June 3, 1958 R. MILLERSHIP 2,837,721

MEANS FOR DELAYING ELECTRIC IMPULSES

Filed Feb. 24, 1953

FIG. 1.

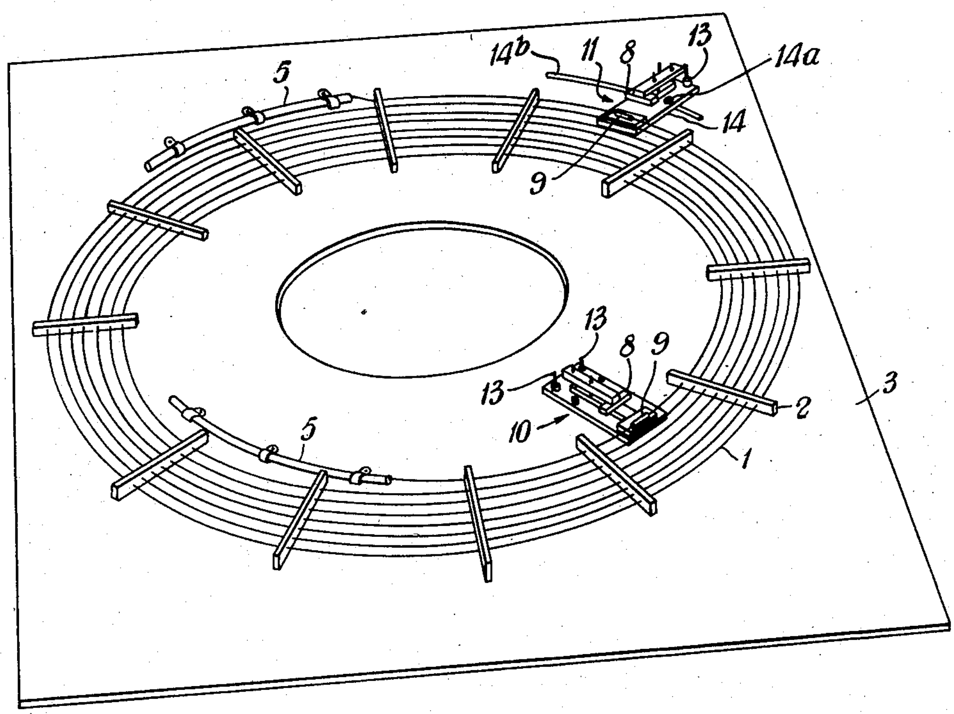


FIG. 2.

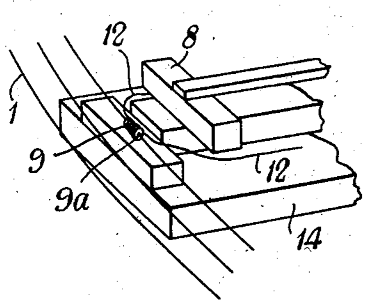


FIG. 3.

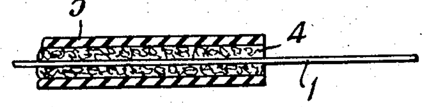


FIG. 4.

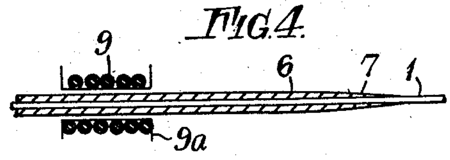


FIG. 5.

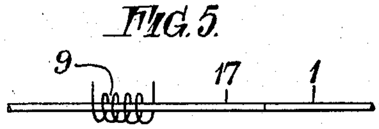


FIG. 6.

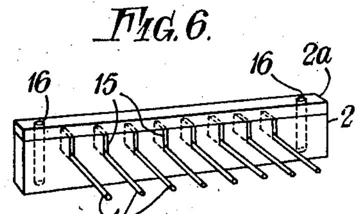
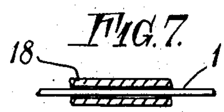


FIG. 7.



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United States Patent Office

2,837,721

Patented June 3, 1958

2,837,721

MEANS FOR DELAYING ELECTRIC IMPULSES

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Application February 24, 1953, Serial No. 338,530

Claims priority, application Great Britain February 22, 1952

9 Claims. (Cl. 333—30)

This invention relates to means for delaying electric impulses and is concerned more particularly with a so-called "delay line" of the character in which the period of delay is determined by the time required for the travel of an acoustic pulse from one end to the other of a length of solid material, the electric pulse which is to be delayed being supplied to means at one end of the length of material which will generate a corresponding acoustic pulse and means being disposed at the other end of the length of material which is capable of converting an acoustic pulse into an electric pulse.

It is known to construct such delay lines from a length of a magnetostrictive material, usually in the form of a wire, tape or tube, which is coupled electromagnetically at each end to means, such as a coil surrounding the material or an electromagnet, which, at the "transmitting" end, will cause a change in the magnetic induction within the material when its winding is supplied with an electric pulse and, at the "output" end, will yield an electric pulse across the ends of its winding when a change occurs in the magnetic induction in the material.

The change in the magnetic induction within the material at the transmitting end causes a change in the dimensions of the material, by virtue of its magnetostrictive properties, and an acoustic pulse is therefore launched towards the output end. Similarly, as an acoustic pulse passes along the portion of the material threaded through the output coil, the dimensions of this portion of the material will change and, by the reverse magnetostrictive effect, the magnetisation thereof will change also.

The time delay between the input and output electric pulses is determined both by the length of the path for the acoustic pulse between the transmitting and output ends of the delay line and by the velocity of the acoustic pulse, this velocity being mainly determined by the elasticity and density of the solid material through which it travels.

Such a delay line composed entirely of magnetostrictive material suffers from certain disadvantages. For example, the length of line required for any particular period of delay is determined by the properties of the magnetostrictive material and there is only a limited choice of materials which are suitably magnetostrictive. Furthermore, with most of these materials, a change in the ambient temperature produces a change in the time delay produced so that for many applications temperature control has to be employed.

The main object of the present invention is to provide an improved form of delay line of the character indicated above which, while making use of the properties of magnetostrictive materials, shall not be subject to the disadvantages mentioned.

According to this invention, a delay line is constituted by a main length of a solid material having good acoustic pulse transmission properties and two lengths of a different solid material having magnetostrictive properties and each intimately connected with the main length of material at or adjacent to one of the ends thereof for association with the respective transmitting or output device.

The lengths of magnetostrictive material may be attached to the main length of material, to constitute extensions thereof but it is preferred that they be constituted of thin films deposited on the main length of material at the appropriate positions.

The material constituting the main body of the delay line is chosen for its properties other than its magnetostrictive properties, for example, for its ability to conduct acoustic waves at a velocity which is substantially unaffected by temperature changes and for the specific velocity of propagation of sound therethrough.

It is also an important feature of this invention to construct the delay line from a length of material which is of very small cross-sectional area compared with its length and has sufficient flexibility to enable it to be coiled or arranged in a zig-zag fashion so that delay lines of very considerable length may be accommodated in a relatively small space.

With advantage the delay line is composed of a thin wire which may be disposed in a flat spiral or in a helix or in some cases in a zig-zag arrangement with parallel runs of the wire connected by curved portions of the wire. The wire is suitably supported on an appropriate backing or carrier of insulating material and may be retained in its desired shape by any suitable means. For example, the carrier may be formed with a groove to receive the wire and the mouth of the groove may be closed by a cover plate. The wire may, however, be disposed axially within a flexible sleeve of an insulating material which may be coiled or otherwise arranged as required and itself attached to a carrier element such as a plate or drum. In all cases the wire is supported so that it is not subjected to any constraint, it being loosely disposed within the groove or sleeve with considerable lateral play. Where it is required to ensure that there shall be no reflections of the acoustic pulses from the ends of the wire, the latter are embedded in a body of grease or other suitable substance. With advantage, this grease or the like may be arranged to fill the terminal portions of the groove or sleeve.

In order that the invention may be clearly understood some examples thereof will now be described with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of one example of a delay line system according to the invention;

Fig. 2 is an enlarged view of the transmitting device of Fig. 1, a similar device being used as the output device;

Fig. 3 is an enlarged fragmentary part-sectional view of one of the terminal portions of the delay line of Fig. 1;

Fig. 4 is an enlarged fragmentary part-sectional view showing a coating of magnetostrictive material applied to the main delay line in the region of the transmitting device, a similar coating being provided in the region of the output device;

Fig. 5 is an enlarged view showing a length of magnetostrictive material in the form of a wire intimately connected to one end of the main delay line in acoustic pulse transmitting relationship;

Fig. 6 is an enlarged view of the delay line supporting means shown in Fig. 1; and

Fig. 7 is an enlarged fragmentary part-sectional view showing the delay line extending axially within a sleeve which may be used to support the wire.

In the example illustrated in Fig. 1 the main portion of the delay line is constituted by a length of thin copper wire 1 wound in the form of a flat spiral supported at intervals along its length by supports 2 which will be described in greater detail hereafter with reference to Fig. 6. The wire 1 is approximately ten feet long and the supports 2 are mounted on a carrier or base plate 3 which in the present example is a square of side sixteen inches. Each end of the wire 1 is embedded in a body of grease 4 (Fig. 3) within a sleeve 5 secured to the base plate 3 so that any acoustic pulses reaching the ends of the wire 1 are absorbed by the grease 4 and no reflections occur. The wire 1 is coated or plated adjacent each end with a thin coating or film 6 (Fig. 4) of a magnetostrictive material such as nickel, the length of this coating being relatively short.

Each plated layer 6 is tapered at the ends as at 7 to avoid any acoustic pulse reflections which might occur if the plated layers or films 6 terminated abruptly. A polarising magnet 8 (Figs. 1 and 2) is associated with each plated layer 6 to produce a magnetic field of a predetermined magnitude around each layer 6. A coil 9 of insulated wire is wound on a former 9*a* of insulating material which surrounds each plated layer 6. The arrangement is such that the passage of an electric current pulse through the coil 9 will produce a corresponding change in the effective magnitude of the associated magnetic field with a consequent change in the length of the plated layer 6, or conversely any change in the length of the plated layer 6 will produce a corresponding change in the flux distribution of the coil 9 to induce a corresponding electric current pulse therein. In the present example one of the polarising magnets 8 and the associated coil 9 constitute a transmitting device indicated generally at 10 (Fig. 1) and the other polarising magnet 8 and the associated coil 9 constitute an output device indicated generally at 11, although it will be appreciated that the same result will be achieved by reversing the functions of the devices 10 and 11. Electric leads 12 (Fig. 2) connect the coil 9 to terminals 13 (Fig. 1) on a mounting 14 of the respective device 10 or 11, the terminals 13 being electrically connected in known manner to the apparatus with which the delay line is associated. The position of the output device 11 may be adjusted along the length of the wire 1 by means of holding screws 14*a* which extend through a slot 14*b* in the base plate 3 and which when tightened hold the device 11 in the selected position. This enables the delay period to be accurately adjusted.

Each support 2 comprises a block of insulating material having slots 15 (Fig. 6) cut in one face to loosely support the respective turns of the wire 1, the slots 15 being closed by a further block of material 2*a* secured to the main block 2 by bolts 16.

In the operation of the delay line an electric current pulse is passed through the coil 9 of the transmitting device 10 to produce a corresponding change in the effective magnitude of the magnetic field within which the associated plated layer 6 extends. This produces a change in the length of this layer 6 which change in length is propagated as an acoustic pulse through the wire 1 in both directions. The acoustic pulse propagated towards the adjacent one end of the wire immersed in the body of grease 4 is absorbed by the grease and the acoustic pulse propagated towards the other end of the wire 1, after producing a corresponding change in the length of the plated layer 6 associated with the output device 11, is absorbed by the second body of grease 4, within which this other end is immersed. This change of length produces a corresponding change in the effective magnitude of the associated magnetic field which change induces a corresponding electric current pulse in the coil 9 of the output device 11. As it takes more than one millisecond for the acoustic pulse to travel along the length of the wire 1 it will be seen that the electric current pulse supplied to the transmitting device 10 produces a corresponding electric current pulse in the output device 11 after an interval of time greater than one millisecond. It should be noted that with a wire 1 composed entirely of nickel the variation in the delay produced with changes in temperature would be too large for many applications and temperature control would have to be adopted and that the length of such a wire 1 would be of the order of sixteen feet for a corresponding delay. By the use of the present invention the need for temperature control may be avoided, in many cases, by utilising as the main body of the delay line a material in which the velocity of sound is substantially independent of temperature, such a material being, for example, that sold under the trademark "Nispan C." If a resonant section is required at either the transmitting or the output end of the wire 1, the tapering of the plated deposit 6 is not necessary and this deposit may be applied in such a way that it will be resonant at the desired frequency.

In an alternative arrangement, the main body of the delay line 1, instead of having plated ends, may have a piece of magnetostrictive material 17 (Fig. 5) attached to each end in order to constitute an extension thereof. For example, a short length of nickel wire may be brazed on to the end of a main wire 1 composed of copper or "Nispan C."

An alternative method of mounting the wire 1 is to dispose it axially within a flexible sleeve 18 (Fig. 7) of an insulating material which may be coiled helically or otherwise arranged as required and itself attached to a carrier element such as a plate or a drum. In all cases the wire 1 is supported so that it is not subjected to any constraint, it being loosely supported within the slots 15 of the supports 2 (Fig. 6) or within the sleeve 18 (Fig. 7).

What I claim is:

1. Means for delaying an electric pulse comprising in combination an aperiodic member in the form of a length of copper wire, a first coating of nickel surrounding and intimately bonded to said wire adjacent the one end thereof, the thickness of said coating being tapered each end of the length thereof, means surrounding said one end of said wire in acoustic pulse absorbing relationship, means for producing a first magnetic field of a predetermined magnitude around said first coating for at least a part of its length, a first coil of conductor wire surrounding said first coating in said first magnetic field to produce a change in the effective magnitude of the latter upon the passage of an electric current pulse through said first coil to produce a change in the length of said first coating, a second coating of nickel, the thickness of said coating being tapered towards each end of the length thereof, means surrounding said other end of said wire in acoustic pulse absorbing relationship, means for producing a second magnetic field of a predetermined magnitude around said second coating for at least a part of its length, and a second coil of conductor wire surrounding said second coating in said second magnetic field to produce an electric current pulse upon a change in the effective magnitude of said second magnetic field due to a change in the length of said second coating of material.

2. Means according to claim 1 wherein the means surrounding said one end of said wire in acoustic pulse absorbing relationship is a body of grease.

3. Means for delaying an electric pulse comprising in combination an aperiodic member in the form of a length of wire of a material having good acoustic pulse transmission qualities which are substantially constant over a wide range of ambient temperatures, a first coating of a material having magnetostrictive properties surrounding and intimately bonded to said wire adjacent the one end thereof, the thickness of said coating being tapered each end of the length thereof, means surrounding said one end of said wire in acoustic pulse absorbing relationship, means for producing a first magnetic field of a predetermined magnitude around said first coating for at least a part of its length, a first coil of conductor wire surrounding said first coating in said first magnetic field to produce a change in the effective magnitude of the latter upon the passage of an electric current pulse through said

first coil to produce a change in the length of said first coating, a second coating of a material having magnetostrictive properties surrounding and intimately bonded to said wire adjacent to the other end thereof, the thickness of said second coating being tapered towards each end of the length thereof, means surrounding said other end of said wire in acoustic pulse absorbing relationship, means for producing a second magnetic field of a predetermined magnitude around said second coating for at least a part of its length, and a second coil of conductor wire surrounding said second coating in said second magnetic field to produce an electric current pulse upon a change in the effective magnitude of said second magnetic field due to a change in the length of said second coating of material.

4. Means for delaying an electric pulse comprising in combination an aperiodic member in the form of a length of wire of a material having good acoustic pulse transmission qualities which are substantially constant over a wide range of ambient temperatures, a first coating of a material having magnetostrictive properties surrounding and intimately bonded to said wire adjacent the one end thereof, the thickness of said coating being tapered each end of the length thereof, a transmitting device associated with said first coating to produce a change in the length thereof upon the passage of an electric pulse through said transmitting device, a second coating of a material having magnetostrictive properties surrounding and intimately bonded to said wire adjacent to the other end thereof, the thickness of said second coating being tapered towards each end of the length thereof, an output device associated with said second coating to produce an electric pulse in said output device upon a change in the length of said second coating, and means surrounding the free ends of said wire in acoustic pulse absorbing relationship.

5. Means according to claim 4 wherein said wire is supported intermediate its length by at least one grooved carrier, the dimensions of the groove in the carrier being such as to support said wire with freedom to transmit acoustic pulses.

6. Means according to claim 4 wherein said wire is supported intermediate its length with a flexible sleeve.

7. Means for delaying an electric pulse comprising in combination an aperiodic member in the form of a length of wire of a material having good acoustic pulse transmission qualities which are substantially constant over a wide range of ambient temperatures, a flexible sleeve surrounding said wire intermediate the length thereof in non-acoustic pulse absorbing relationship to support said wire, a first coating of a material having magnetostrictive properties surrounding and intimately bonded to said wire adjacent the one end thereof, the thickness of said coating being tapered each end of the length thereof, a transmitting device associated with said first coating to produce a change in the length thereof upon the passage of an electric pulse through said transmitting device, a second coating of a material having magnetostrictive properties surrounding and intimately bonded to said wire adjacent to the other end thereof, the thickness of said second coating being tapered towards each end of the length thereof, an output device associated with said second coating to produce an electric pulse in said output device upon a change in the length of said second coating, and means surrounding the free ends of said wire in acoustic pulse absorbing relationship.

8. Means for delaying an electric pulse comprising in combination an aperiodic member in the form of a length of wire of a material having good acoustic pulse transmission qualities which are substantially constant over a wide range of ambient temperatures, at least one grooved carrier disposed intermediate the length of said wire with a part of the length of said wire freely received within the groove thereof with clearance, a first coating of a material having magnetostrictive properties surrounding and intimately bonded to said wire adjacent the one end thereof, the thickness of said coating being tapered each end of the length thereof, a transmitting device associated with said first coating to produce a change in the length thereof upon the passage of an electric pulse through said transmitting device, a second coating of a material having magnetostrictive properties surrounding and intimately bonded to said wire adjacent to the other end thereof, the thickness of said second coating being tapered towards each end of the length thereof, an output device associated with said second coating to produce an electric pulse in said output device upon a change in the length of said second coating, and means surrounding the free ends of said wire in acoustic pulse absorbing relationship.

9. Means according to claim 4 including at least one grooved carrier disposed intermediate the length of said wire with an intermediate portion of said wire disposed in said groove with clearance.

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