(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 655 751 A2**

(12) # EUROPEAN PATENT APPLICATION

(21) Application number : **94308821.1**

(51) Int. Cl.[6] : **H01B 11/18**

(22) Date of filing : **29.11.94**

(30) Priority : **29.11.93 JP 326313/93**

(43) Date of publication of application :
31.05.95 Bulletin 95/22

(84) Designated Contracting States :
DE FR GB IT SE

(71) Applicant : **JUNKOSHA CO. LTD.**
25-25, Miyasaka 2-chome
Setagaya-ku Tokyo 156 (JP)

(72) Inventor : **Takeo, Monbara**
6-12-23 Higashi-Fujisawa
Iruma-City, Saitama (JP)

(74) Representative : **Horner, Martin Grenville et al**
Cruikshank & Fairweather
19 Royal Exchange Square
Glasgow G1 3AE Scotland (GB)

(54) **A coaxial cable and core and a method for manufacturing the same.**

(57) The present invention comprises an electrical cable core with one or more of various electrical characteristics (such as the electrostatic capacity, characteristic impedance, and propagation delay time) controlled (e.g., made uniform) in the lengthwise direction of the cable, and a method for manufacturing the same. The invention further comprises a coaxial cable in which said core is used. This cable core is achieved by means of a computer that computes the difference in the event that a difference is produced between a specific predetermined electrostatic capacity per unit of length for the core and the measured value for electrostatic capacity per unit of length of the cable. If a difference is detected, extrusion apparatus applying a second dielectric layer is controlled by the control apparatus so that the thickness of the dielectric layer is modified to deliver the desired electrical properties.

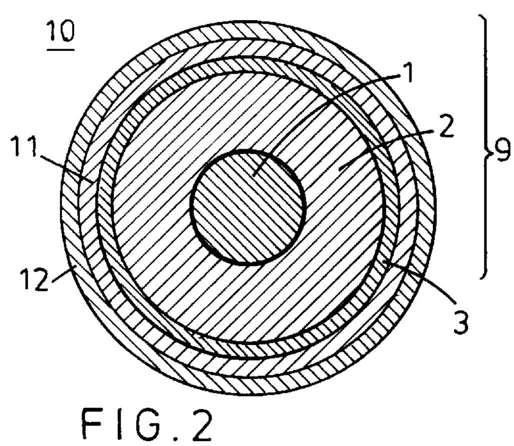

FIG. 2

EP 0 655 751 A2

FIELD OF THE INVENTION

The present invention concerns a cable core with electrical characteristics being uniform in the lengthwise direction. The present invention also concerns a coaxial cable in which said core is used and a method for manufacturing the same.

BACKGROUND OF THE INVENTION

Conventional coaxial cables often use an open-cell porous expanded polytetrafluoroethylene material (hereinafter referred to ePTFE), for example, as the dielectric layer. One common construction method with this type of coaxial cable employs a strip of ePTFE tape wrapped around the outside of an internal conductor in a spiral to form a dielectric layer. An external conductor layer, consisting of a braided conductor or similar structure, is then positioned around the outside of the dielectric layer, and the outside of this external conductor layer is then covered with an insulator as needed. The dielectric layer of such a coaxial cable has excellent dielectric characteristics in that its dielectric constant is low and its dielectric loss tangent is also small, so these cables are often used for high-speed digital signal transmission in a variety of applications, such as in computers. From the standpoints of higher signal transmission speed, noise elimination, etc., there is a need for further enhancement of various electrical characteristics of such coaxial cables, e.g., their electrostatic capacity, characteristic impedance, and propagation delay time, etc.

However, the strip of ePTFE tape that serves as the dielectric layer in such a coaxial cable tends to be very susceptible to plastic deformation by external forces. For instance, it can be flattened out by tension while it is being wound in a spiral around the outside of the internal conductor, which leads to local changes in the dielectric constant. Other areas of concern include the tape overlap width varying during spiral winding, or the tape being flattened out during the positioning of the external conductor layer of the coaxial cable. These and other such problems make it difficult to achieve uniformity in the lengthwise direction of the coaxial cable for electrical properties (e.g., the dielectric constant) of this dielectric layer.

In an effort to ameliorate the above-mentioned flattening with the dielectric layer during the positioning of the external conductor layer of the coaxial cable and other such problems, coaxial cables have been developed in which a second dielectric layer composed of a thermoplastic resin in the form of a relatively thin tape (hereinafter sometimes referred to as a "skin layer") is wound so as to cover the outside of the above-mentioned dielectric layer. Even if this skin layer is used, however, it cannot prevent the partial flattening of the dielectric layer of the coaxial cable, nor can it completely prevent variance in the electrical characteristics in the lengthwise direction of the conductor.

The present invention was conceived in light of these problems encountered with prior art, and its objective is to offer a coaxial cable core with which at least one property from among electrical characteristics of the coaxial cable, such as its electrostatic capacity, characteristic impedance, and propagation delay time, can be made uniform in the lengthwise direction of the coaxial cable, and also to offer a coaxial cable in which said core is used and a method for manufacturing the same.

It is accordingly a primary purpose of the present invention to provide a coaxial cable that retains the beneficial electrical properties of expanded polytetrafluoroethylene as a dielectric layer while diminishing or eliminating the distortion and deformation that can occur with presently used processing procedures.

SUMMARY OF THE INVENTION

The present invention is an improved core for use in a coaxial or differential cable that provides the desired level of electrical performance while being readily processed with minimal concern to damage to the dielectric layer during manufacture. The cable core of the present invention is equipped with a conductor, a first dielectric layer that covers this conductor, and a second dielectric layer that covers the outside of this first dielectric layer. The thickness of the second dielectric layer is adjusted in the lengthwise direction so that at least one property from among electrostatic capacity, characteristic impedance, and propagation delay time is controlled (e.g., made uniform) in the lengthwise direction of the cable.

The method for manufacturing a cable core of the present invention comprises: (i) an extrusion step in which a cable core is molded by extruding a second dielectric layer composed of a thermoplastic resin such that it covers the outside of a first dielectric layer that covers a conductor; (ii) a step in which the electrostatic capacity per unit of length and the outside diameter of the above-mentioned cable core are each measured; (iii) a computation step in which any difference in electrostatic capacity per unit of length or the outside diameter of the cable is determined; and (iv) a control step in which the amount in and/or pressure at which the above-mentioned thermoplastic resin is extruded in the above-mentioned extrusion step is controlled based on the output signal from the computation step. In this manner, the thickness of the above-mentioned second dielectric layer is thereby regulated.

Controlling the thickness of the second dielectric layer in the cable core of the present invention allows a composite dielectric constant of the above-mentioned first and second dielectric layers and the outside diameter of the cable core to be fine tuned. This permits exact selection and control of at least one of the above-mentioned electrical characteristics required of the cable to be kept within the required range over the entire length of the cable. The above-mentioned second dielectric layer also provides the same effect as a conventional skin layer.

In the above-mentioned method for manufacturing a cable core, the outside diameter of this cable core and the electrostatic capacity per unit of length of this coaxial cable core are each automatically measured on the extrusion step manufacturing line after the extrusion step in which the second dielectric layer is formed. These measurement results are processed through a computation step and a control step and reach a system of feedback to the extrusion step, which permits the thickness of the second dielectric layer to be controlled. The thickness of the second dielectric layer is modified by adjusting the amount or pressure, or both, of the thermoplastic resin that is extruded in the extrusion step. Example of how this may be accomplished include maintaining line speed and adjusting molten plastic flow, or maintaining plastic flow constant and adjusting line speed. As a result, the outside diameter and the composite dielectric constant of the first and second dielectric layers of the cable core can be fine tuned, and one or more of the various electrical characteristics, such as electrostatic capacity, characteristic impedance, and propagation delay time, required of a cable in which this cable core is used can be kept within the desirable and required range thereof.

Also, since the above is accomplished at a stage prior to the step in which the external conductor layer is positioned, the product will not proceed to the subsequent step unless the requirements have been satisfied, so unnecessary steps are eliminated, and this means that productivity is markedly better than with a conventional manufacturing method.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-section view illustrating a practical example of a cable core pertaining to the present invention.

Figure 2 is a cross-section view illustrating a practical example of the coaxial cable pertaining to the present invention, in which the cable core shown in Figure 1 is used.

Figure 3 is a plan view illustrating a practical example of the cable core manufacturing method pertaining to the present invention, which is used to manufacture the coaxial cable core shown in Figure 1.

DETAILED DESCRIPTION OF THE INVENTION

The cable core of the present invention, a coaxial cable in which said core is used, and the manufacturing method thereof will now be described by giving specific examples, but, naturally, the present invention is not limited to or by these practical examples, and variations are possible within the technological essence of the present invention.

Figure 1 is a cross-section illustrating an embodiment of a cable core of the present invention. In Figure 1, the cable core 9 is the product of forming a first dielectric layer by wrapping a strip of ePTFE tape in a spiral around the outside of a conductor 1 (having an outside diameter d) until an outside diameter D' is reached, and then covering the outside of this first dielectric layer with a second dielectric layer composed of a thermoplastic resin so that the outside diameter of the cable core 9 will be D. Thickness t of the second dielectric layer is regulated such that at least one of the various electrical characteristics required in the lengthwise direction of this coaxial cable, such as electrostatic capacity, characteristic impedance, and/or propagation delay time, can be kept within the required range thereof by the method described below. The material of the second dielectric layer can be an extrusion-moldable fluororesin, such as a tetrafluoroethylene - perfluoroalkyl vinyl ether copolymer (PFA), a tetrafluoroethylene - hexafluoropropylene copolymer (FEP), or another such thermoplastic fluororesin, or polyethylene, polyester, polyolefin, or another thermoplastic resin. These thermoplastic resins used in the second dielectric layer can be foamed as required.

Figure 2 is a cross-section of a practical example of a coaxial cable in which the cable core 9 shown in Figure 1 is used. Those constituent components that are the same as in Figure 1 are indicated by the same labels, and redundant descriptions will be omitted. As seen in Figure 2, the coaxial cable 10 is the product of further enveloping the outside of the cable core 9 with an external conductor layer 11, and then covering these components with an insulation covering 12.

Since the outside diameter d of the conductor 1 of this coaxial cable 10 here is known, the electrostatic capacity C, the characteristic impedance Zo, the propagation delay time Tr, and other such electrical characteristics are dependent on the outside diameter D of the core, the outer diameter d of the conductor, and the composite dielectric constant e of the first dielectric layer 2 and the second dielectric layer 3 of the coaxial cable core 9. Specifically, since the electrostatic capacity C is dependent on $\{e \div 1n\ (D \div d)\}$, the composite dielectric constant e can be computed if the electrostatic capacity C and the outside diameter D are given, and since the characteristic impedance Zo is proportional to $\{1n\ \{D \div d) \div \sqrt{e}\}$ and the propagation delay time Tr is proportional to $\sqrt{e}$, these characteristics can also be computed. Here 1n = log or natural log and e = εr or composite dielectric constant.

Therefore, measuring the outside diameter D and the electrostatic capacity C per unit of length of the cable core 9 on the manufacturing line, and then controlling the thickness of the second dielectric layer 3 in the lengthwise direction of the coaxial cable core 9 based on these measurement results, makes it possible to fine tune the composite dielectric constant e and the outside diameter D of the coaxial cable 10. As a result, this makes it possible to keep one or more of the various electrical characteristics, such as the electrostatic capacity C, the characteristic impedance Zo, and the propagation delay time Tr, within the desired range in the lengthwise direction of the coaxial cable.

The diameter of the core may be measured through use of a continuous outer diameter measuring apparatus employing a laser beam, such as one available from Anritsu Electric Co., Ltd., in Japan. Capacitance may be measured by using a continuous static capacity meter, such as Type 40E0128 manufactured by Brunorichter in Germany.

A preferred method for manufacturing the coaxial cable core of the present invention and a coaxial cable in which said core is used will now be described while referring to Figure 3. Figure 3 is a plan view illustrating one practical example of the manufacturing method used to manufacture the coaxial cable core shown in Figure 1. The constituent components that are the same as in Figure 1 are indicated by the same labels, and redundant descriptions will be omitted.

In Figure 3, the outside of the conductor 1 (see Figure 1) is covered with the first dielectric layer 2 as discussed above by means of a tape winding machine (not depicted). This product is moved in the direction indicated by the arrow A, and the outside is covered by the extrusion of the second dielectric layer 3 composed of a thermoplastic resin from an extrusion apparatus 4, which forms the coaxial cable core 9. During this time the outside diameter D of the coaxial cable core 9 is successively measured. This is preferably performed by inputting the output signals S5 into a computer 7, while the electrostatic capacity from the outer periphery of the conductor 1 to the outer periphery of the dielectric layer 3 per unit of length (including the measured outside diameter portion) is measured by an electrostatic capacity measurement apparatus 6, and these measurement results (i.e., the output signals S6) are input to the computer 7. Here, should there be any difference between the values of the output signals S5 and the output signals S6 and one or more predetermined specific values for the electrostatic capacity C, the calculated characteristic impedance Zo, and/or the calculated propagation delay time Tr required when the core 9 is used in the coaxial cable 10, the computer 7 will compute this difference, and the resulting output signal S7 is input to the control apparatus 8 from the computer 7. Based on the control signal S7 from the computer 7, a control output signal S8 is output to the extrusion apparatus 4 from the control apparatus 8, and the thickness t of the dielectric layer 3 may be adjusted by control of the resin pressure, resin quantity, etc., in the extrusion apparatus 4. Alternatively, the resin pressure and resin quantity can be left constant and the line speed or draw rate can be raised or lowered to alter thickness. The end result is a uniformity in the lengthwise direction of the coaxial cable in terms of the electrostatic capacity C, the characteristic impedance Zo, the propagation delay time Tr, and/or various other electrical characteristics. It should be evident that the same apparatus may likewise be used to provide controlled changes in any of these or other electrical properties at desired locations along the length of a given cable.

By way of example of the steps of processing of the core of the present invention, if the value of capacitance which is really measured is larger than the value of capacitance which is predetermined, during operation, the diameter D will be greater by the control of the extrusion volume. If the value of impedance which is really measured is larger than the value of impedance which is predetermined, during operation, the diameter D will be smaller by the control of the extrusion volume. If the value of signal propagation delay time which is really measured is larger than the value of signal propagation delay time which is predetermined, during operation, the diameter D will be greater by the control the extrusion volume.

Thus, with the present invention, an evaluation as to whether the variety of electrical characteristics required of a coaxial cable are within their desired ranges can be accomplished at a stage prior to the step in which the external conductor layer 11 is positioned, i.e., during the manufacture of the core 9. This can eliminate the unnecessary work after the manufacture of the core 9 that would occur in the event that the electrical characteristics of the coaxial cable were outside their predetermined specific ranges when the electrical characteristics of the coaxial cable were examined after the external conductor layer, etc., had been positioned, as with a conventional manufacturing method.

As described above, the present invention offers a cable core with the desired uniformity of one or more of the various required electrical characteristics, such as electrostatic capacity, characteristic impedance, and propagation delay time, in the lengthwise direction, and offers a coaxial cable or differential cable in which said core is used. Also, with the manufacturing method of the present invention, adjusting the thickness of the second dielectric layer based on the results of measuring the electrostatic capacity per unit of length and the outside diameter of the cable core provides a benefit unique to the present invention in that it is possible to manufacture a coaxial cable core that has the desired uniformity of one or more of a variety of electrical characteristics, such as electrostatic capacity, characteristic impedance, propagation delay time, in the lengthwise direction, as well as a coaxial cable in which said core is used.

Although a primary benefit of the core of the present invention is for use in coaxial cables, it should be appreciated that the core may also be useful in other electrical applications, such as in differential signal transmission cable (e.g., twin ax or quad ax cables) and the like.

While particular embodiments of the present invention are described herein, it is not intended to limit the invention to such disclosure and changes and modifications may be incorporated and embodied within the scope of the appended claims.

Claims

1. An electrical cable core comprising
   a conductor;
   a first dielectric layer that covers the conductor; and
   a second dielectric layer that covers the outside of the first dielectric layer;
   wherein said cable core is characterized by the fact that the thickness of the second dielectric layer is controlled in a lengthwise direction so that at least one property from among electrostatic capacity, characteristic impedance, and propagation delay time is made uniform in the lengthwise direction.

2. The cable core of claim 1 wherein the core is surrounded by an external conductor layer and an insulation covering to form a coaxial cable assembly.

3. The cable core of claim 1 wherein the first dielectric layer comprises a tape wrapped around the conductor.

4. The cable core of claim 3 wherein the second dielectric layer comprises a continuous resin layer surrounding the first dielectric layer.

5. A coaxial cable comprising
   a conductor;
   a first dielectric layer that covers the conductor;
   a second dielectric layer that covers the outside of this first dielectric layer; and
   an external conductor layer that envelops the second dielectric layer;
   wherein said coaxial cable is characterized by the fact that the thickness of the second dielectric layer is changed along a lengthwise direction of the cable so that at least one property from among electrostatic capacity, characteristic impedance, and propagation delay time is controlled in the lengthwise direction of the cable.

6. The coaxial cable of claim 5 wherein the second dielectric layer comprises a continuous resin layer applied in varying thicknesses over the first dielectric layer.

7. The coaxial cable of claim 6 wherein the resin layer comprises an extrudable thermoplastic resin.

8. The coaxial cable of claim 6 wherein the second dielectric layer is changed along the lengthwise direction of the cable so that one property from among electrostatic capacity, characteristic impedance, and propagation delay time is maintained uniform over the lengthwise direction of the cable.

9. A method for manufacturing a coaxial cable core, which comprises
   (i) an extrusion step in which a coaxial cable core is molded by extruding a second dielectric layer composed of a thermoplastic resin such that it covers the outside of a first dielectric layer that covers a conductor;
   (ii) a measurement step in which at least one property of the coaxial cable core is measured;
   (iii) a computation step in which the measured property is compared with a predetermined value for that property; and
   (iv) a control step in which the flow of thermoplastic resin extruded in the above-mentioned extrusion step is controlled based on an output signal from the computation step, and the thickness of the above-mentioned second dielectric layer is thereby regulated.

10. The method of claim 9 that further comprises
   a measurement step whereby the properties of the coaxial cable core that are measured comprise the electrostatic capacity per unit of length of the cable core and the outside diameter of the cable core.

11. The method of claim 10 that further comprises
   a computation step in which any difference calculated between a specific predetermined property of the coaxial cable core electrostatic capacity per unit of length for the coaxial cable core and the value for electrostatic capacity per unit of length obtained in the measurement step.

12. The method of claim 9 that further comprises
   a control step whereby the flow of resin is

controlled by varying the amount of resin extruded. or the pressure at which the resin is extruded.

13. The method of claim 9 that further comprises a control step whereby the flow of resin is controlled by varying the pressure at which the resin is extruded.

14. The method of claim 9 that further comprises providing a first dielectric layer comprising a tape of dielectric material wrapped around the conductor.

15. The method of claim 9 that further comprises a control step whereby the thickness of the second dielectric layer is further regulated by adjusting a rate at which the first dielectric layer passes through the extruder.

16. A method for manufacturing a cable core, which comprises

(i) an extrusion step in which a cable core is molded by extruding a second dielectric layer composed of a thermoplastic resin such that it covers the outside of a first dielectric layer that covers a conductor;
(ii) a measurement step in which at least one property of the coaxial cable core is measured;
(iii) a computation step in which the measured property is compared with a predetermined value for that property; and
(iv) a control step in which a rate at which the first dielectric layer passes through the extruder in the above-mentioned extrusion step is controlled based on an output signal from the computation step, and the thickness of the above-mentioned second dielectric layer is thereby regulated.

17. The method of claim 16 that further comprises a measurement step whereby the properties of the cable core that are measured comprise the electrostatic capacity per unit of length of the cable core and the outside diameter of the cable core.

18. The method of claim 17 that further comprises a computation step in which any difference calculated between a specific predetermined property of the cable core electrostatic capacity per unit of length for the cable core and the value for electrostatic capacity per unit of length obtained in the measurement step.

19. The method of Claim 16 that further comprises a control step whereby the thickness of the second dielectric layer is further regulated by adjusting a rate at which flow of thermoplastic resin is extruded.

20. The method of claim 16 that further comprises a control step whereby the flow of resin is controlled by varying the pressure at which the resin is extruded.

21. The method of claim 16 wherein a rate at which the first dielectric layer passes through the extruder is varied to regulate the thickness of the second dielectric layer.

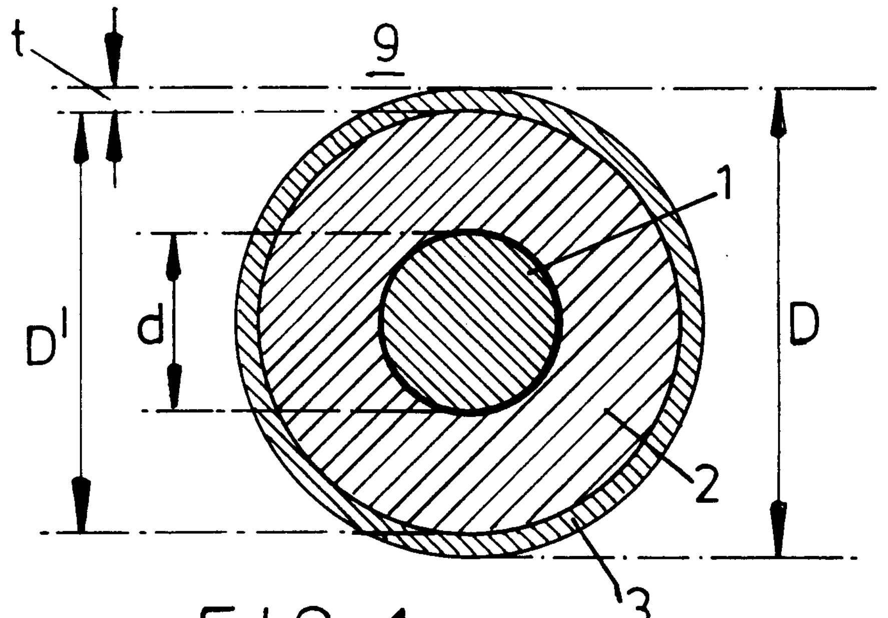

FIG.1

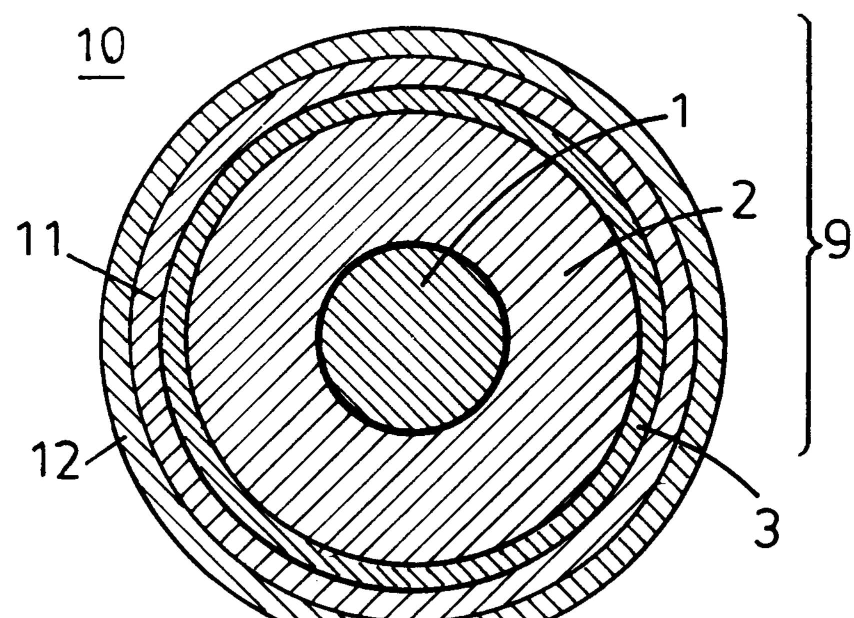

FIG.2

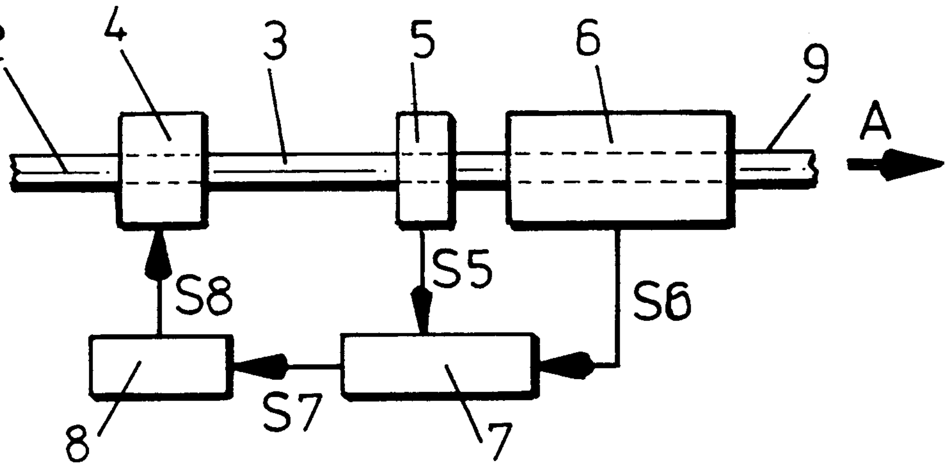

FIG.3