Dec. 13, 1955 J. J. LUCAS 2,727,213

TIME-DELAY NETWORK

Filed Jan. 19, 1953

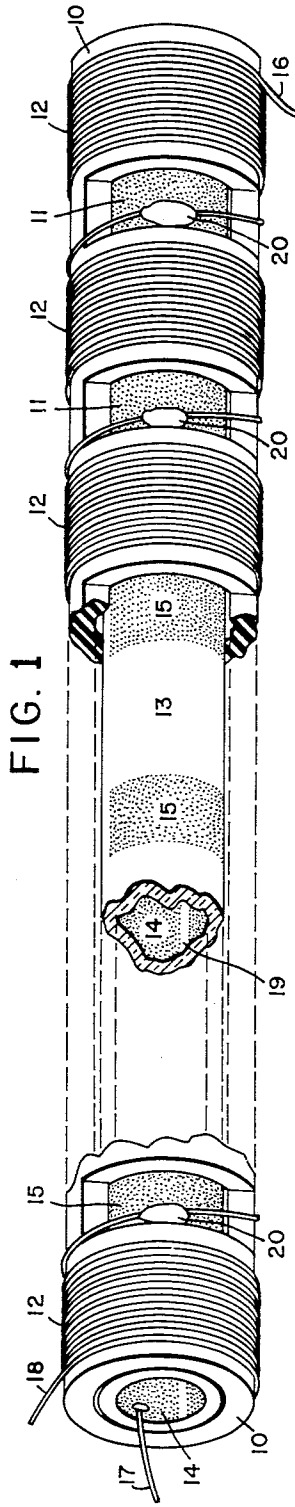


FIG. 1

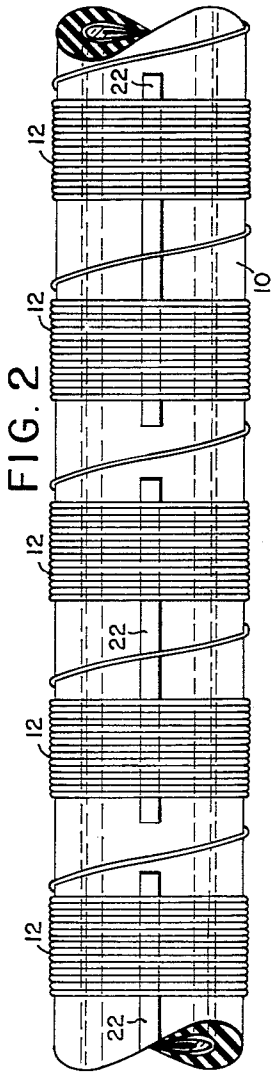


FIG. 2

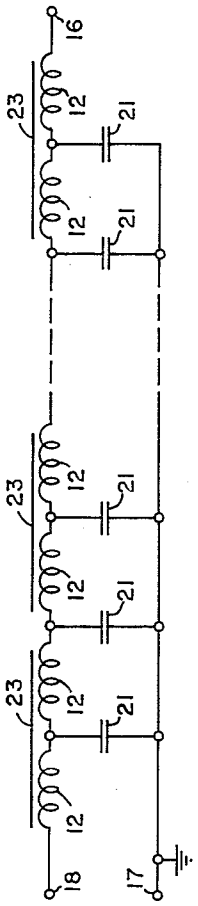


FIG. 3

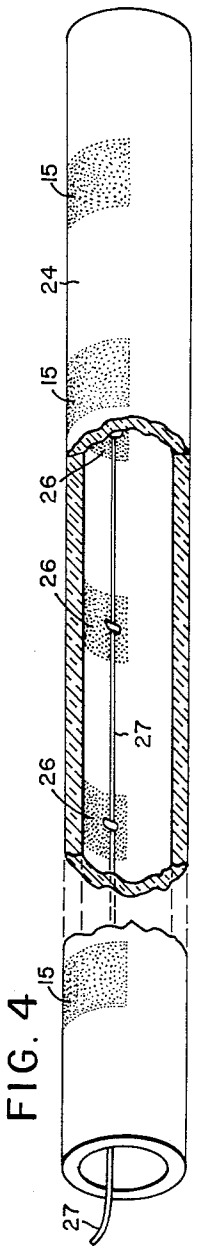


FIG. 4

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United States Patent Office 2,727,213
Patented Dec. 13, 1955

2,727,213

TIME-DELAY NETWORK

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Application January 19, 1953, Serial No. 331,848

11 Claims. (Cl. 333—29)

This invention is directed to the structure and method of making time-delay networks of the lumped-parameter type for translating signal components included within a predetermined range of frequencies.

Time-delay networks, as such, have long been known in the art and have taken the form of distributed- or lumped-parameter circuits. A well-known distributed-parameter delay network in accordance with the prior art comprises at least one distributed winding wound around a supporting, grounded core structure and an associated ground-return path. The capacitance between the winding and its core structure supplies the distributed capacitance of the network which, together with the inductance of the winding, determines the total time delay exhibited by the network. A time delay of any particular amount may be obtained by appropriately selecting the physical characteristics of the winding and its core structure. However, in order to provide such a prior art time-delay network which exhibits desirable electrical characteristics over an appreciable passband while still imparting a considerable time delay to an applied signal, it has been necessary to make the network relatively long and bulky. Moreover, it is difficult to compensate such a network in an attempt to improve or modify its electrical characteristics.

A lumped-parameter type time-delay network, on the other hand, due to its electrical and physical dimensions is relatively small as far as volume is concerned and exhibits excellent electrical characteristics in that it is capable of translating signal components included within a relatively wide range of frequencies (for example, 0–4.5 megacycles) with negligible attenuation at the higher frequencies while imparting an approximately equal time delay to all frequency components. It is also relatively easy to shape the response characteristic of such a network due to the fact that it has many dimensions that may be varied. However, in the construction of lumped-parameter delay networks in the past, it has been customary to employ a multiplicity of separate external condensers individually connected to an assigned junction of a corresponding multiplicity of series-connected winding sections. It will be appreciated that such a construction is relatively expensive and cumbersome and does not readily lend itself to economical mass production.

It is, accordingly, an object of the present invention to provide an improved time-delay network of the lumped-parameter type for translating signal components included within a predetermined range of frequencies that is simple and economical in construction.

It is another object of the invention to provide such an improved network that lends itself to mass production.

It is a further object of the invention to provide a novel method of constructing a lumped-parameter type of time-delay network.

In accordance with the invention, a lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprises an elongated coil form of insulating material which

has a series of apertures spaced from one another along the length of the coil form, dividing the form into an axially extending multiplicity of coil-supporting sections. The network includes a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of the sections of the coil form. An elongated core member of dielectric material is positioned within the coil form and has one set of surface portions exposed by the apertures thereof. The network further comprises at least one conductive surface on the core in spaced, opposed relation to the exposed portions; and conductive elements disposed in the apertures of the coil form, electrically connected to the winding intermediate successive sections thereof and mechanically connected to the exposed portions of the core to constitute, in conjunction with the conductive surface of the core, shunt-connected condensers for the network. Finally, the network has input and output connections extending from opposite ends of the winding.

The features of this invention which are believed to be new are set forth with particularity in the appended claims. The invention, however, together with further objects and advantages thereof, may best be understood by reference to the following description in conjunction with the accompanying drawings, in which:

Figure 1 is a schematic representation, partially cutaway, of a lumped-parameter time-delay network constructed in accordance with the present invention;

Figure 2 is another view of the embodiment shown in Figure 1;

Figure 3 is an equivalent circuit diagram of the network of Figures 1 and 2; and

Figure 4 discloses another embodiment of the core member of a delay line constructed in accordance with the invention.

Referring now more particularly to Figures 1–3, the time-delay network there represented is of the lumped-parameter type for translating signal components included within a predetermined range of frequencies. While the illustrated arrangement is of the three-terminal or unbalanced type, the invention is equally applicable to balanced networks. The network shown is in the form of a simulated transmission line and comprises an elongated hollow coil form **10**, which may be cylindrically shaped or have any desired configuration and preferably is constructed of insulating material, such as Bakelite. Coil form **10** has a series of apertures **11** disposed transversely of and equally spaced from one another along the length of the form, thereby dividing coil form **10** into an axially extending multiplicity of coil-supporting sections. The network also includes a distributed winding **12** which has a multiplicity of series-connected winding sections individually wound around and supported by a section of form **10**.

An elongated hollow core member **13** of a suitable dielectric material, such as ceramic, preferably having the same cross-sectional configuration as coil form **10** but having an external dimension less than the internal dimension of the coil form is concentrically positioned within the form. There is at least one conductive surface **14** within core **13** which may conveniently be formed by spraying the internal surface of the core with a silver firing mixture. This conductive surface is made discontinuous, as represented by the discontinuity **19** which may be a non-conductive strip; otherwise conductive surface **14** would have the effect of a shorted-turn secondary for winding **12**. Also, a series of silver patches **15** are fired on the external periphery of the core to provide conductive elements which are spaced along the core so as to be exposed through apertures **11** of coil form **10**.

Conductive elements **15** are electrically connected, by means of soldered connections **20**, to turns of winding

12 which extend diagonally across slots 11 of coil form 10 and which may be considered as inter-section winding turns inasmuch as they constitute the conductive connections extending between contiguous sections of the winding. With this arrangement, a series of shunt-connected condensers 21, as shown in Figure 3, are provided in the network, each condenser comprising a conductive element 15 as one electrode and conductive surface 14 as a common electrode with a dielectric layer (core member 13) interposed therebetween. An input connection 18 extends from one end of winding 12 and an output connection 16 extends from the other end. A common connection 17, which may be grounded, is soldered to the internal conductive surface 14 of core member 13 to complete both the input and output circuits of the delay network.

The capacitance of each condenser 21 is determined by the physical dimensions of each conductive element 15, and the thickness and dielectric constant of core 13. The self and mutual inductance of winding 12 is determined by the diameter of coil form 10, the size and type of conductor used in fabricating the winding, the number of turns per winding section and the distance between successive sections. The shunt capacitance, in conjunction with the inductance, determines the total time delay of the network which is so selected that a signal applied to input terminals 17, 18 is delayed for the desired duration before it appears at output terminals 16, 17. The selection of these parameters is also governed by the frequency-response characteristic desired; that is, the desired frequency range over which signal components must not be attenuated appreciably nor subjected to phase distortion.

While a lumped-parameter time-delay network constructed in the manner described may exhibit a linear phase shift characteristic over a limited frequency range, it has been found that by providing a capacitive coupling bridged across successive winding sections, the linear response may be extended further into the frequency spectrum. To this end, a further series of elongated conductive elements 22 are printed, fired or in any way mechanically affixed to coil form 10, on the obverse side to that which is slotted, before winding 12 is wound thereon. Each such element extends longitudinally of the form to span at least two successive winding-support sections of the coil form and, consequently, two continuous sections of winding 12. The insulation of the winding conductor serves as the dielectric, while the turns of the winding overlying elements 22 and the elements themselves serve as the condenser electrodes with the result that the winding sections spanned by elements 22 are capacitively intercoupled, as shown by condensers 23 in Figure 3.

In constructing the described network the several component parts thereof are individually fabricated. For example, coil form 10 is provided with cut-away portions or apertures 11 and printed conductive strips 22 while core member 13 is provided with silver-fired surfaces 14 and 15. The core is then inserted into the coil form and properly oriented so that the surfaces 15 thereof are aligned with and exposed through apertures 11. The core is then inserted into the coil form and properly oriented so that the surfaces 15 thereof are aligned with and exposed through apertures 11. The core is then securely fixed in position by any suitable binding technique such as cementing. Sectionalized winding 12 is subsequently wound around the core and coil form assembly with each section thereof supported by a section of the coil form and with inter-section winding turns extending diagonally across slots 11 and, therefore, across conductive elements 15. The inter-section turns are soldered to such surfaces 15 and a ground strap 17 is then soldered to the internal surface 14.

Preferably, a common electrode is employed for the shunt-connected condensers 21, being provided by one common conductive surface 14 as shown in Figure 1. However, the modified core member 24 of Figure 3 may also be utilized in the described network. In this modification a series of conductive surfaces 26 are mechanically affixed to the internal periphery of the core individually opposite a corresponding external conductive element 15. Internal conductive surfaces 26 are electrically joined together by means of a common connection 27 which serves the same function as conductor 17 of Figure 1.

While the invention is not limited to any specific circuit constant or physical dimensions, the following electrical and physical dimensions of the embodiment of Figure 1 are given as illustrative of a proven network having a linear phase shift characteristic and having only a 3 decibel attenuation over a pass-band from 0 to 4.5 megacycles while at the same time exhibiting a total time delay of 2.70 micro-seconds.

Type of material of coil form 10	Bakelite
Outside diameter of coil form 10	.368 inch
Inside diameter of coil form 10	.250 inch
Width of apertures 11	.125 inch
Arc of apertures 11	150°
Distance between centers of apertures 11	.377 inch
Type of conductor for winding 12	Celenamel No. 41 AWG
Number of turns per winding section	57
Total number of winding sections	78
Type of material of dielectric core member 13	Barium titanate ceramic of dielectric constant 80
Outside diameter of core member 13	.235 inch
Inside diameter of core member 13	.180 inch
Number of conductive elements 15	76
Type of conductive elements 15	Silver fired patches
Dimensions of conductive elements 15	.125×.375 inch
Type of conductive surface 14	Silver fired surface
Width of strip 19	.125 inch
Width of conductive element 22	.022 inch
Length of conductive element 22	.635 inch

The invention provides, therefore, an improved lumped-parameter time-delay network that is extremely simple and economical in construction and yet is effective to translate signal components included within a predetermined range of frequencies.

While particular embodiments have been shown and described, modifications may be made, and it is intended in the appended claims to cover all such modifications as may fall within the true spirit and scope of the invention.

I claim:

1. A lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated coil form of insulating material having a series of apertures spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated core member of dielectric material concentrically positioned within said coil form and exposed by said apertures of said

coil form; at least one conductive surface within said core; conductive elements disposed in said apertures of said coil form, electrically connected to said winding intermediate successive sections thereof and mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, shunt-connected condensers for said network; and input and output connections extending from opposite ends of said winding.

2. A lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated coil form of insulating material having a series of apertures disposed transversely of said coil form and spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated hollow core member of dielectric material concentrically positioned within said coil form and exposed by said apertures of said coil form; at least one elongated conductive surface within said core; conductive elements disposed in said apertures of said coil form, electrically connected to said winding intermediate successive sections thereof and mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, shunt-connected condensers for said network; and input and output connections extending from opposite ends of said winding.

3. A three-terminal lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated coil form of insulating material having a series of apertures disposed transversely of said coil form and spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated hollow core member of dielectric material concentrically positioned within said coil form and exposed by said apertures of said coil form; at least one elongated conductive surface on the internal periphery of said core; conductive elements disposed in said apertures of said coil form, electrically connected to said winding intermediate successive sections thereof and mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, shunt-connected condensers for said network; input and output connections extending from opposite ends of said winding; and a common connection extending from said internal conductive surface of said core.

4. A three-terminal lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated, cylindrically shaped coil form of insulating material having a series of apertures disposed transversely of said coil form and spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated, cylindrically shaped hollow core member of dielectric material having an outside diameter less than the inside diameter of said coil form concentrically positioned within said coil form and exposed by said apertures of said coil form; at least one elongated conductive surface on the internal periphery of said core; conductive elements disposed in said apertures of said coil form, electrically connected to said winding intermediate

successive sections thereof and mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, shunt-connected condensers for said network; input and output connections extending from opposite ends of said winding; and a common connection extending from said internal conductive surface of said core.

5. A three-terminal lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated, cylindrically shaped coil form of insulating material having a series of apertures disposed transversely of said coil form and spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated, cylindrically shaped hollow core member of dielectric material having an outside diameter less than the inside diameter of said coil form concentrically positioned within said coil form and exposed by said apertures of said coil form; a first series of conductive surfaces on the internal periphery of said core; a second series of conductive surfaces on the external periphery of said core disposed in said apertures of said coil form and individually disposed opposite an assigned one of said first series of conductive surfaces, electrically connected to said winding intermediate successive sections thereof and mechanically connected to the exposed portions of said core to constitute, in conjunction with said first series of conductive surfaces, a series of shunt-connected condensers for said network; input and output connections extending from opposite ends of said winding; and a common connection joining, and extending from, said first series of conductive surfaces of said core.

6. A three-terminal lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated coil form of insulating material having a series of apertures disposed transversely of said coil form and spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated hollow core member of dielectric material concentrically positioned within said coil form and exposed by said apertures of said coil form; at least one elongated conductive surface on the internal periphery of said core; conductive elements disposed in said apertures of said coil form, electrically connected to said winding intermediate successive sections thereof and mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, shunt-connected condensers for said network; additional conductive elements mechanically affixed to said coil form and longitudinally extending along the length of said coil form to span at least two successive winding sections, insulated from but capacitively coupled to said winding sections, to provide in said network a capacitive coupling between such spanned sections for shaping the frequency-phase characteristic of said network; input and output connections extending from opposite ends of said winding; and a common connection extending from said internal conductive surface of said core.

7. A three-terminal lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated, cylindrically shaped coil form of insulating material having a series of apertures disposed transversely of said coil form and spaced from one another along the

length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated, cylindrically shaped hollow core member of dielectric material having an outside diameter less than the inside diameter of said coil form concentrically positioned within said coil form and exposed by said apertures of said coil form; at least one elongated conductive surface on the internal periphery of said core; conductive elements disposed in said apertures of said coil form, electrically connected to said winding intermediate successive sections thereof and mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, shunt-connected condensers for said network; elongated conductive strips mechanically affixed to the external periphery of said coil form and longitudinally extending along the length of said coil form to span at least two successive winding sections, insulated from but capacitively coupled to said winding sections, to provide in said network a capacitive coupling between such spanned sections for shaping the frequency-phase characteristic of said network; input and output connections extending from opposite ends of said winding; and a common connection extending from said internal conductive surface of said core.

8. A three-terminal lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated, cylindrically shaped hollow coil form of insulating material having a series of rectangularly shaped apertures disposed transversely of said coil form and equally spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated, cylindrically shaped hollow core member of dielectric material having an outside diameter less than the inside diameter of said coil form concentrically positioned within said coil form and exposed by said apertures of said coil form; at least one elongated conductive surface mechanically affixed to the internal periphery of said core; a series of rectangularly shaped conductive elements disposed in said apertures of said coil form having substantially the same physical dimensions as said rectangularly shaped apertures, electrically connected to said winding intermediate successive sections thereof and mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, a series of shunt-connected condensers for said network; an elongated conductive strip mechanically affixed to the external periphery of said coil form and longitudinally extending along the length of said coil form to span at least two successive winding sections, insulated from but capacitively coupled to said winding sections, to provide in said network a capacitive coupling between such spanned sections for shaping the frequency-phase characteristic of said network; input and output connections extending from opposite ends of said winding; and a common connection extending from said internal conductive surface of said core.

9. A lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated coil form of insulating material having a series of apertures disposed transversely of said coil form and spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of winding sections individually wound around and supported by an assigned one of said sections of said coil form, said winding further having inter-section winding turns extending across said apertures of said coil form and connecting said winding sections in series relation; an elongated hollow core member of dielectric material concentrically positioned within said coil form and exposed by said apertures of said coil form; at least one elongated conductive surface within said core; conductive elements disposed in said apertures of said coil form, electrically connected to said inter-section turns and mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, shunt-connected condensers for said network; and input and output connections extending from opposite ends of said winding.

10. A lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated coil form of insulating material having a series of apertures disposed transversely of said coil form and spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of winding sections individually wound around and supported by an assigned one of said sections of said coil form, said winding further having inter-section winding turns extending across said apertures of said coil form and connecting said winding sections in series relation; an elongated hollow core member of dielectric material concentrically positioned within said coil form and exposed by said apertures of said coil form; at least one elongated conductive surface on the internal periphery of said core; conductive elements disposed in said apertures of said coil form, mechanically connected to the exposed portions of said core to constitute, in conjunction with the internal conductive surface of said core, a multiplicity of condensers for said network; conductive bonding connections connecting said inter-section turns to said conductive elements for connecting said condensers in shunt relation with said winding sections; input and output connections extending from opposite ends of said winding; and a common connection extending from said internal conductive surface of said core.

11. A lumped-parameter time-delay network for translating signal components included within a predetermined range of frequencies comprising: an elongated coil form of insulating material having a series of apertures spaced from one another along the length of said coil form dividing said coil form into an axially extending multiplicity of coil-supporting sections; a distributed winding having a multiplicity of series-connected winding sections individually wound around and supported by an assigned one of said sections of said coil form; an elongated core member of dielectric material positioned within said coil form and having one set of surface portions exposed by said apertures of said coil form; at least one conductive surface on said core in spaced, opposed relation to said exposed portions; conductive elements disposed in said apertures of said coil form, electrically connected to said winding intermediate successive sections thereof and mechanically connected to said exposed portions of said core to constitute, in conjunction with said conductive surface of said core, shunt-connected condensers for said network; and input and output connections extending from opposite ends of said winding.

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