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(54) **Double-walled structure and method of producing the same**

(57) A double-walled-structure, such as a silencer for use in a ventilation duct system, comprises a perforated inner tube (10), an outer casing (30) which is arranged at a distance from the inner tube (10) and encloses the same, and a tubular, sound-absorbing element (20) which is arranged between the inner tube (10) and the casing (30). The tubular element (20) has an increasing density radially outwards from the centre axis (C) of the inner tube (10). The silencer (1) is produced by the sound-absorbing element (20) being arranged on the inner tube (10), and the inner tube (10) with the sound-absorbing element arranged thereon being enclosed in the surrounding outer casing (30).

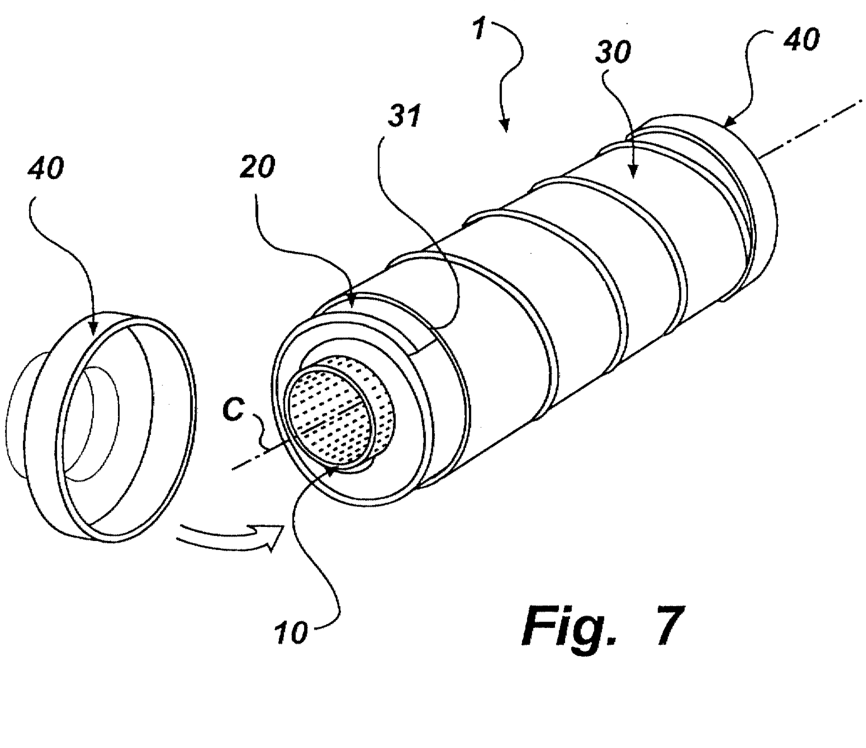


Fig. 7

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## Description

### Field of the Invention

**[0001]** The present invention relates to a double-walled structure, such as a silencer, for use in a ventilation duct system, the structure being of the type as defined in the preamble to appended claim 1. The invention also concerns a method of producing such a double-walled structure.

### Background Art

**[0002]** Double-walled sound-absorbing structures for use in ventilation duct systems are well known. A per se well-functioning double-walled silencer is known, for instance, from a catalogue entitled "Ventilation 95, Manual and Catalogue" published by Lindab AB in 1995. Page 4/6 describes the general construction of a circular silencer. This prior-art silencer is composed of a circular inner tube of perforated sheet metal, a surrounding circular spirally-wound lock-seam tube of sheet metal, and an intermediate layer of sound-absorbing mineral wool. Between the perforated inner tube and the sound-absorbing material there is a protective layer, such as fibre cloth or fabric of e.g. glass wool, for preventing mineral wool from being drawn into the duct.

**[0003]** US-A-5,911,457 discloses a method for producing a double-walled structure, such as a silencer according to US-A-5,801,342, which to some extent resembles a silencer of the above type. A perforated metal strip is wound together with a strip of air-permeable fabric to form a tube the outside of which is coated with said fabric. The coated, perforated tube is provided on its outside with a tubular layer of sound-absorbing material and then inserted into a casing for completing the silencer.

### Summary of the Invention

**[0004]** An object of the present invention is to provide a double-walled structure with improved sound-absorbing properties which is further developed in relation to prior art. A further object of the invention is to provide a method of producing an inventive double-walled structure. These and other objects that will appear from the following description are achieved by means of a double-walled sound-absorbing structure, a silencer and a production method having the features as defined in the independent claims.

**[0005]** Further features and advantages of the invention are evident from the dependent claims and the following description.

**[0006]** The double-walled structure is adapted to absorb sound which propagates from the inner tube towards the casing.

**[0007]** An advantage of letting the density of the sound-absorbing element of the inventive double-walled structure increase radially outwards from the centre axis of the inner tube is that the sound-absorbing properties of the double-walled structure will be improved. Comparative tests of inventive double-walled structures with a radially increasing density and double-walled structures whose sound-absorbing insulation has a constant density, have been carried out. The method used for testing is "Standard ISO 7235" which is well known to those skilled in the art. The tests showed that improved sound absorption by from one dB up to as much as 10 dB is obtained in the frequency range 100-1500 Hz, in which the greatest improvement is achieved between 200 and 1000 Hz where the difference is 4-10 dB.

**[0008]** By letting, according to a preferred embodiment of the invention, the sound-absorbing element comprise two or more layers of sound-absorbing material, the element can, in a simple manner in terms of manufacture, be given an increasing density radially outwards from the centre axis of the inner tube. For instance, the layers can consist of different materials having different density.

**[0009]** An advantage of arranging, according to one embodiment of the invention, a tubular cylinder which is rigid and sound-permeable, between and coaxially with two neighbouring layers of sound-absorbing material is that one layer of sound-absorbing material can be wound round another layer, without affecting the density thereof. The air permeability allows transmission of sound in the radial direction from the centre axis of the double-walled structure.

**[0010]** In one embodiment, one or more layers consist of a tubular casing. A tubular casing can be circular in cross-section or consist of e.g. two tubular casing halves which are semicircular in cross-section. The use of tubular casings facilitates the work in assembling the double-walled structure.

**[0011]** In another preferred embodiment, one or more layers consist of a sound-absorbing material which is wound at least one turn round the outer circumferential surface of the inner tube. This permits variation of the density in the sound-absorbing material in a simple manner owing to the possibility of varying the degree of firmness with which each layer is wound.

**[0012]** According to another embodiment of the invention, the sound-absorbing element comprises a material with a density gradient, whereby only one layer and only one turn of winding or layer round the outer circumferential surface of the inner tube is necessary.

**[0013]** By winding a sound-absorbing material a plurality of turns round the inner tube, the firmness of the winding can be varied to achieve a density gradient. Besides, by means of the plurality of turns of winding a continuous joint is prevented, which may be desirable to achieve additionally improved sound-absorbing properties.

**[0014]** The sound-absorbing element is advantageously made of a yieldable material to facilitate the work in mounting it in the double-walled structure. Moreover it is possible to readily achieve variations in the density of the element in the winding speed when producing double-walled structures with wound sound-absorbing elements. Preferably, the sound-absorbing element is made of a fibre material, such as mineral wool. A fibre material makes is possible to provide a sound-absorbing element and, thus, a double-walled sound-absorbing structure having a low weight. This is, of course, an advantage in connection with long sound-absorbing double-walled structures in the form of entire ducts, since for instance the mounting work is facilitated.

**[0015]** If the double-walled structure has an inner tube, which according to a preferred embodiment is made to be sound permeable and which is provided with perforations, the sound in the duct can be better transmitted to the sound-absorbing element for more efficient absorption. According to one embodiment, the perforations are distributed over essentially the entire wall of the inner tube.

**[0016]** The method of producing the inventive double-walled structure has advantages which correspond to the advantages of the actual double-walled structure, especially as regards rational production of the same.

Brief Description of the Drawings

**[0017]** The invention and its many advantages will be described in more detail below with reference to the accompanying schematic drawings which by way of example illustrate some presently preferred embodiments.

Figs 1-8 illustrate an embodiment of a double-walled sound-absorbing structure and its components, and assembly of the same, where
Fig. 1 shows a perforated inner tube and a sound-absorbing element for composing a double-walled sound-absorbing structure,
Fig. 2 shows the inner tube and the sound-absorbing element fixed to its outer circumferential surface,
Fig. 3 shows the inner tube and the sound-absorbing element which is fixed thereto and which has been wound one turn round the inner tube,
Fig. 4 shows the inner tube and the sound-absorbing element which is fixed thereto and which has been wound a plurality of turns round the inner tube,
Fig. 5 shows the inner tube with the completely wound sound-absorbing element,
Fig. 6 shows the inner tube with the sound-absorbing element wound round the same, partly inserted into an outer casing,
Fig. 7 shows the inner tube with the sound-absorbing element wound round the same, completely inserted into the casing, and
Fig. 8 is a cross-sectional view of the double-walled structure in Fig. 7.
Figs 9-13 are cross-sectional views of the inventive double-walled structure according to alternative embodiments.

Description of Preferred Embodiments

**[0018]** A double-walled sound-absorbing structure 1 and the production thereof according to a preferred embodiment of the invention are shown in Figs 1-8. In the shown, nonlimiting example, the double-walled structure consists of a silencer for use in a ventilation duct system. The silencer 1 comprises an inner tube 10, a sound-absorbing element 20, an outer casing 30 and two end pieces 40. The inner tube 10 is circular in cross-section and has a first and a second open end 11, 12 (see Fig. 1). For instance, the inner tube 10 can be made by spirally lock-seaming a strip of sheet metal. The inner tube 10 is provided with perforations 13, and its outer circumferential surface 14 is preferably covered by an air-permeable fabric (not shown). The sound-absorbing element 20 is a rectangular sheet or web. The sheet 20 is made of a yieldable, sound-absorbing material, such as mineral wool, and has a first and a second short side 21, 22.

**[0019]** As shown in Figs 2 and 3, the sound-absorbing element 20 is along one short side 21 held in place on the outer circumferential surface 14 of the inner tube 10 in such manner that the short side 21 is parallel with the centre axis 20 of the inner tube 10. This can be provided, for instance, by means of clamps or forks (not shown) which are removed after completion of the winding. Subsequently, the inner tube 10 is rotated in a direction R in such manner that the sound-absorbing element 20 is wound round the inner tube 10. The width B of the sound-absorbing element 20 is somewhat smaller than the length L of the inner tube 10, and therefore the inner tube 10 will at its two ends 11, 12 protrude a distance outside the applied sound-absorbing element 20. The element 20 is wound symmetrically relative to the two ends 11, 12 of the inner tube 10. It is also evident from Fig. 3 that the first short side 21 of the yieldable sound-absorbing sheet 20 is compressed under the beginning of the next turn of winding, whereby a relatively smooth transition between the turns of the sheet 20 is obtained.

**[0020]** Figs 3 and 4 show how during the winding phase a force F is applied to the sound-absorbing element 20 in its longitudinal direction. During the winding phase, the sheet 20 is compressed more and more, whereby its turns are given higher and higher density. It is shown in Figs 4 and 5 that the sound-absorbing element 20 has been applied in such manner that for each turn or layer, the thickness decreases and the density increases radially outwards from the centre axis C of the inner tube 10. After completion of the winding, the element 20 is along its second short side 22 held in place against the interiorly situated layer of the element 20 until the inner tube 10 and the element 20 are inserted into the outer casing 30.

**[0021]** Figs 6 and 7 show the casing 30 which is circular in cross-section and has a first and a second end 31, 32. The casing 30 can, like the inner tube 10, be manufactured, for instance, by spirally lock-seaming a strip of sheet metal. The inner tube 10 and the sound-absorbing element 20 wound round the same are jointly inserted into the casing 30 which is then closed at both ends 31, 32 by means of the end pieces 30 for completion of the silencer 1. Alternatively, one of the end pieces 40 can be mounted on the casing 30 even before the inner tube 10 and the sound-damping element 20 are inserted (not shown).

**[0022]** Fig. 8 is a cross-sectional view of the silencer 1 described above. Figs 9-13 are cross-sectional views of double-walled sound-absorbing structures according to alternative embodiments of the invention. Each of these embodiments comprises the inner tube 10, the sound-absorbing element 20 and the outer casing 30. The design of the sound-absorbing element 20 differs, but in all embodiments the density increases radially from the centre axis C of the inner tube 10 according to the invention.

**[0023]** In the inventive double-walled structure shown in Fig. 9, the element 20 consists of two coaxial, spirally wound layers 21, 22 of sound-absorbing material. The inner layer 21 closest to the inner tube 10 is more loosely wound than the outer layer 22 and will thus have a lower density than the latter (provided that the materials in their unwound state have the same density). The layers 21, 22 can be made of the same material or of different materials with, for instance, different density. A tubular cylinder 23 is placed between the inner layer 21 and the outer layer 22, coaxially therewith. The cylinder 23, which has essentially the same length as the width of each of the layers 21, 22, is made of, for instance, metal wire netting. The meshes of the wire netting are preferably about 10 x 10 mm. Thanks to the cylinder 23, which is rigid, the outer layer 22 can be wound without affecting the density of the inner layer 21.

**[0024]** Figs 10 and 11 are cross-sectional views of a double-walled structure with a sound-absorbing element 20, whose layers consist of so-called tubular casings 24a, 25a (Fig. 10) which are circular in cross-section or of tubular casing halves 24b, 24c, 25b, 25c (Fig. 11) which are semicircular in cross-section. The tubular casings 24a-c arranged closest to the inner tube 10 have a lower density than the tubular casings 25a-c arranged closest to the outer casing 30. Each layer in the embodiments according to Figs 10 and 11 can alternatively consist of an insulating mat which is wound one turn round the outer circumferential surface of the inner tube 10. In variants (not shown) of the embodiments illustrated in Figs 10 and 11, the inside of the tubular casing 24a or tubular casing halves 24b, 24c is lined with a fabric which forms the inner tube 10.

**[0025]** According to Fig. 12, an applied inner layer 26 can be combined with an outer layer 27 which is a tubular casing.

**[0026]** In the embodiment shown in Fig. 13, the sound-absorbing element 20 is formed of a layer of an insulating mat 28 which has been wound one turn round the inner tube 10. The insulating mat 28 has in itself a density gradient in such a direction that, when the mat 28 is wound round the inner tube 10, a sound-absorbing element 20 with a density increasing radially outwards from the centre axis C of the inner tube 10 is provided.

**[0027]** According to a variant (not shown) of the embodiment illustrated in Fig. 13, the insulating mat 28 is a tubular casing, alternatively two or more tubular casing parts, with a built-in density gradient. The inside of the tubular casing 28 is lined with a fabric which forms the inner tube 10.

**[0028]** Practical experiments with inventive double-walled structures have produced excellent results. Tests of double-walled structures designed according to the embodiments in Fig. 9 and Fig. 12, respectively, and of a conventional silencer (SLGU 900-200-100, Lindab AB) have been carried out according to a standard, ISO 7235. The conventional silencer has an absorbing insulation with a constant density. The tests demonstrated that improved sound absorption by from one dB up to 10 dB is obtained in the frequency range 100-1500 Hz with the inventive double-walled structures. In this range, the greatest improvement is achieved between 200 and 1000 Hz where the difference is 4-10 dB.

**[0029]** The invention has been described above with reference to some embodiments chosen by way of example, but it will be appreciated that modifications are feasible within the scope of the invention as defined in the appended claims. For instance, more than two layers can be used. Moreover different types of layer, such as tubular casings and windings, can be combined to further alternative embodiments of the double-walled structure. The sound-absorbing element could also comprise more than one insulating mat or tubular casing of the kind which in itself has a density gradient. Furthermore the choice of materials for different layers in the sound-absorbing element can be varied to achieve the desired density gradient. For example, a double-walled structure or silencer can be formed with four layers of the following materials: melamine (10 kg/m$^3$), polyester (22 kg/m$^3$), glass wool (20-30 kg/m$^3$) and rock wool (80 kg/m$^3$) in this order, seen from inside the circumferential surface of the inner tube. The melamine layer eliminates the need for a special protective layer, such as a fibre cloth or fabric, on the inner tube. When winding glass wool and polyester wool, the density of these materials can be increased by up to about 50-100%.

**[0030]** The choice of materials for the inner tube and casing of the double-walled structure is not critical.

**[0031]** The elements included in the double-walled structure can be non-circular in cross-section, such as oval or rectangular. For instance, the inner tube can be circular and the casing rectangular. In this case, tubular casing parts, such as tubular casing halves which are internally semicircular in cross-section and externally rectangular in cross-section, can be used. A double-walled structure need not be straight like in the embodiments shown by way of example.

**[0032]** A sound-absorbing structure provided with end pieces has been described above, but within the scope of the invention also longer double-walled structures are feasible, which are not provided with end pieces but constitute entire ventilation ducts.

**[0033]** Further the method in which a sound-absorbing material is wound round the inner tube can be varied by the sound-absorbing material being either spirally wound or formed as one or more narrow strips which are wound along a helical line in one or more layers. The actual winding can take place by the inner tube being rotated, by the sound-absorbing material being wound round a stationary inner tube or by the material being wound round a rotating tube.

**[0034]** The intermediate tubular cylinder which is used in the embodiment according to Fig. 9 can be made of a wire netting of metal or some other rigid material, or of a perforated, e.g. spirally lock-seamed, tube.

**[0035]** It should also be pointed out that the inventive double-walled structure is applicable to other systems than ventilation duct systems, such as silencers for vehicles, compressors and the like.

## Claims

1. A double-walled structure, comprising an inner tube (10), an outer casing (30) which is arranged at a distance from the inner tube (10) and encloses the same, and a tubular sound-absorbing element (20) which is arranged between the inner tube (10) and the casing (30), **characterised** in that the tubular element (20) has an increasing density radially outwards from the centre axis (C) of the inner tube (10).

2. The structure as claimed in claim 1, wherein said tubular element (20) comprises at least two layers of sound-absorbing material.

3. The structure as claimed in claim 1 or 2, wherein said tubular element (20) comprises at least one tubular cylinder (23), which is rigid and sound-permeable and which is arranged between and coaxially with two neighbouring layers of sound-absorbing material.

4. The structure as claimed in claim 2 or 3, wherein at least one of said layers of sound-absorbing material consists of at least one tubular casing.

5. The structure as claimed in any one of claims 2-4, wherein at least one of said layers of sound-absorbing material is wound at least one turn round the outer circumferential surface of the inner tube (10).

6. The structure as claimed in any one of claims 1-5, wherein the tubular element (20) comprises at least one tubular casing.

7. The structure as claimed in claim 1, wherein the tubular element (20) comprises a material which has a density gradient and which is wound round the outer circumferential surface of the inner tube (10) to form a layer of said material.

8. The structure as claimed in claim 7, wherein said material is spirally wound.

9. The structure as claimed in claim 7, wherein said material is helically wound.

10. The structure as claimed in claim 1, wherein the tubular element (20) comprises a material which is wound a plurality of turns round the outer circumferential surface of the inner tube (10).

11. The structure as claimed in claim 5 or 10, wherein said material is spirally wound.

12. The structure as claimed in claim 5 or 10, wherein said material is helically wound.

13. The structure as claimed in any one of the preceding claims, wherein the sound-absorbing element (20) essentially is made of a yieldable material.

14. The structure as claimed in any one of the preceding claims, wherein the sound-absorbing element (20) essentially is made of a fibre material, preferably mineral wool.

15. The structure as claimed in any one of the preceding claims, wherein the inner tube (10) essentially is designed to be sound-permeable.

16. The structure as claimed in any one of the preceding claims, wherein the inner tube (10) is provided with perforations (13).

17. The structure as claimed in any one of the preceding claims, wherein the inner tube (10) essentially is made of sheet metal.

18. A silencer for ventilation duct systems, **characterised** in that it comprises a double-walled structure according to any one of the preceding claims.

19. A method of producing a double-walled structure, which comprises an inner tube (10), an outer casing (30) which is arranged at a distance from the inner tube (10) and encloses the same, and a tubular sound-absorbing element (20) which is arranged between the inner tube (10) and the casing (30),

**characterised** in

that the sound-absorbing element (20) is arranged on the outside of the inner tube (10) in such manner that the density of the element (20) increases radially outwards from the centre axis (C) of the inner tube (10), and
that the inner tube (10) with the sound-absorbing element (20) arranged thereon are enclosed in the outer casing (30).

**20.** The method as claimed in claim 19, wherein the sound-absorbing element (20) is arranged on the outside of the inner tube (10) by the sound-absorbing element (20) first being secured to the inner tube (10) and by the sound-absorbing element (20) being made of a material which is subsequently wound round the outer circumferential surface of the inner tube (10).

**21.** The method as claimed in claim 20, wherein said material is spirally wound.

**22.** The method as claimed in claim 20, wherein said material is helically wound.

**23.** The method as claimed in any one of claims 20-22, wherein during the winding a counterforce (F) is applied to said material in such manner that the sound-absorbing element (20) is given a density increasing radially outwards from the centre axis (C) of the inner tube (10).

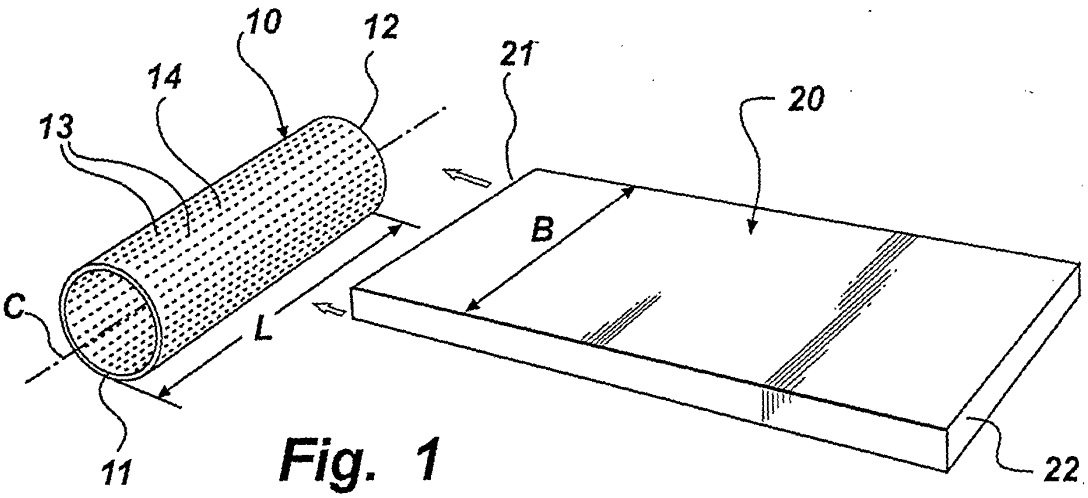


Fig. 1

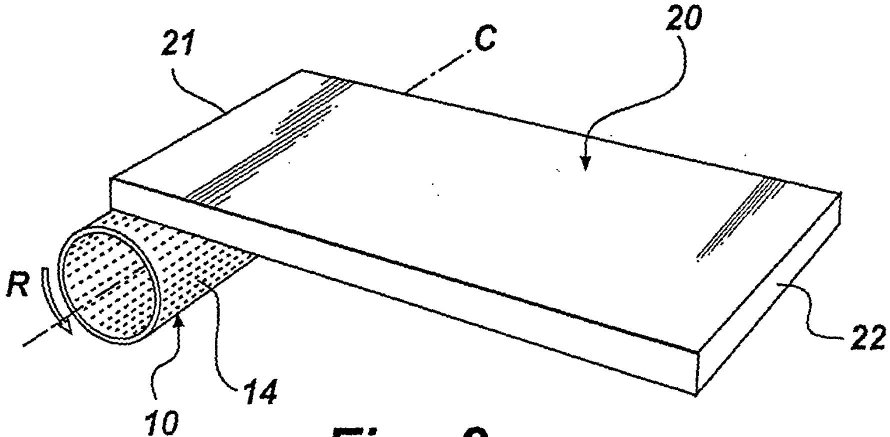


Fig. 2

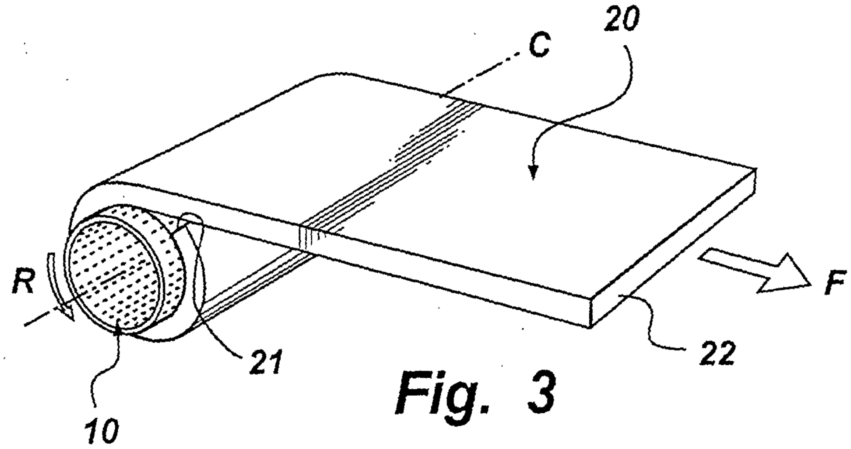


Fig. 3

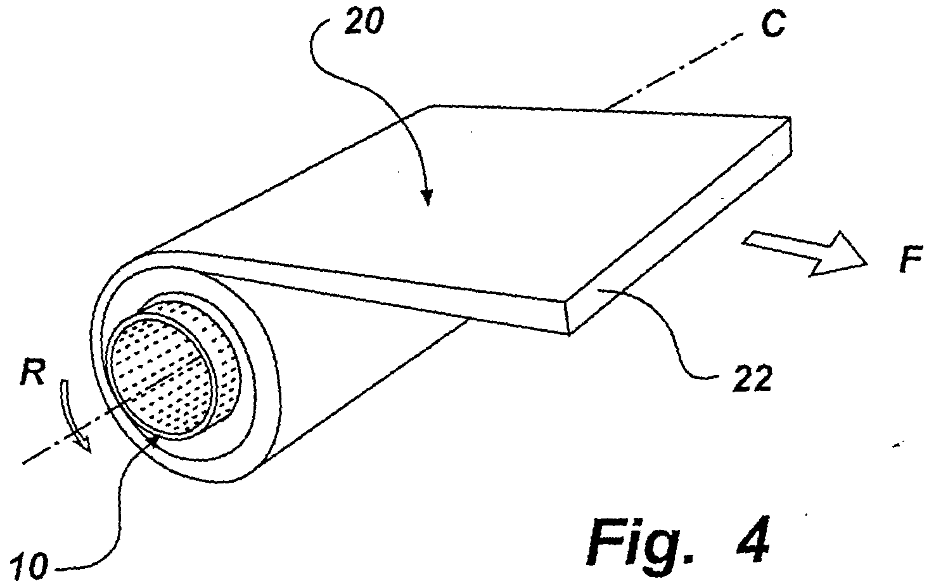


Fig. 4

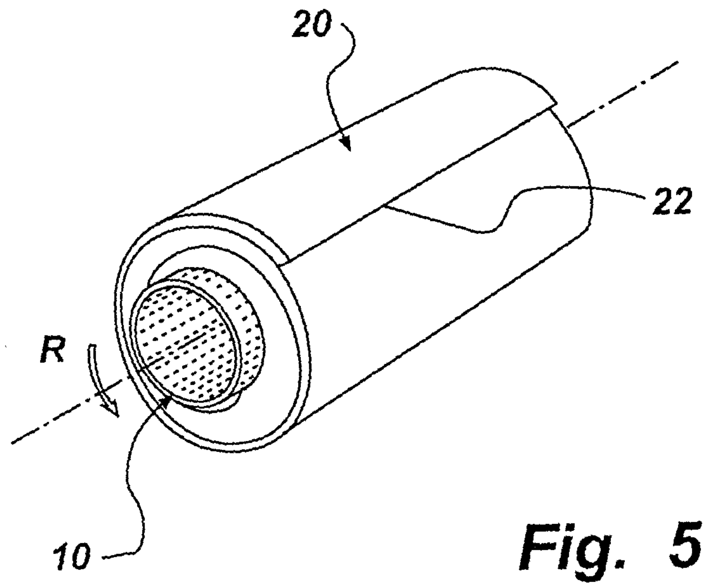


Fig. 5

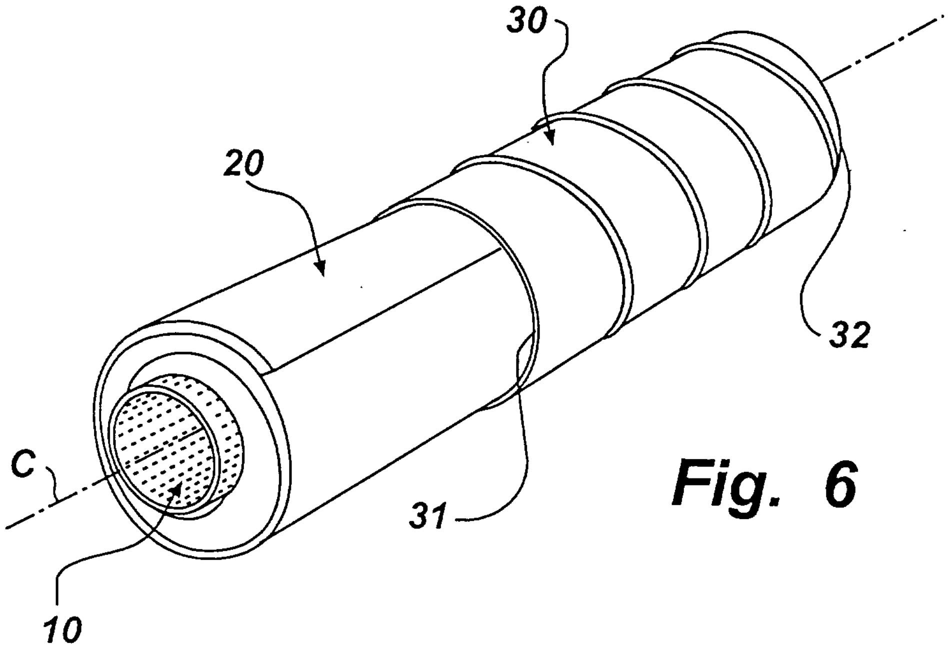


Fig. 6

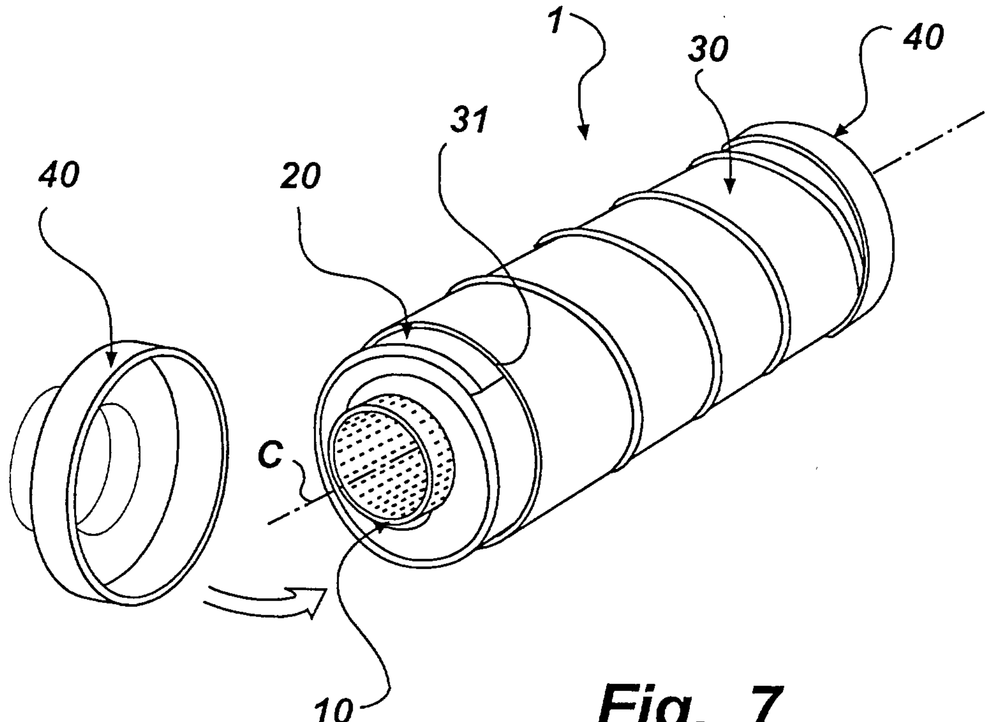


Fig. 7

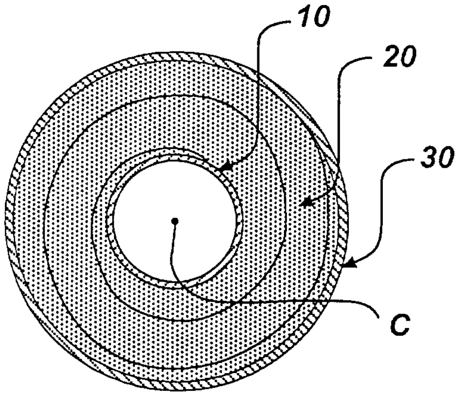


Fig. 8

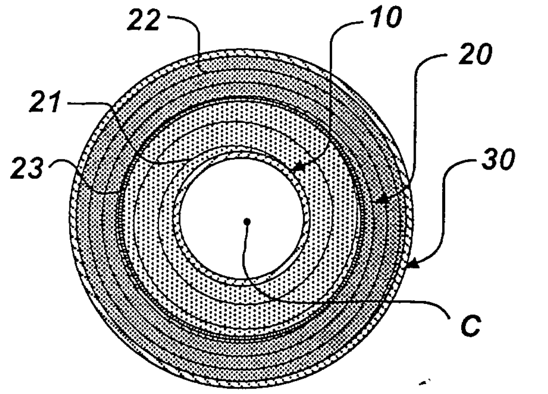


Fig. 9

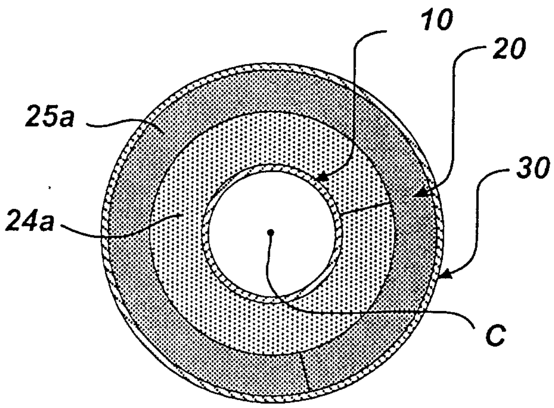


Fig. 10

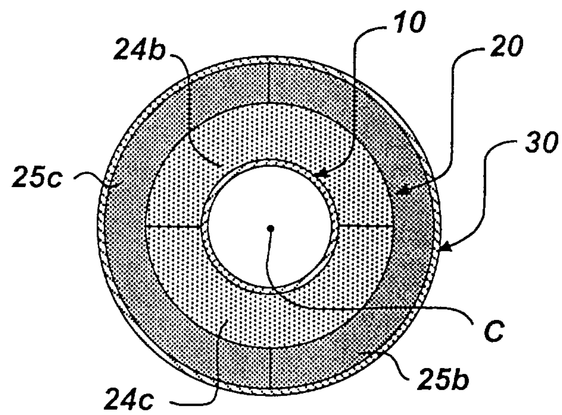


Fig. 11

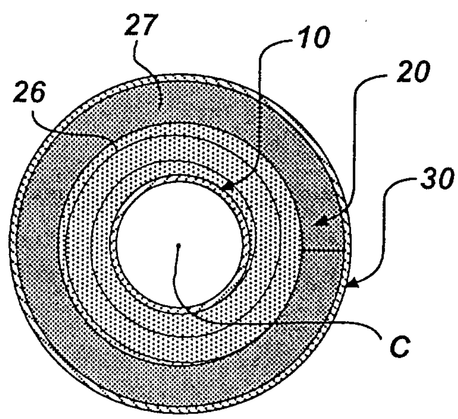


Fig. 12

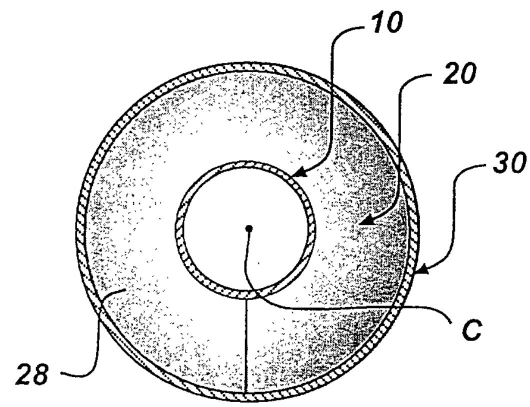


Fig. 13