and magnetic properties of the pump elements have substantially no effect upon the R.F. characteristics of the line.

The pump **47** is completely sealed within the housing **1** and comprises a hollow cylindrical housing **49** seated in the aperture **48** in side wall **5**. The pump housing **49** includes a peripheral flange **50** adapted to be bolted to the external surface of wall **5** to secure the pump **47** to the wall **5** and seal the opening **48**. The lower end of the hollow pump housing **49** as viewed in Figure 2 is closed by a thin metallic diaphragm **51** clamped to the lower surface of the flange **50** by means of an annulus **52**. In consequence, the pump **47** is completely sealed within the housing **1** and no driving connection is provided through the walls thereof. Disposed within the hollow housing **47** is a centrifugal impeller **53** mounted on a shaft **54** journaled in bearings **55** and **56**. The bearing **55** seals the upper end of the pump housing **47** while the bearing **56** is supported on a spider, only one spoke of which, designated by the reference numeral **57**, is illustrated in Figure 2. Mounted on the shaft **54** adjacent the diaphragm **51** is a permanent magnet **58**, preferably having four poles, which cooperates with a power driven permanent magnet **59** disposed externally of the diaphragm **51** to rotate the centrifugal impeller **53**. The impeller **53** is provided with a plurality of passages **60**, each having one end permanently communicating with the central aperture of the pump housing **49** and the other ends selectively and successively registering, upon rotation of the impeller **53**, with one end of a passage **61** in housing **49**, the other end of passage **61** communicating with the cavity **6** of housing **1**. A second passage **62** in the pump housing **49** extends between the cavity **6** in the housing **1** and the central aperture in the pump housing **49**, the passages **61** and **62** being disposed on opposite sides of the plane of the resistive element **29**. It is immediately apparent from the drawings that the pump **47** must be quite small to fit into the housing **1** and to fit into the housing **1** without extending too close to the elements **25** and **33**, and consequently the capacity of the pump **47** is of necessity small compared to the quantity of oil required to fill the housing **1**. To be able to move the oil in sufficient quantity and at a high enough rate to effect appreciable cooling of the resistive elements **25**, **29** and **33** an oil by-pass is provided between the end of the element **29** and the pump housing **49** so that the pump **47** merely serves to jet the liquid into motion, the body of the liquid moving between element **29** and housing **49**. Since the element **29** extends between the side walls **2** and **3** the oil flows in a counter-clockwise path around the element **30** and over the resistive elements **25** and **33**. A small portion of the liquid is drawn into the passage **62** and expelled from the passage **61** so as to initiate and maintain movement of the liquid.

The concept of employing the pump merely to jet the main body of liquid into motion permits the use of a pump which may be quite small and therefore may be located wholly within a double-ground-plane line of practical size without interfering with the field patterns of the double-ground-plane line. The ability to seal the pump **47** within the housing **1**, eliminates the problems normally encountered in providing oil or other liquid seals about rotating shafts. The pump **47** illustrated in Figure 2 is enlarged relative to its true size to illustrate more clearly its various parts.

It is apparent from the description that the present invention provides an attenuator element for utilization with coaxial transmission lines which element is capable of dissipating large amounts of electrical energy in consequence of the circulation of a cooling liquid over the energy dissipating elements. The concept of employing an attenuator comprising a double-ground-plane transmission line greatly simplifies circulation of a cooling medium over the dissipative elements and eliminates the problems normally encountered in cooled coaxial attenuators resulting from disturbance of the field pattern by the liquid entry and exit means. Although the apparatus of the present invention is illustrated and described as a completely sealed unit employing an internally located pump for circulating the cooling liquid, the side walls **4** and **5** may be provided with input and output connections to an externally located liquid circulation system since the principles of the double-ground-

plane line which permit the pump **47** to be located within the housing **1** without disturbing the R.F. field pattern also permit input and output connections to be disposed in the walls **4** and **5** wihout effecting the field pattern.

The embodiment of the invention illustrated in Figures 1 and 2 of the accompanying drawing provides only a single "T-pad" attenuator per housing which due to the fixed nature of the resistive elements **25**, **29** and **33** restricts the utilization of each apparatus to occasions where its specific characteristics are required. In order to extend the range of applicability of each apparatus, each housing is modified to include plural "T-pad" attenuator units cooled by liquid circulated by a single pump.

Refering now more particularly to Figure 3 of the accompanying drawings, wherein prime members designate elements corresponding to identical elements of Figures 1 and 2 having the same basic number, a housing **63** has end walls **7'** and **8'** and side walls **3'**, **4'** and **5'**, the fourth side wall not being illustrated. Three "T-pad" attenuator units **64**, **65** and **66** are arranged side-by-side between side walls **4'** and **5'**, each attenuator unit comprising resistive elements **25'**, **29'** and **33'**. A single pump **47'** is employed to circulate oil over the three units **64**, **65** and **66** and each of the units is designed to produce a different attenuation.

It is possible to locate plural double-ground-plane line attenuator units within a single housing so long as the spacing between the units is such that each unit lies outside of the limits of the R.F. field produced by its adjacent lines and vice versa. The characteristics of a double-ground-plane line which permits a pump to be disposed relatively close thereto also permits plural attenuator units to be disposed side-by-side without disturbing the electrical properties thereof. Although the apparatus is described as providing three units in a single housing, it is not intended to restrict the invention to any specific number.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the general arrangement and of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. A double-ground-plane-line attenuator adapted to be connected in series between two coaxial cables, said attenuator comprising an enclosure having a first pair and a second pair of opposed metallic side walls and a pair of end walls, at least one input terminal means disposed in one of said end walls and at least one output terminal means disposed in the other of said end walls, first resistive means connected in series between said terminal means, the relative widths of said side walls of said first pair of side walls and said first resistive means being such as to provide a double-ground-plane transmission line, second resistive means positioned at right angles to said first resistive means and said side walls and electrically connected between said first resistive means and the side walls of said first pair of side walls, said enclosure being filled with a dielectric fluid and means disposed substantially wholly within said enclosure for circulating said dielectric fluid, said last-mentioned means being disposed such that it does not affect the field pattern of said attentuator.

2. A double-ground-plane-line attenuator for insertion in a coaxial line, said attenuator comprising, an enclosure having a rectangular cross-section, said enclosure including a first pair and a second pair of opposed metallic side walls and a pair of opposed end walls, an input terminal means disposed in one of said end walls and an output terminal means disposed in the other of said end walls, first resistive means connected in series between said terminal means, the relative widths of said first resistive means and said side walls of said first pair of side walls being such as to provide a double-ground-plane transmission line, a flat rectangular resistive means disposed perpendicular to said side walls, means for electrically and physically connecting said rectangular resistive means between the longitudinal centers of said first resistive means and said side walls of said first pair of side walls, said enclosure being filled with a liquid dielectric and means disposed substantially wholly within said enclosure secured to at least one of said side walls of said second pair of walls for circulating said liquid dielectric, said last-mentioned means being disposed such that it does not effect the field pattern of said attenuator.

3. A double-ground-plane-line attenuator for insertion in a coaxial line, said attenuator comprising an enclosure having a rectangular transverse cross-sectional configuration, said enclosure including a first pair and a second pair of opposed side walls and a pair of opposed end walls, a flat rectangular resistive element disposed equidistant between said end walls and perpendicular to said side walls, said resistive element physically and electrically contacting said side walls of said first pair of side walls, an input terminal means adapted to be connected to a coaxial cable and disposed in one of said end walls, an output terminal means adapted to be connected to a coaxial cable and disposed in the other of said end walls, a first hollow cylindrical resistive element centered between said side walls of said first pair and extending between said input terminal means and said rectangular resistive element, a second hollow cylindrical resistive element centered between said side walls of said first pair and extending between said rectangular resistive element and said output terminal means, the diameter of said cylindrical elements being equal and being such with respect to the width of and spacing between said side walls of said first pair of side walls as to provide a double-ground-plane transmission line, said enclosure being filled with a liquid dielectric and a pump disposed within said enclosure and secured to at least one of said side walls of said second pair of side walls for circulating said liquid dielectric, the depth of penetration of said pump into said enclosure being sufficiently small relative to the characteristics of said transmission line as to be electrically isolated from said transmission line.

4. The combination in accordance with claim 3, wherein said terminal means include constant impedance taper means for matching the size of the central conductors of the coaxial cables to the size of the cylindrical resistive elements of said attenuator.

5. The combination in accordance with claim 3, further comprising means for matching the impedance of said rectangular resistive element to the impedance of a coaxial cable to which said attenuator is to be connected, said matching means including tapered inner surfaces of said side walls of said first pair of side walls.

6. The combination in accordance with claim 3, wherein said means for circulating comprises a pump located wholly within said enclosure, and permanent magnet means for coupling said pump to a source of rotary motion located externally of said enclosure.

7. The combination in accordance with claim 6, wherein said pump imparts a high velocity to a quantity of dielectric liquid which is small compared with the total quantity of liquid dielectric in said enclosure and means for locating said pump within said enclosure such that a liquid by-pass region is provided around said pump.

8. A double-ground-plane-line attenuator adapted to be inserted in a coaxial cable comprising an enclosure having a first pair and a second pair of opposed side walls and a pair of end walls, a plurality of input terminal means disposed in one of said end walls, a plurality of output terminal means disposed in the other of said end walls, each of said input terminal means lying along an axis parallel to said side walls and passing through a different one of said output terminal means, a plurality of

first resistive elements, each connected in series between aligned input and output terminal means, the relative widths of each of said first resistive means and said side walls of said first pair of side walls being such as to provide a plurality of electrically independent double-ground-plane transmission lines, a plurality of second resistive means disposed at right angles to said side walls and said first resistive means, each of said second resistive means being electrically connected between the longitudinal center of a different one of said first resistive means and the longitudinal centers of said side walls of said first pair of side walls, said enclosure being filled with a liquid dielectric and means disposed substantially wholly within said enclosure secured to one of said side walls of said second pair of side walls for circulating said liquid dielectric, said last-mentioned means being disposed such that it does not affect the field pattern of said attentuator.

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