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(54) **DEVICE AND METHOD FOR AMPLIFYING SUCTION NOISE**

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F01N 1/16 (2006.01)

(52) **U.S. Cl.** ... **181/271**; 181/167; 181/174; 123/184.57; 123/184.53; 123/184.55; 123/184.54; 123/184.56; 180/309; 180/296; 180/68.3

(58) **Field of Classification Search** 181/271, 181/250, 202, 18, 167, 174, 212, 214; 123/184.53, 123/184.54, 184.55, 184.56, 184.57; 340/381.1, 340/438, 439, 384.3; 180/309, 296, 68.3
See application file for complete search history.

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Primary Examiner — Elvin G Enad
Assistant Examiner — Forrest M Phillips
(74) *Attorney, Agent, or Firm* — Young Basile

(57) **ABSTRACT**

A device for amplifying the suction noise of a vehicle is disclosed. The device comprises an intake duct, a connecting pipe and a composite membrane. The intake duct is for feeding air to an engine intake port. A connecting pipe is connected to an interior of the intake duct. The composite membrane is positioned within the connecting pipe. The composite member blocks an interior passage formed in the connecting pipe. The composite member further includes at least two elastic membranes with one of masses and rigidities that different from each other. A method is also disclosed.

21 Claims, 10 Drawing Sheets

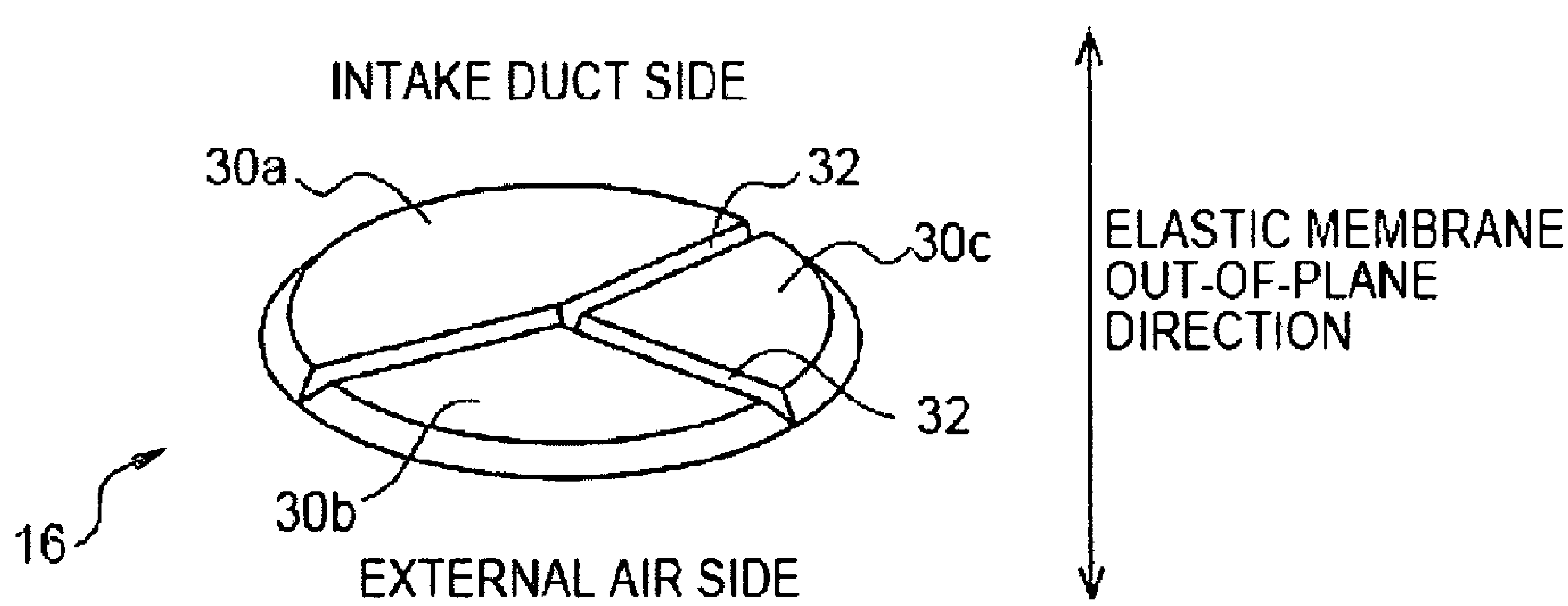

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FIG. 1A

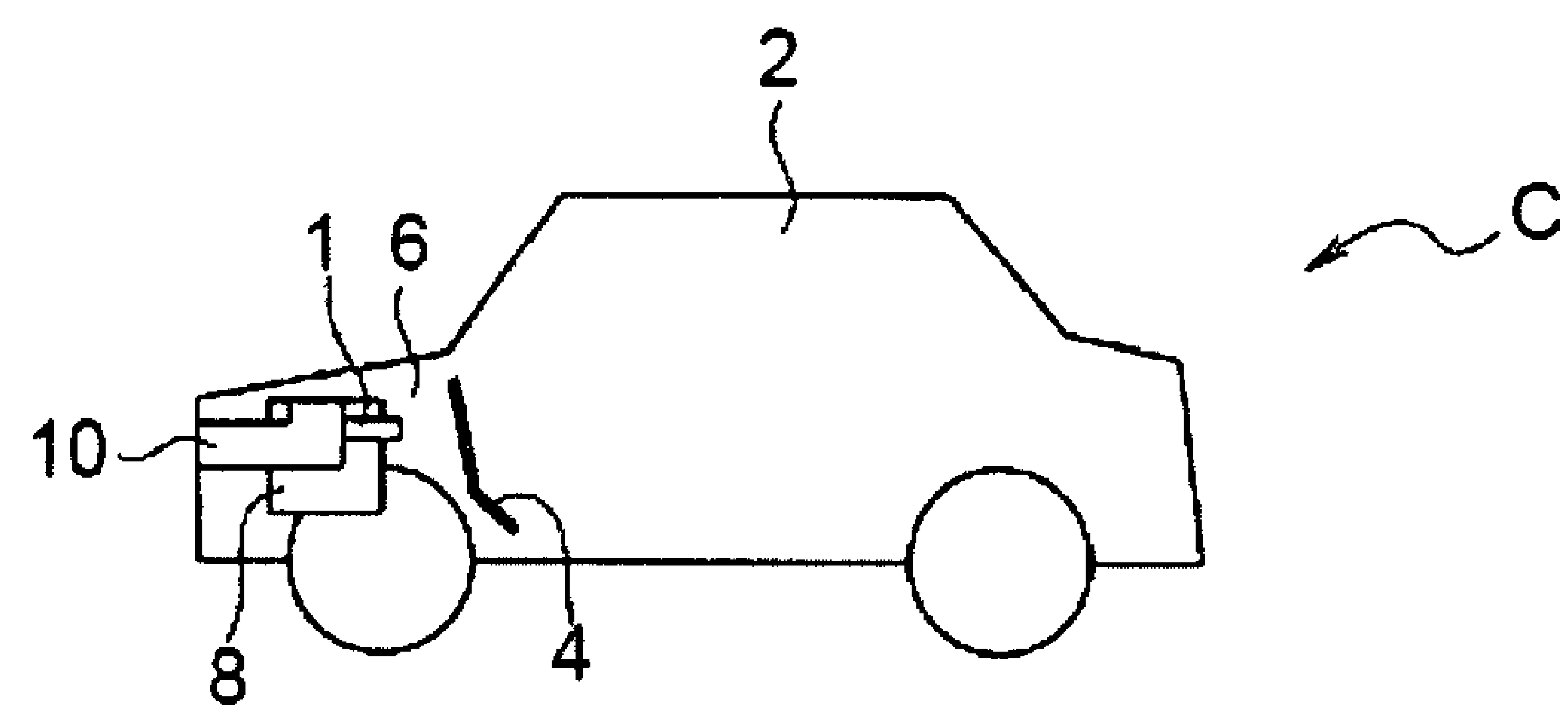


FIG. 1B

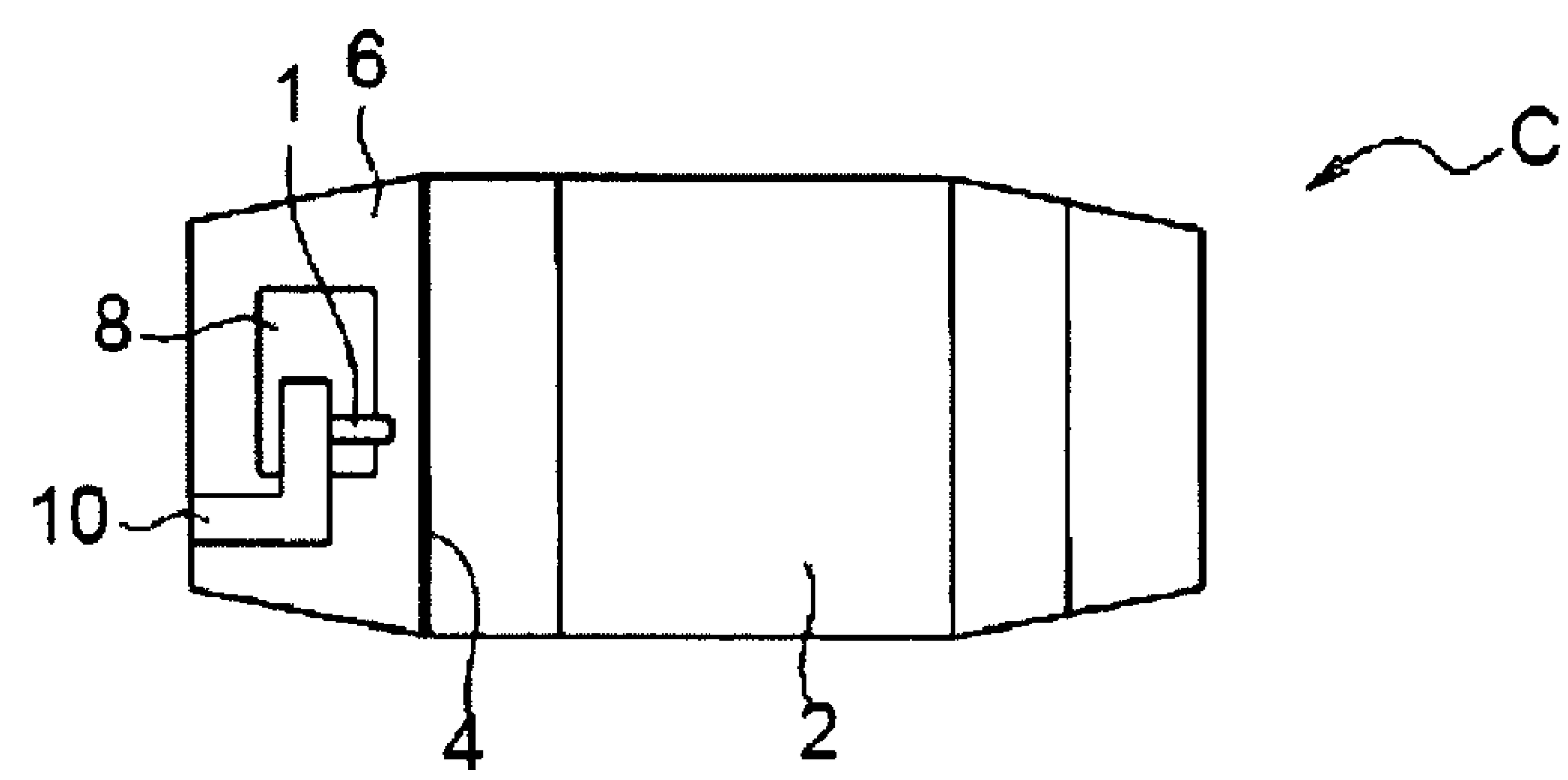


FIG. 1C

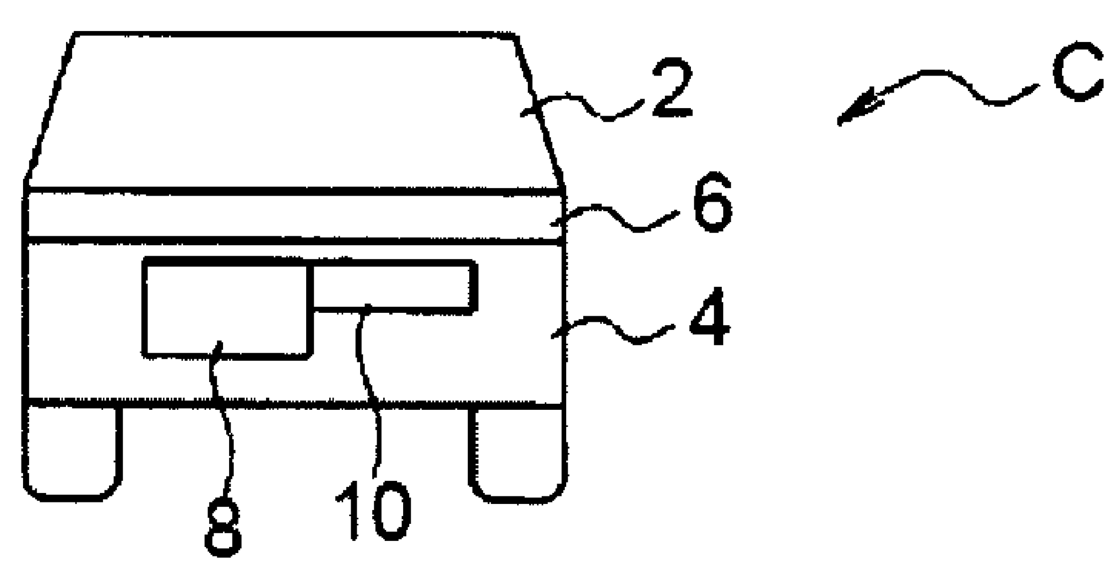


FIG. 2

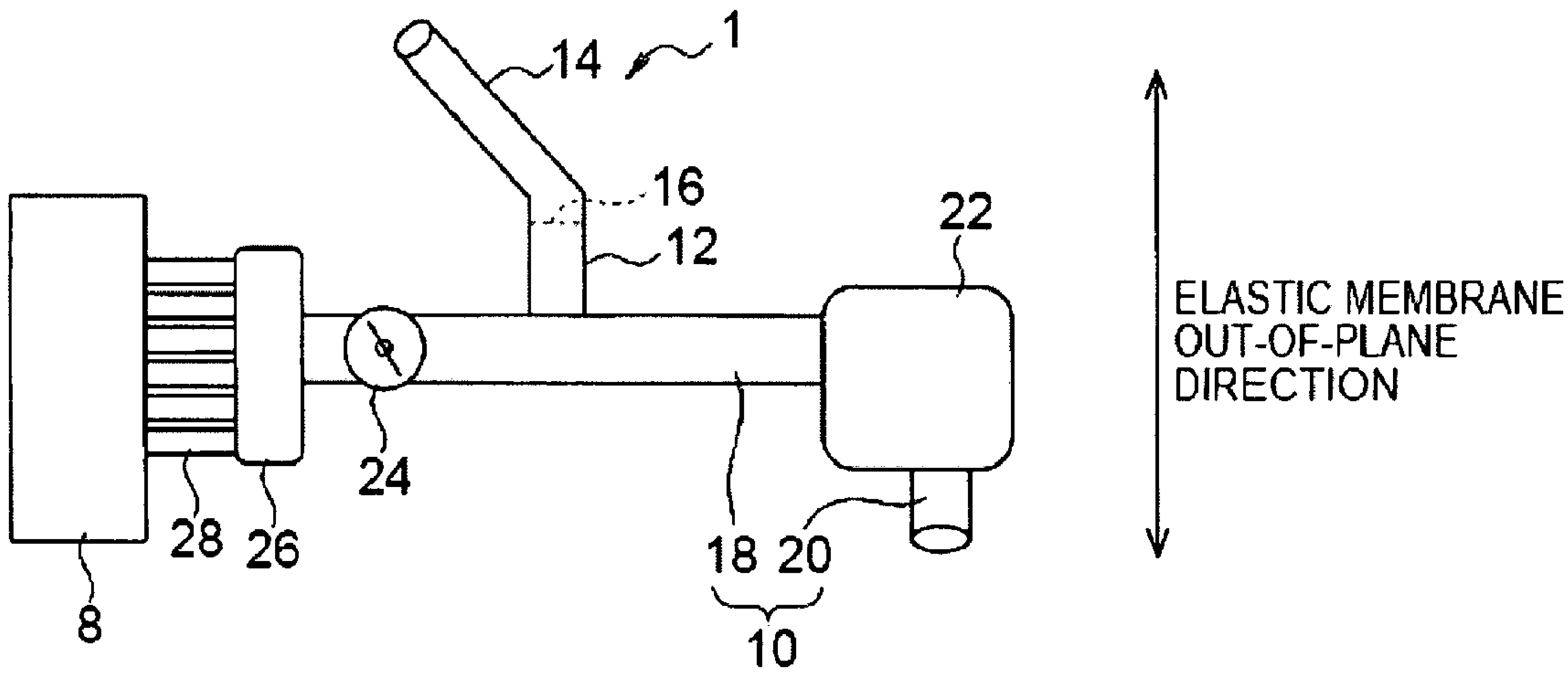

14
1
16
12
22
ELASTIC MEMBRANE OUT-OF-PLANE DIRECTION
24
28
26
8
18
20
10

FIG. 3

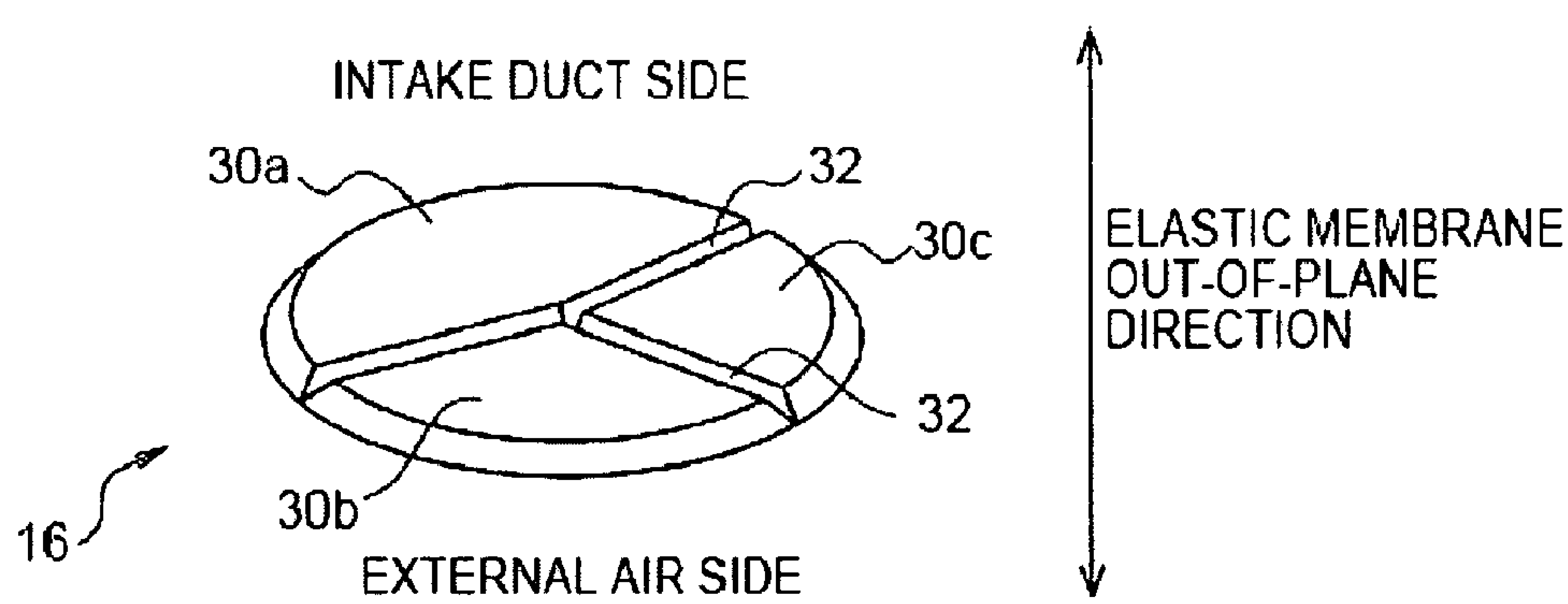

INTAKE DUCT SIDE
30a
32
30c
ELASTIC MEMBRANE OUT-OF-PLANE DIRECTION
32
16
30b
EXTERNAL AIR SIDE

FIG. 4

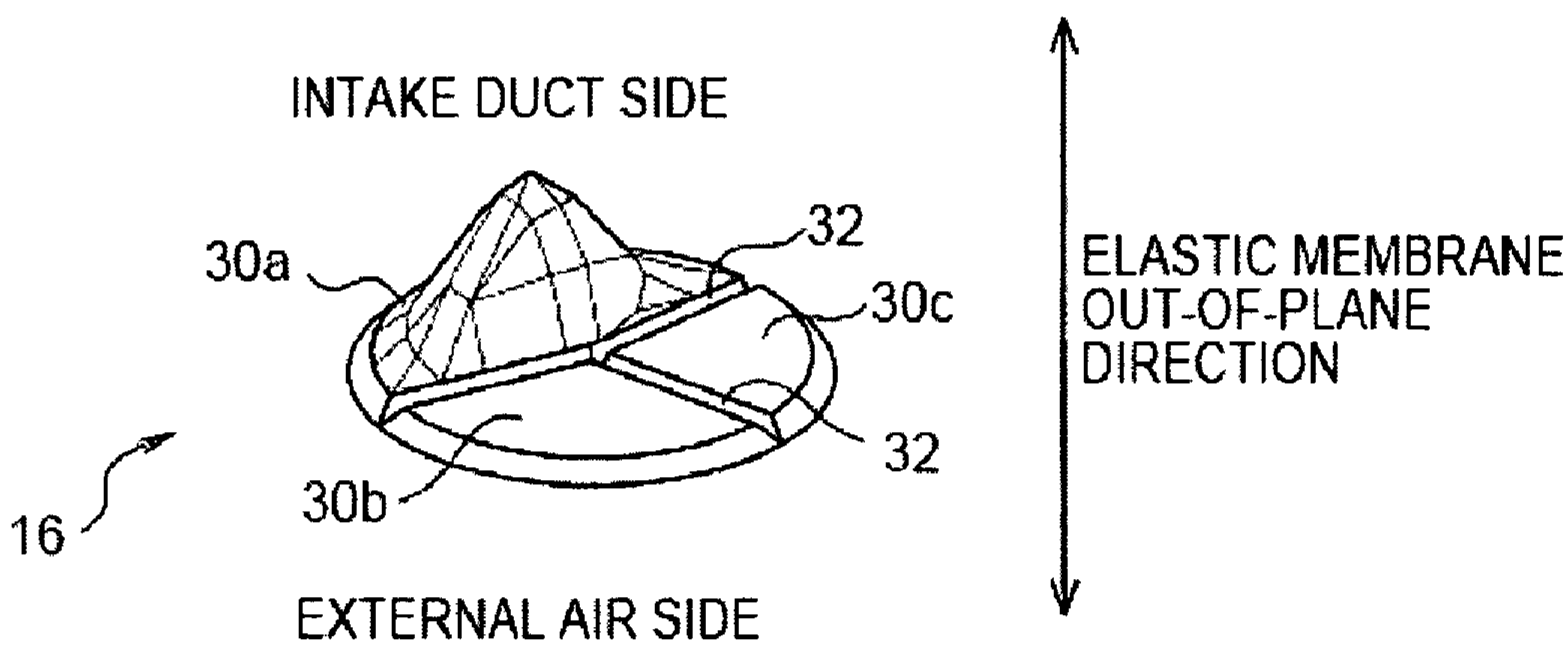

INTAKE DUCT SIDE
30a
32
30c
32
30b
16
EXTERNAL AIR SIDE
ELASTIC MEMBRANE
OUT-OF-PLANE
DIRECTION

FIG. 5

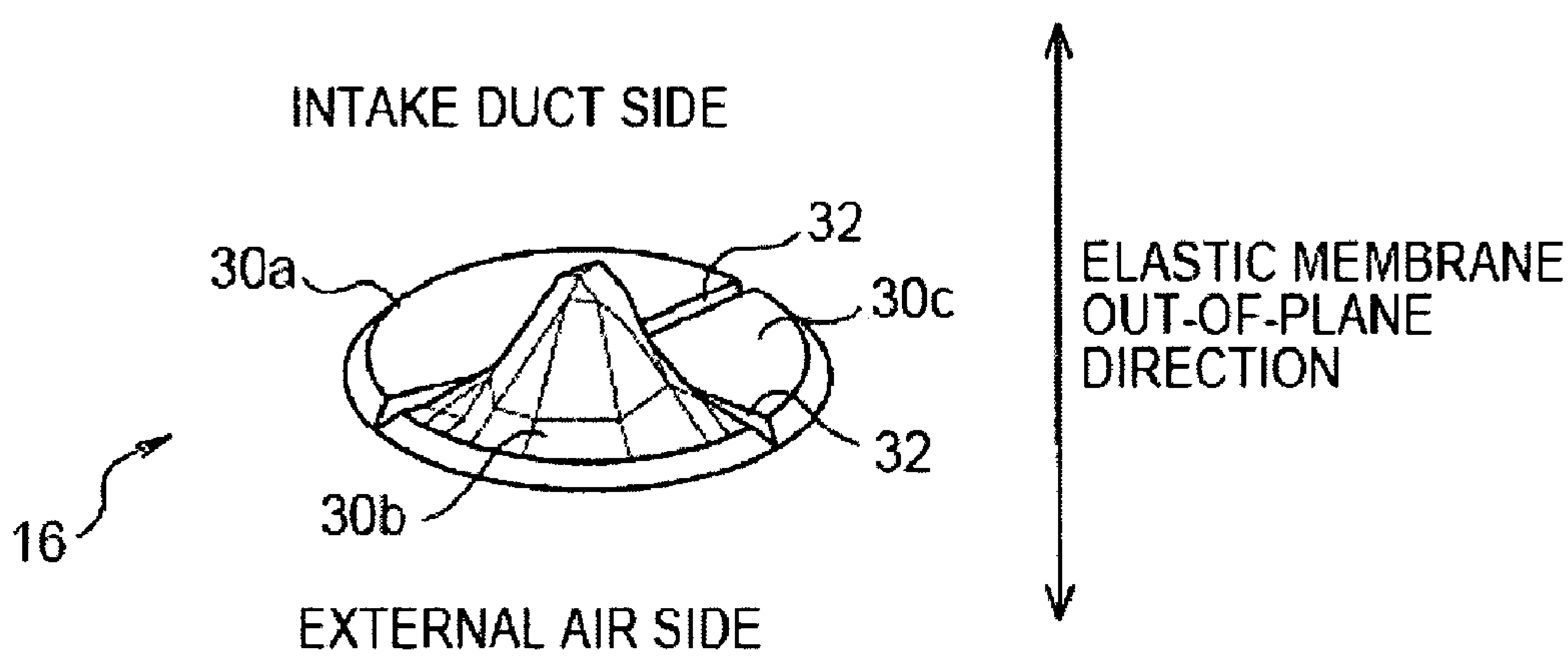

INTAKE DUCT SIDE
30a
32
30c
32
30b
16
EXTERNAL AIR SIDE
ELASTIC MEMBRANE
OUT-OF-PLANE
DIRECTION

FIG. 6

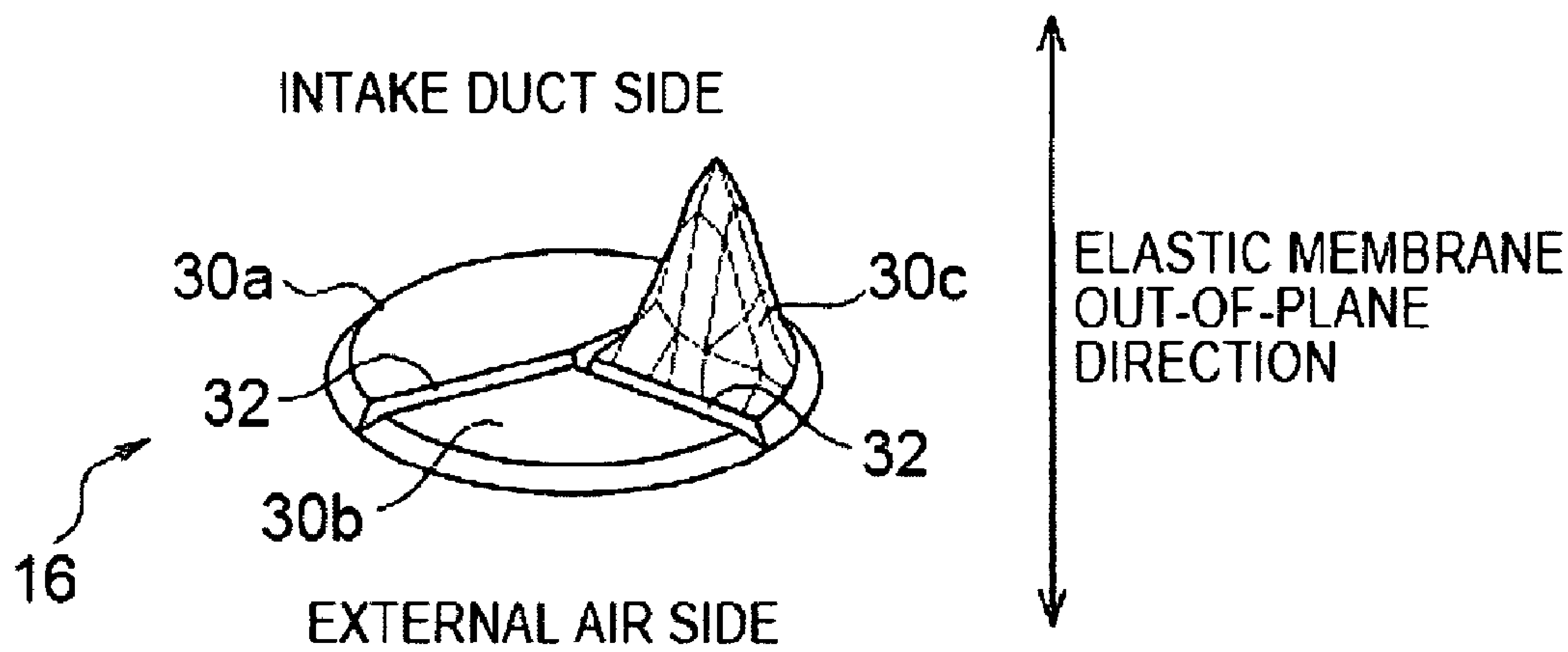

INTAKE DUCT SIDE
30a
30c
32
32
30b
16
EXTERNAL AIR SIDE
ELASTIC MEMBRANE
OUT-OF-PLANE
DIRECTION

FIG. 7

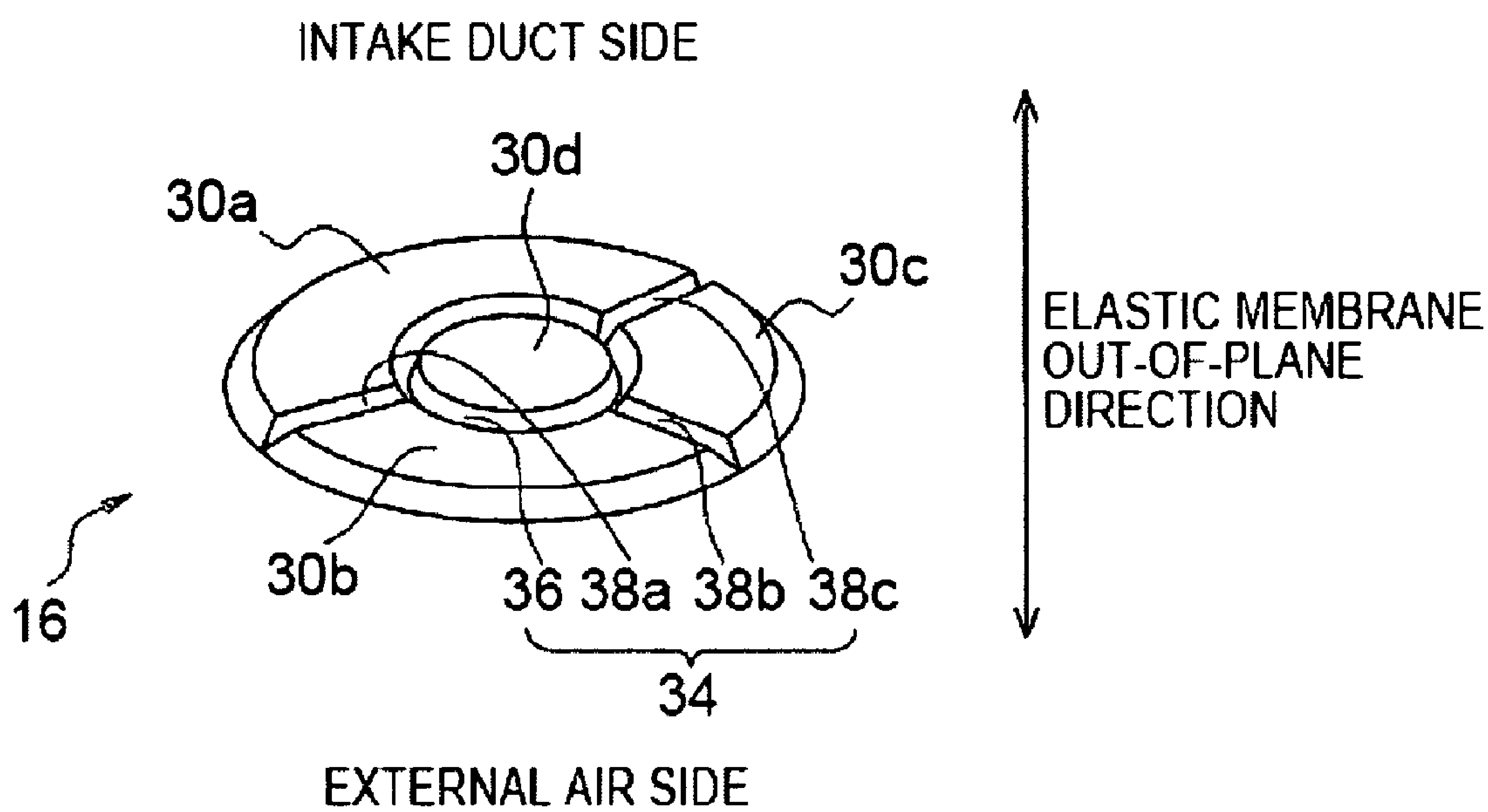

INTAKE DUCT SIDE
30d
30a
30c
30b
16
36 38a 38b 38c
34
EXTERNAL AIR SIDE
ELASTIC MEMBRANE
OUT-OF-PLANE
DIRECTION

FIG. 8

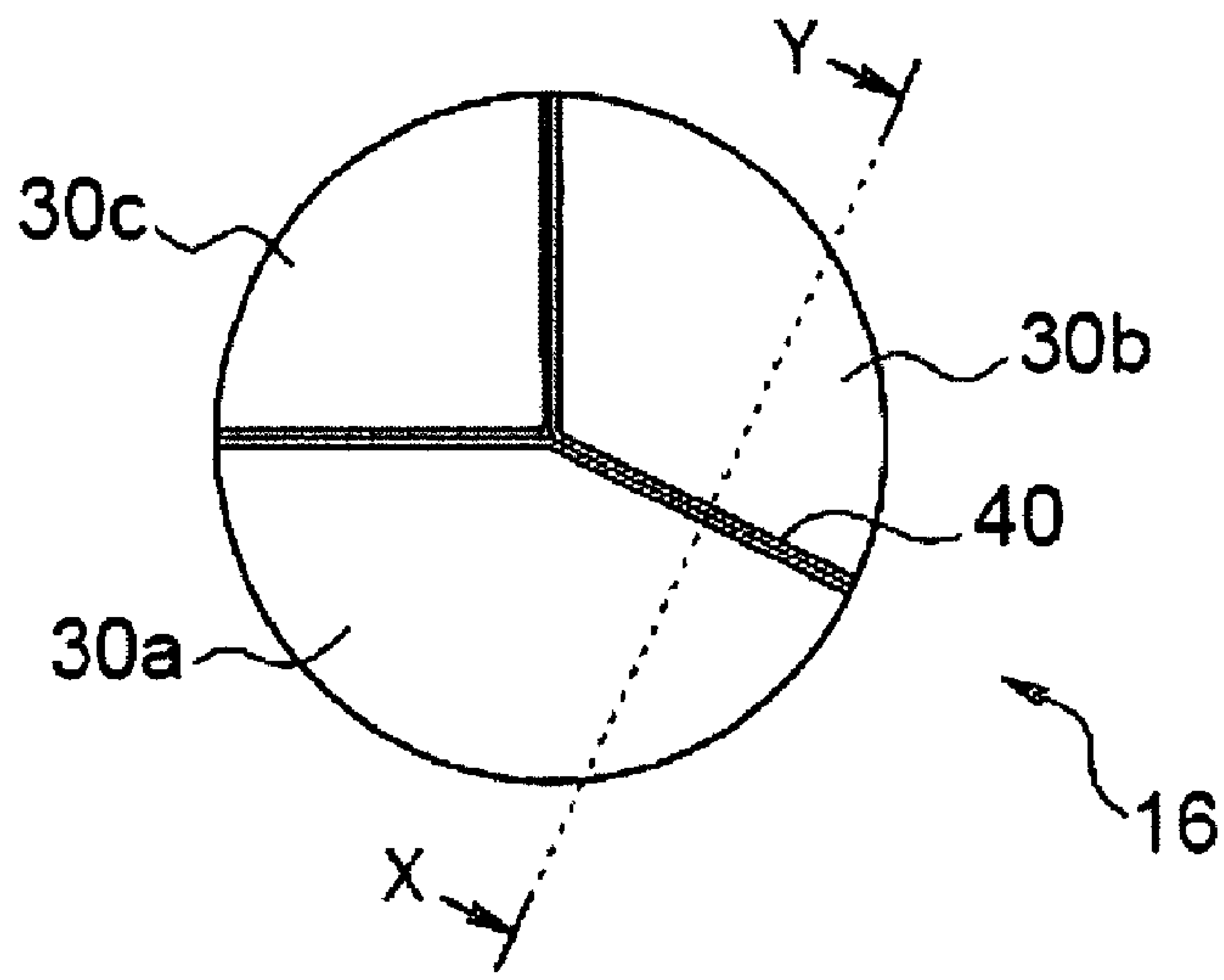


FIG. 9

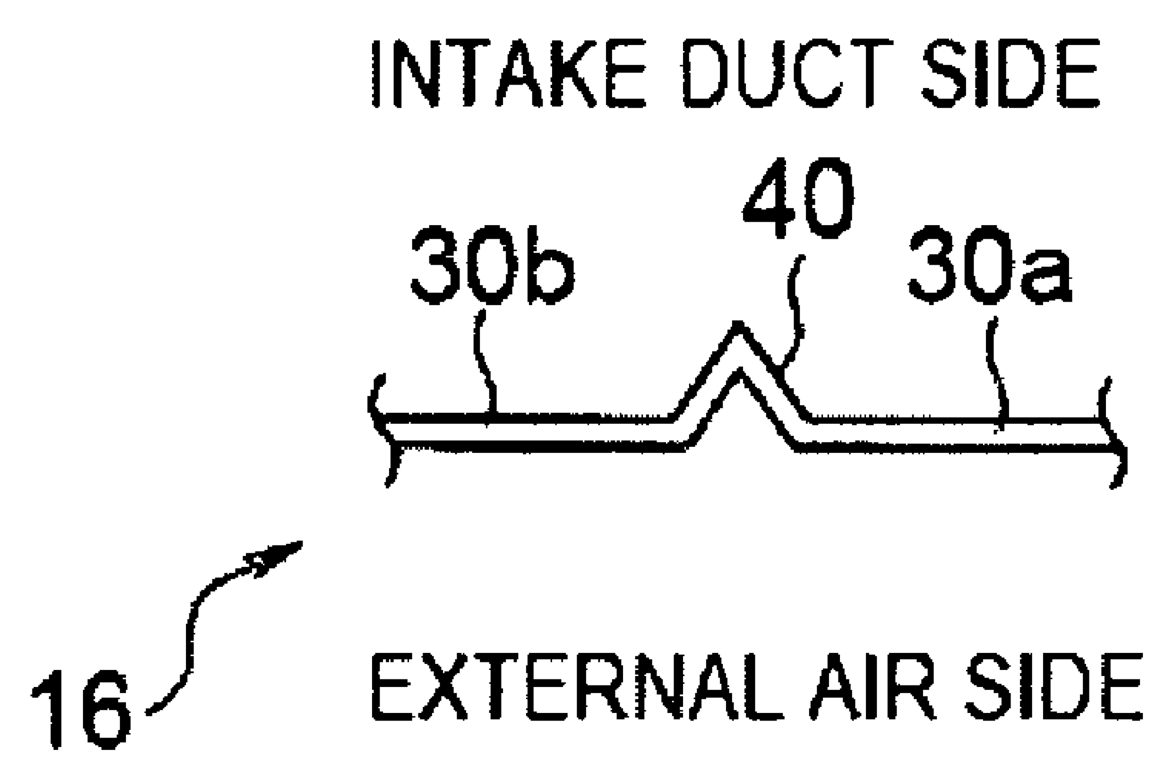


FIG. 10A

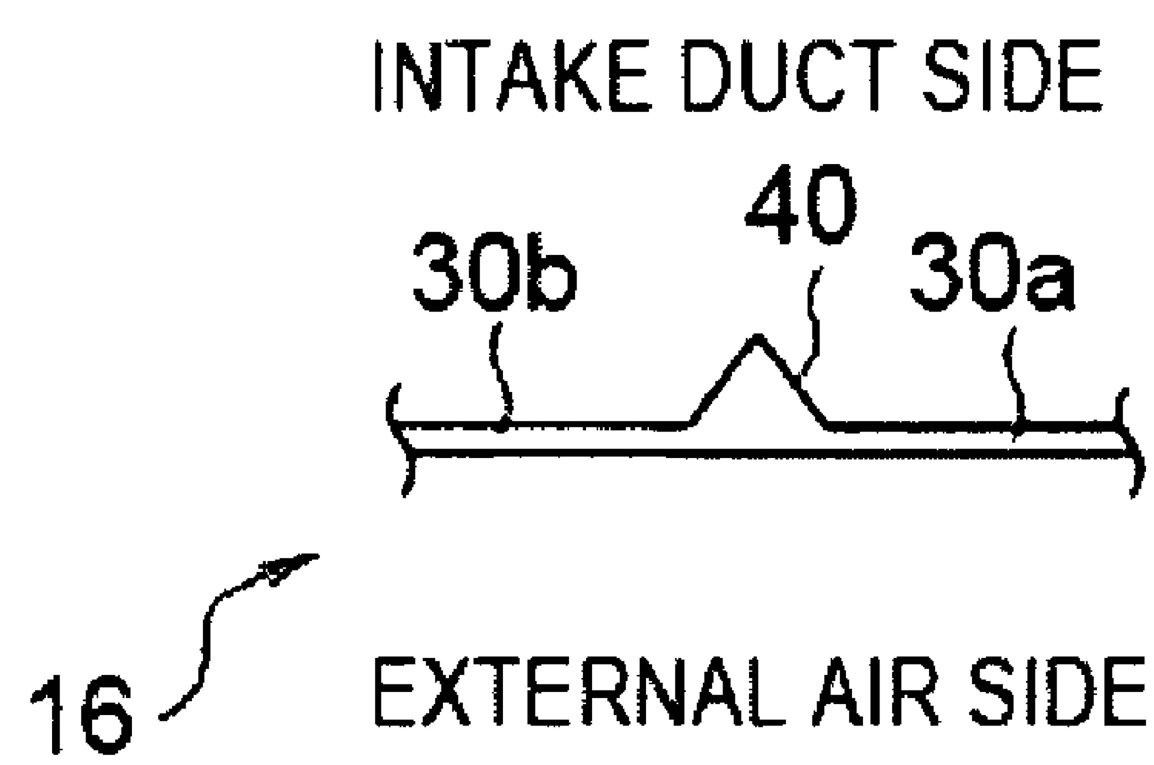


FIG. 10B

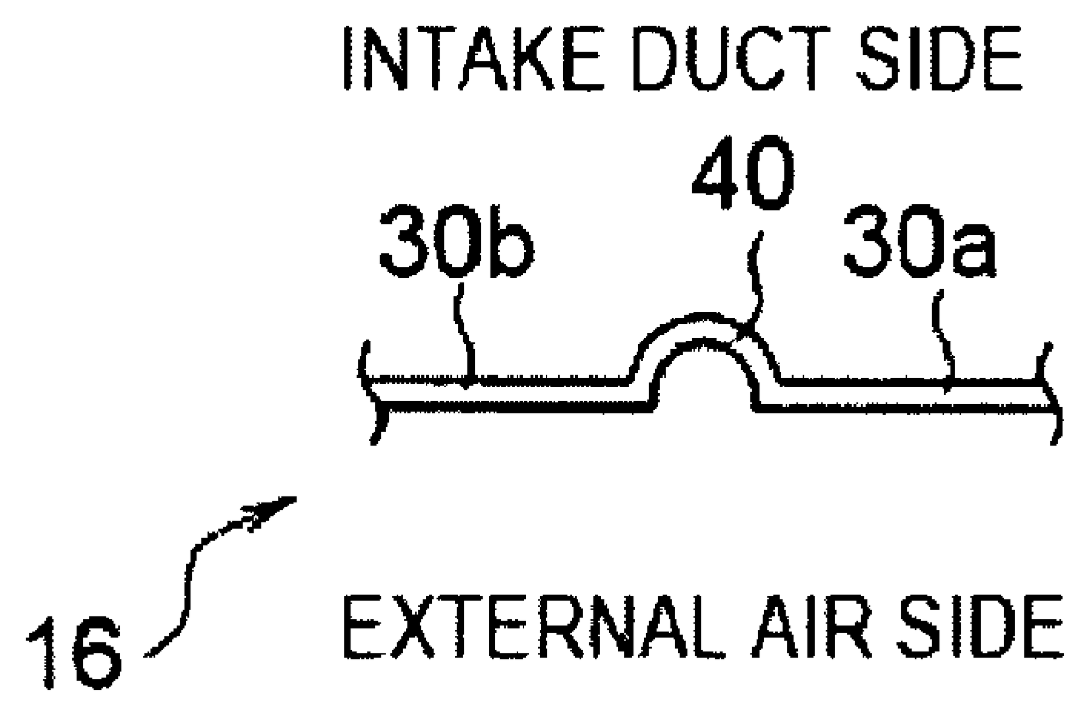


FIG. 10C

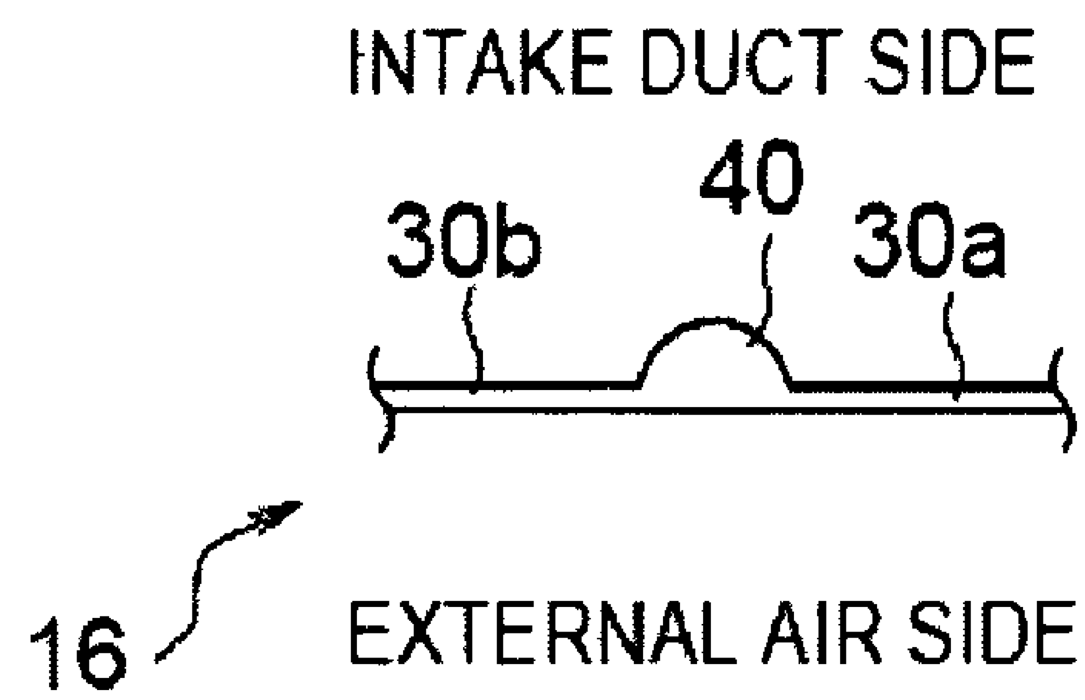


FIG. 11A

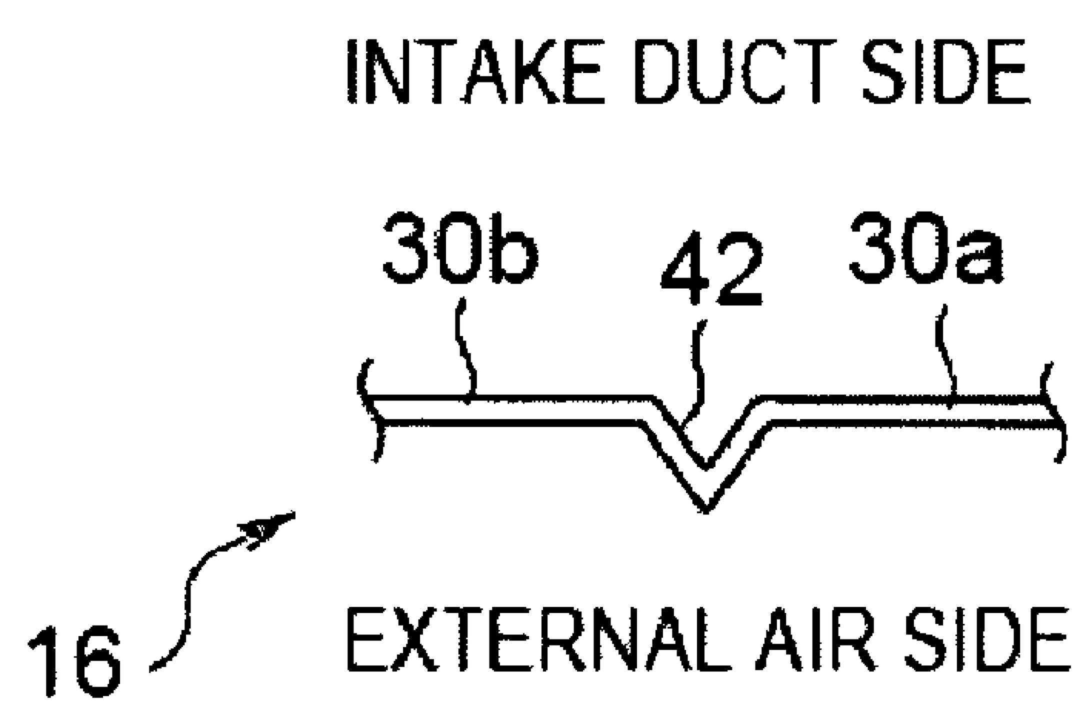


FIG. 11B

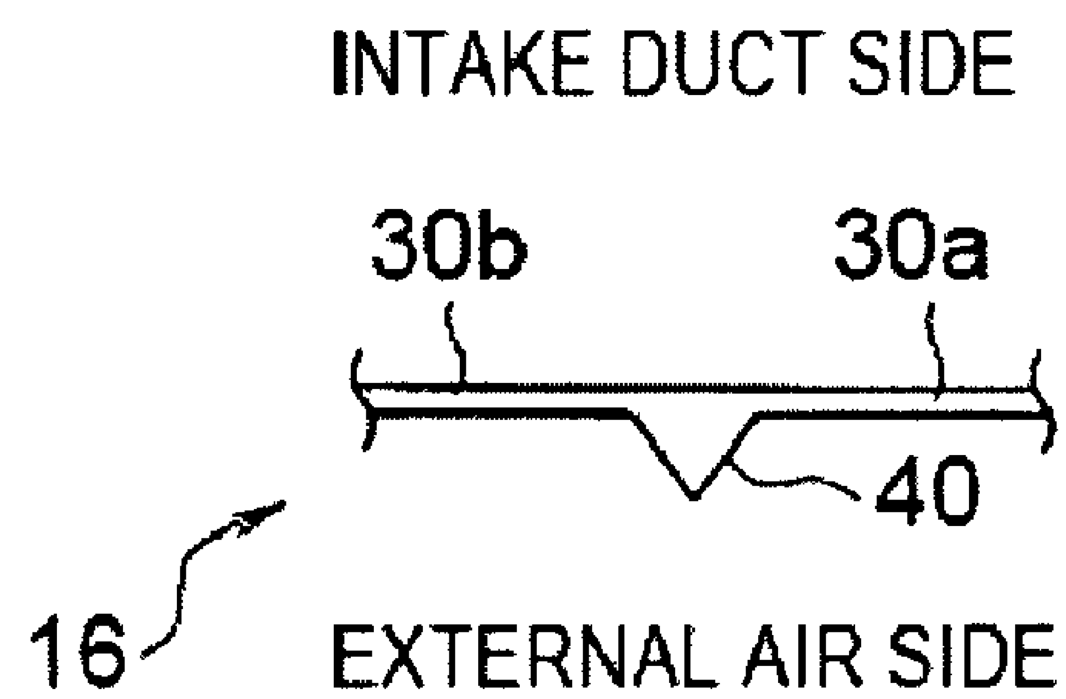


FIG. 11C

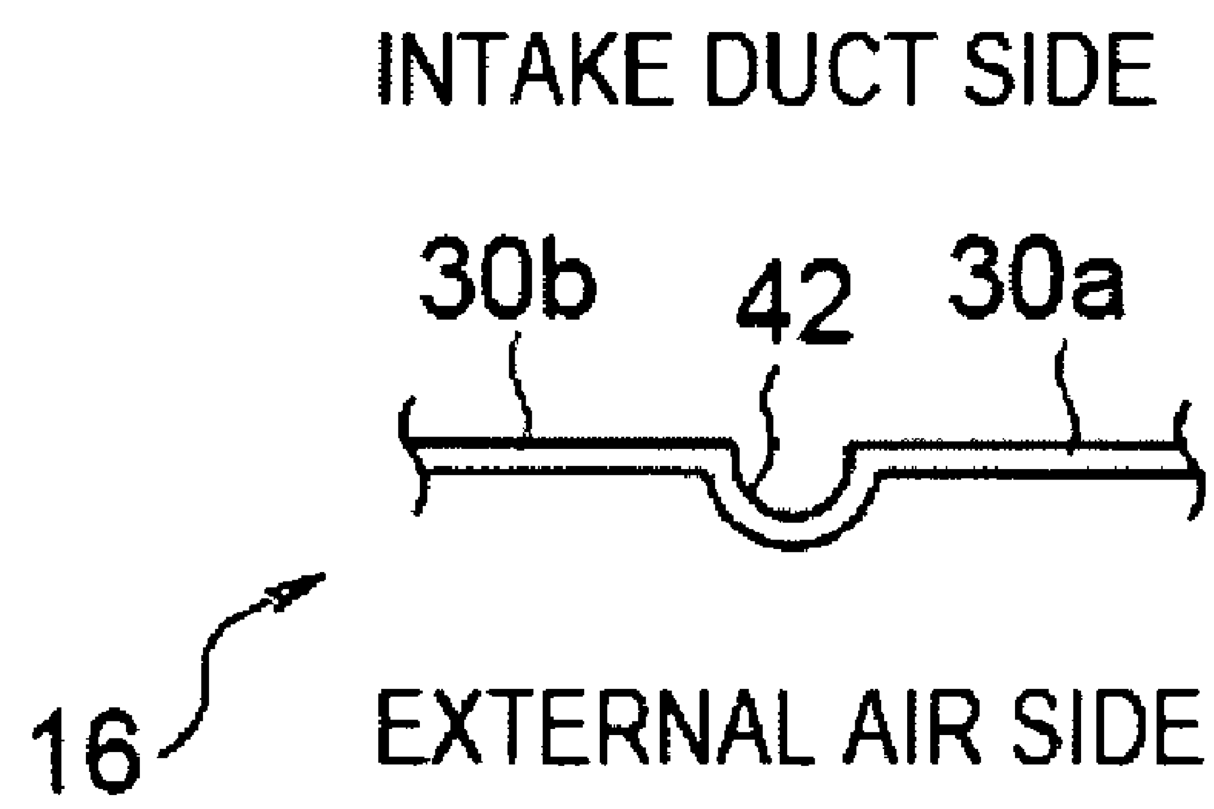


FIG. 11D

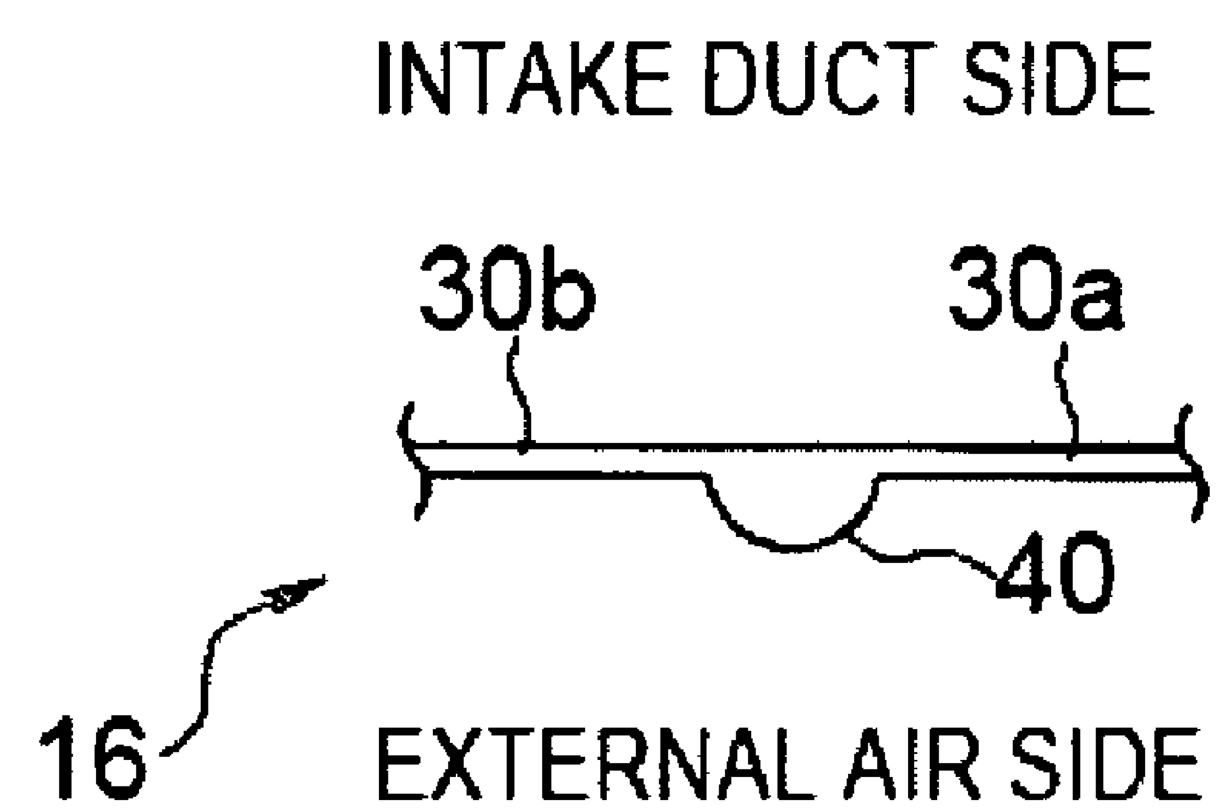


FIG. 12

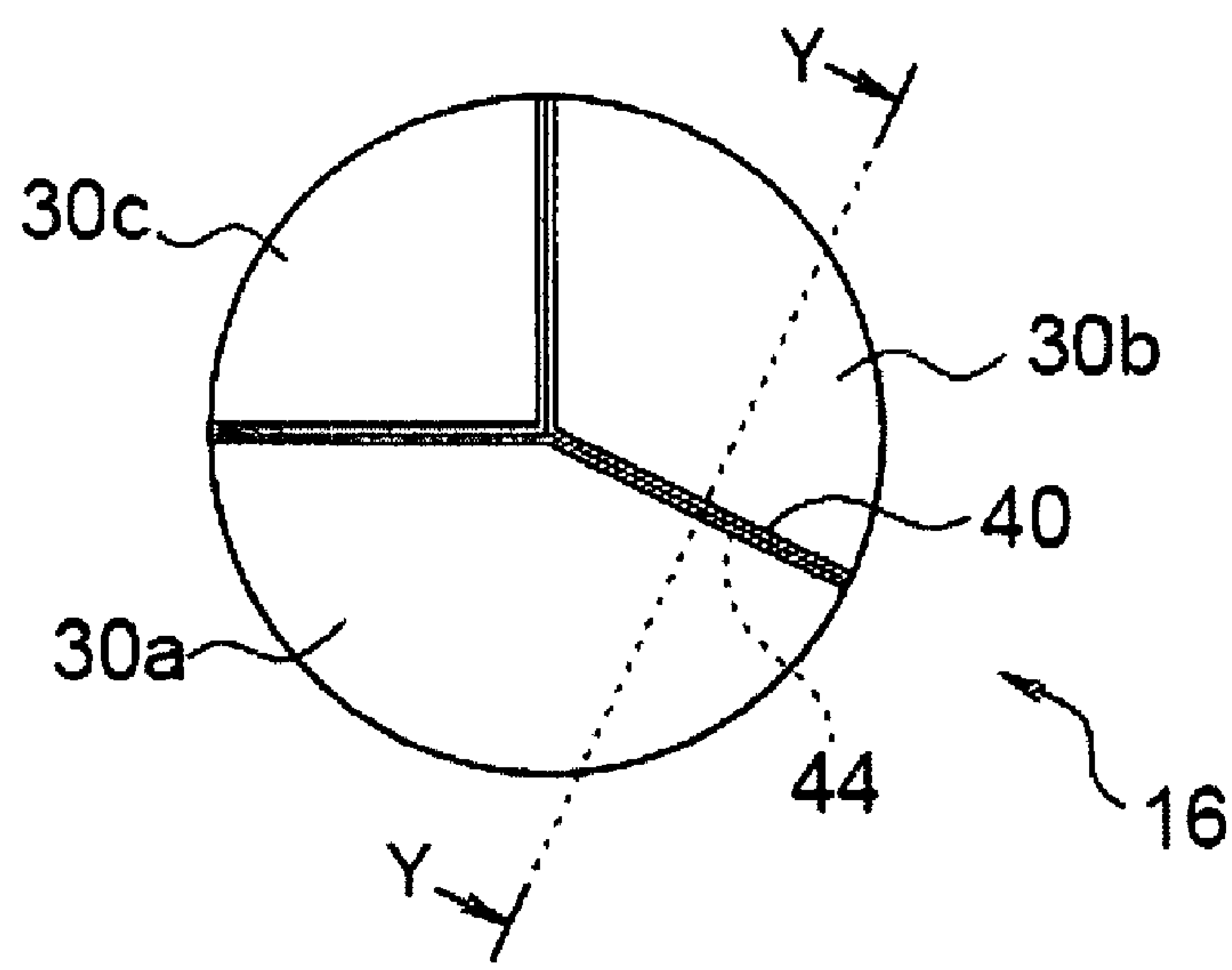


FIG. 13

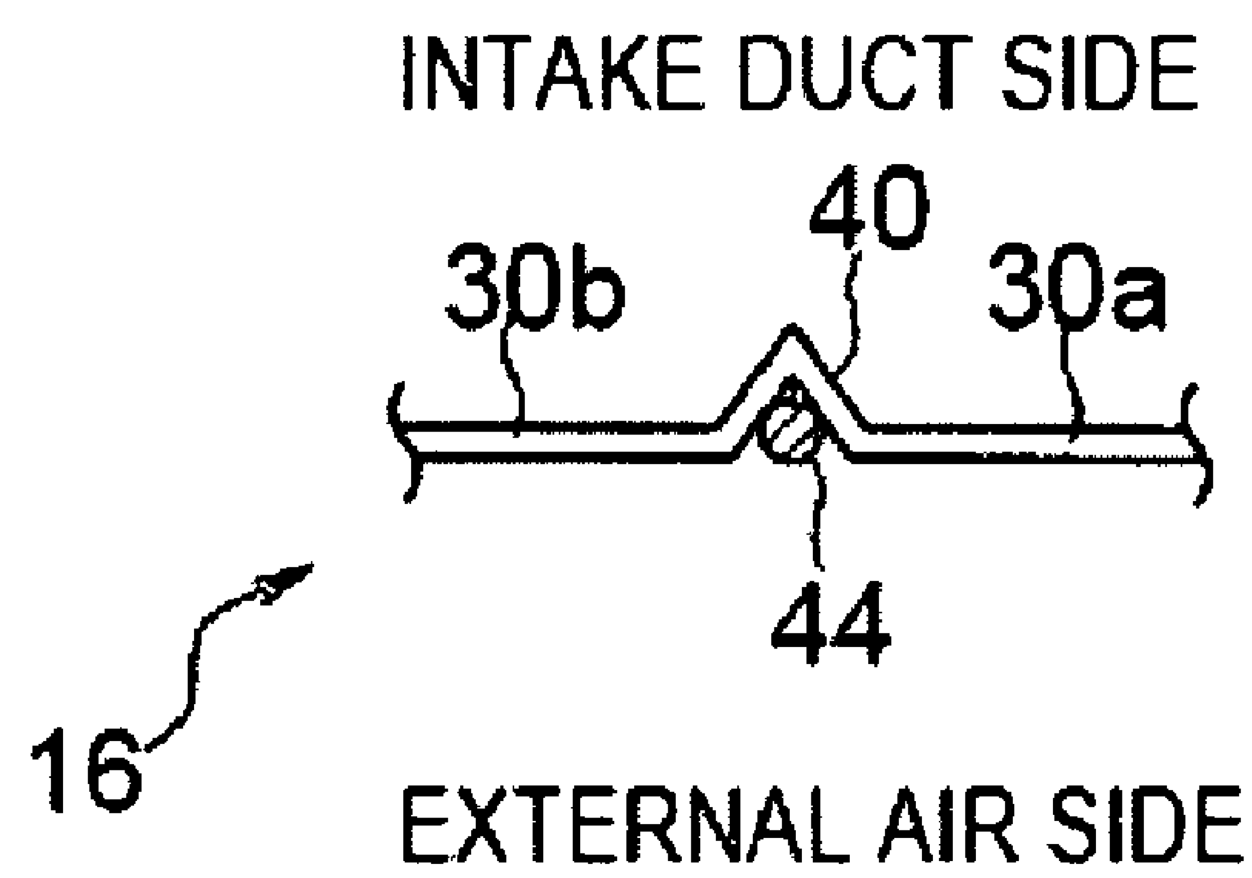


FIG. 14A

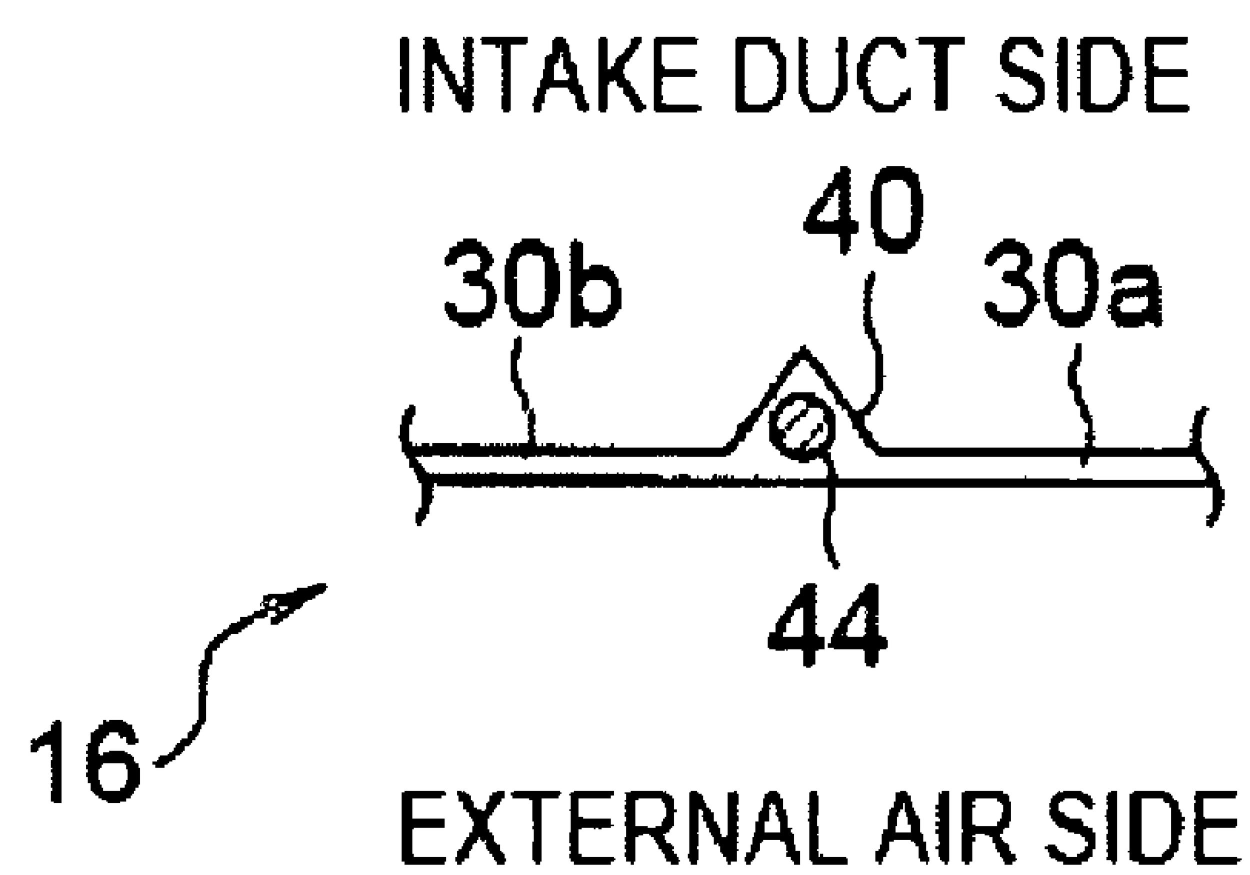


FIG. 14B

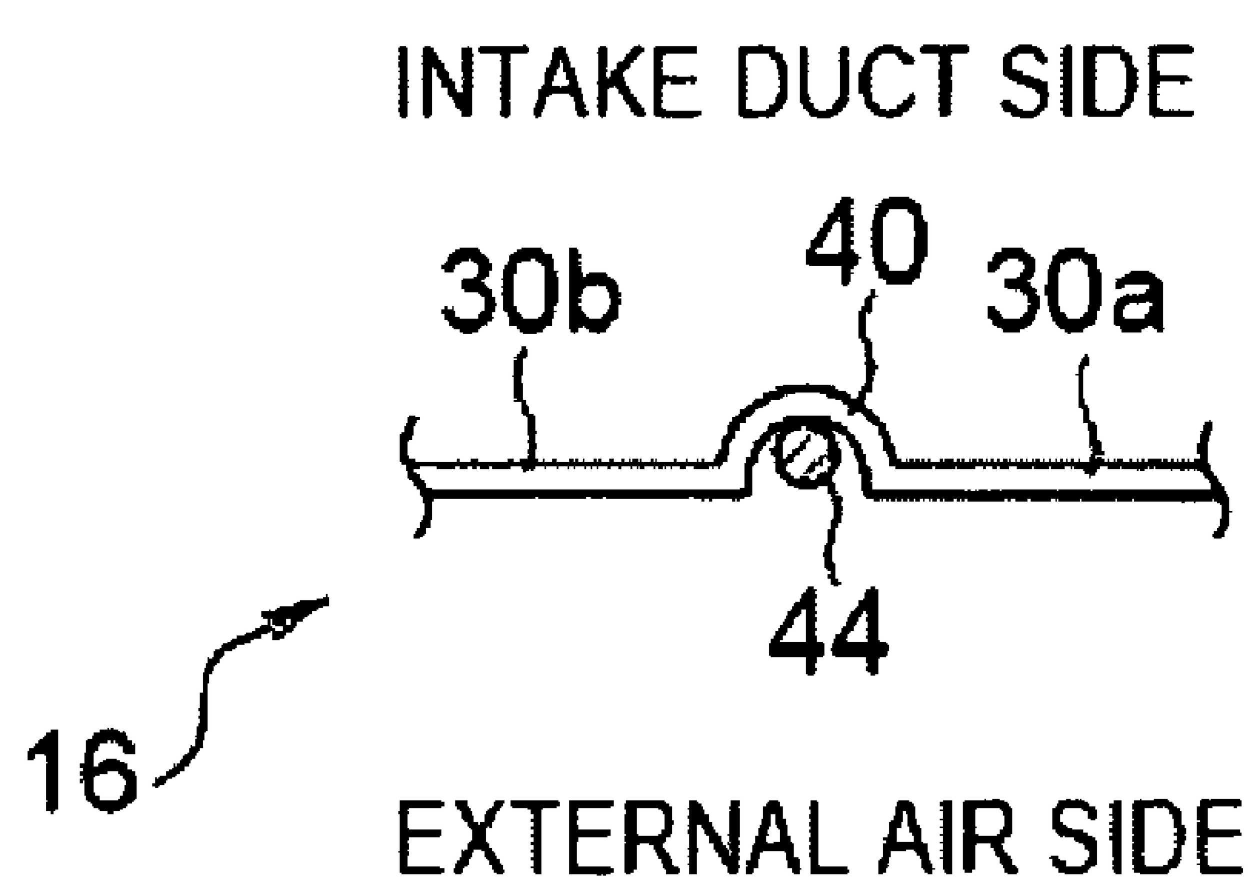


FIG. 14C

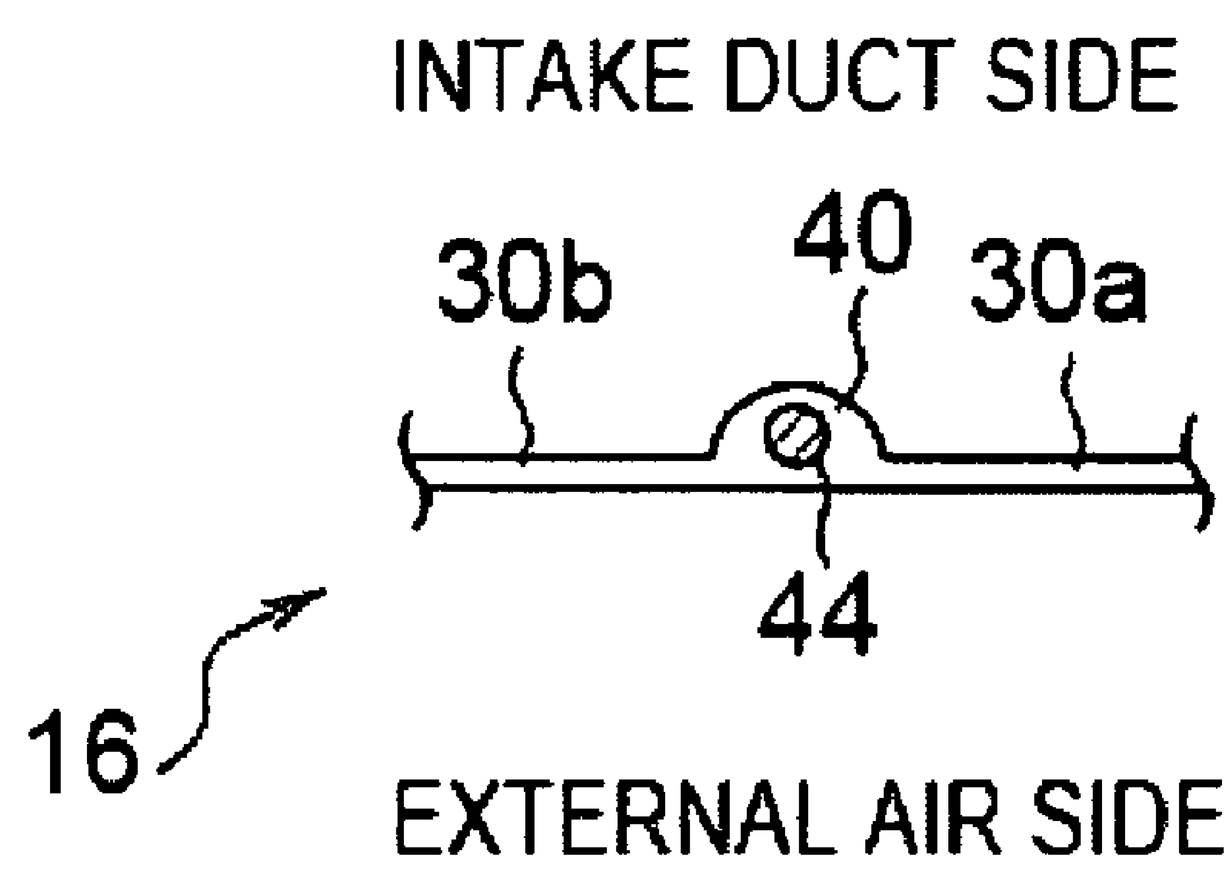


FIG. 15A

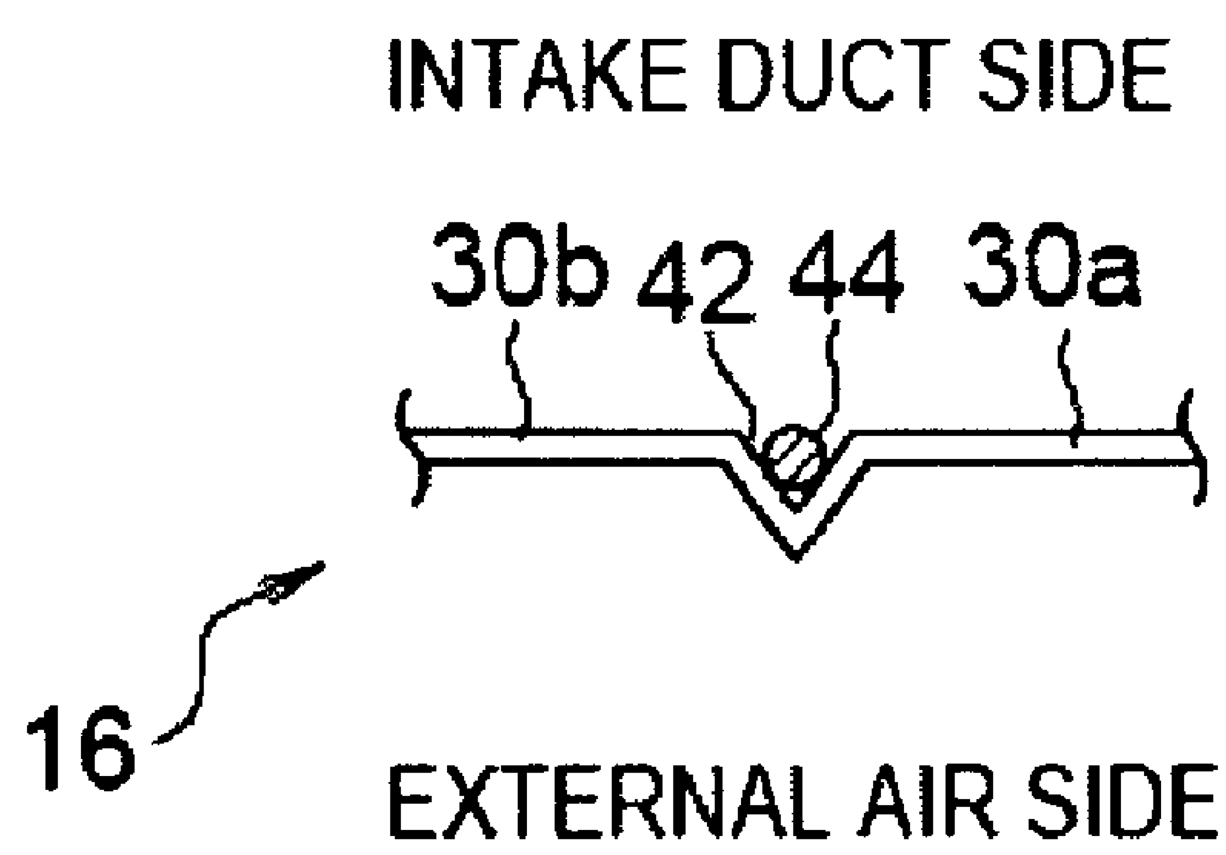


FIG. 15B

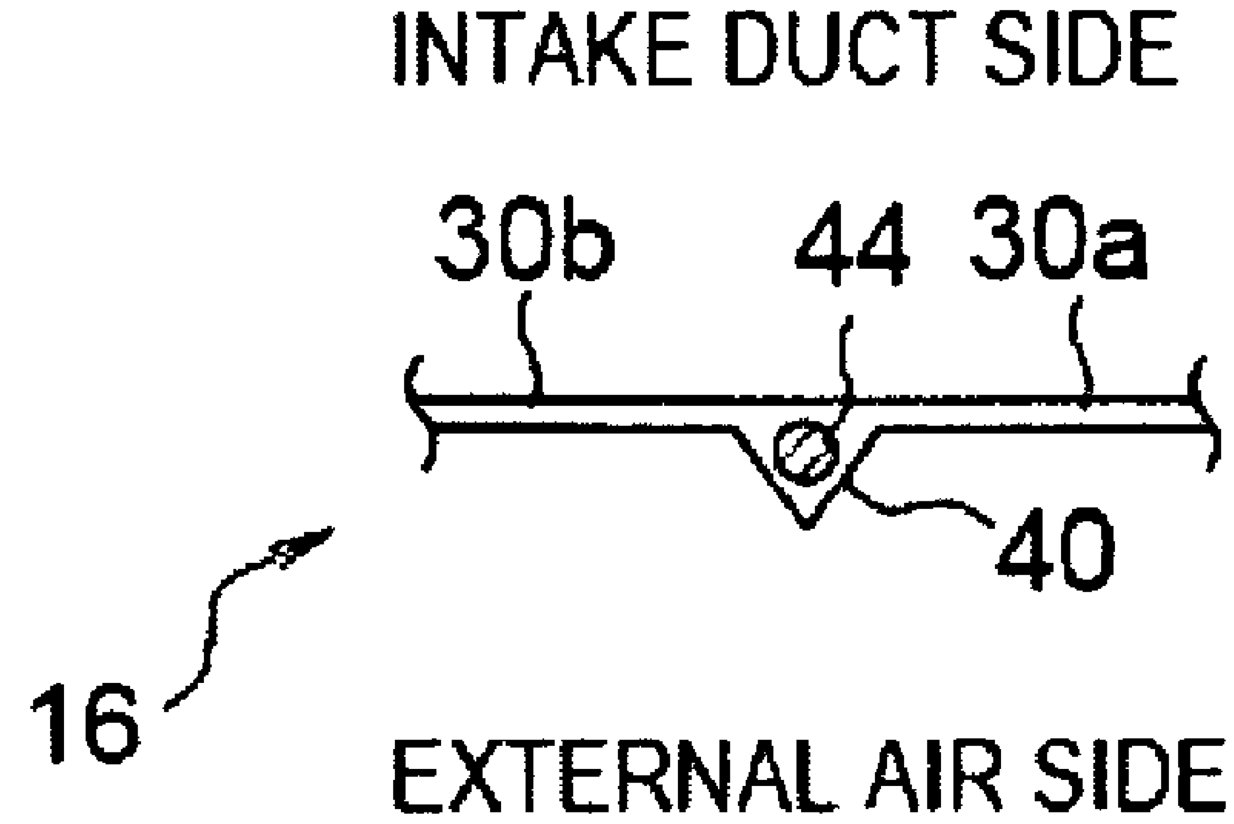


FIG. 15C

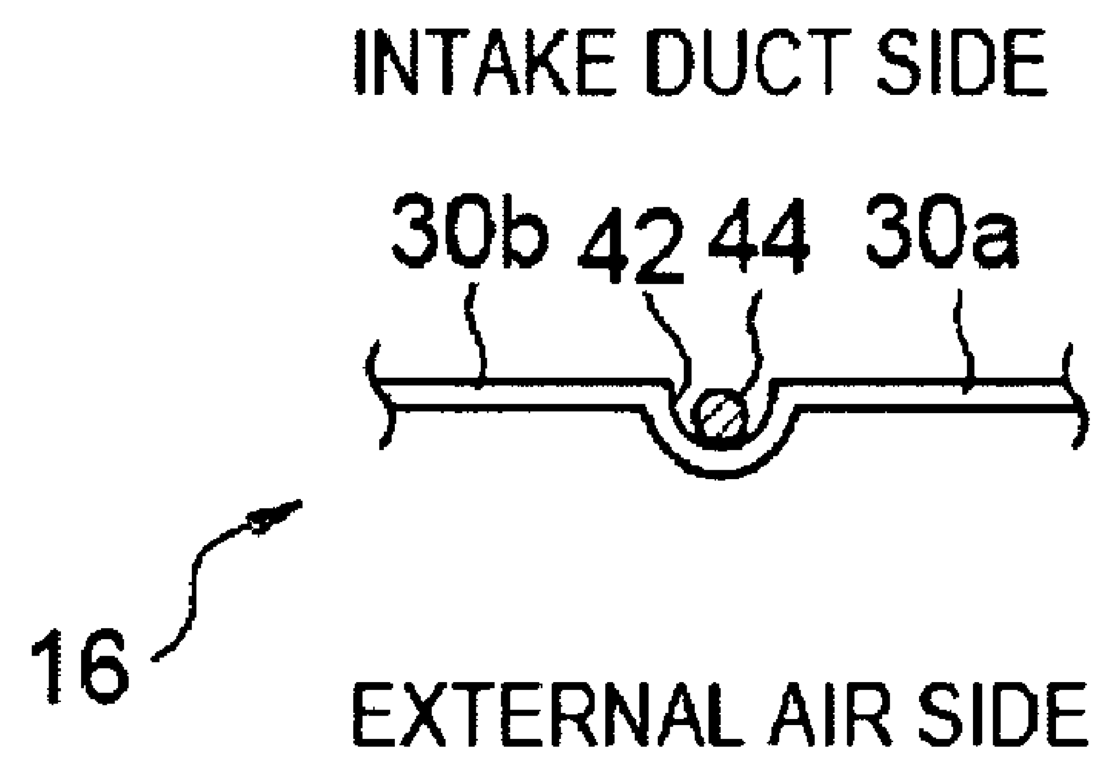


FIG. 15D

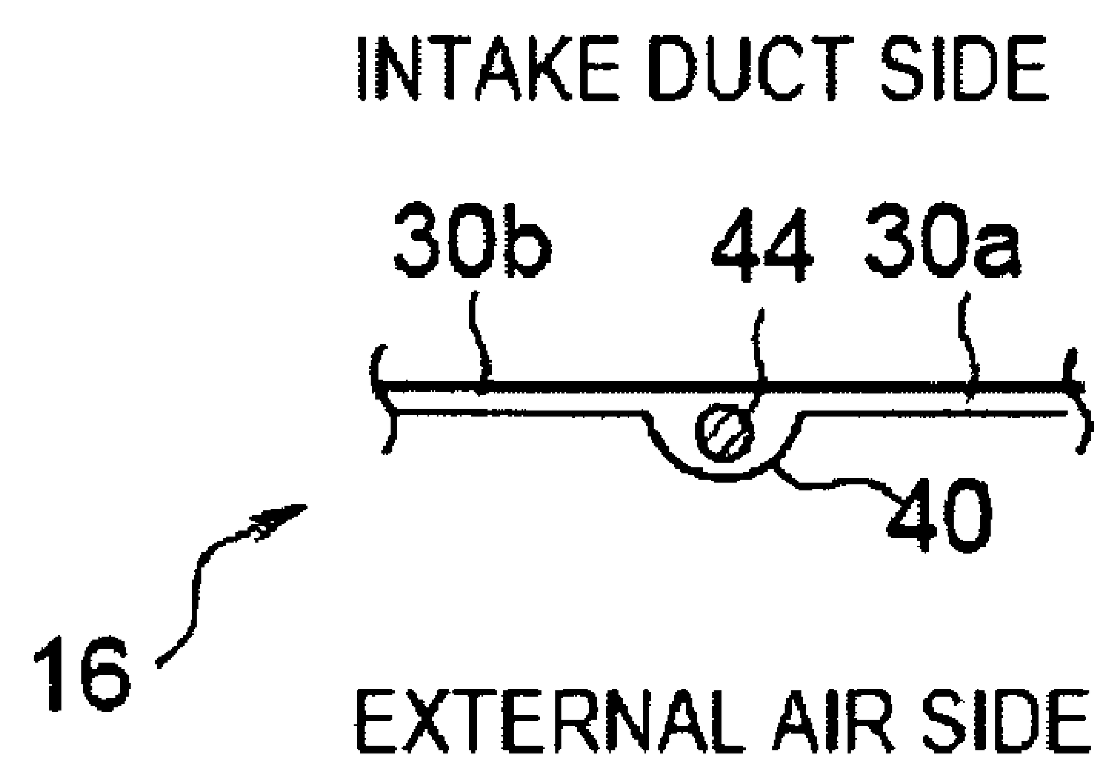
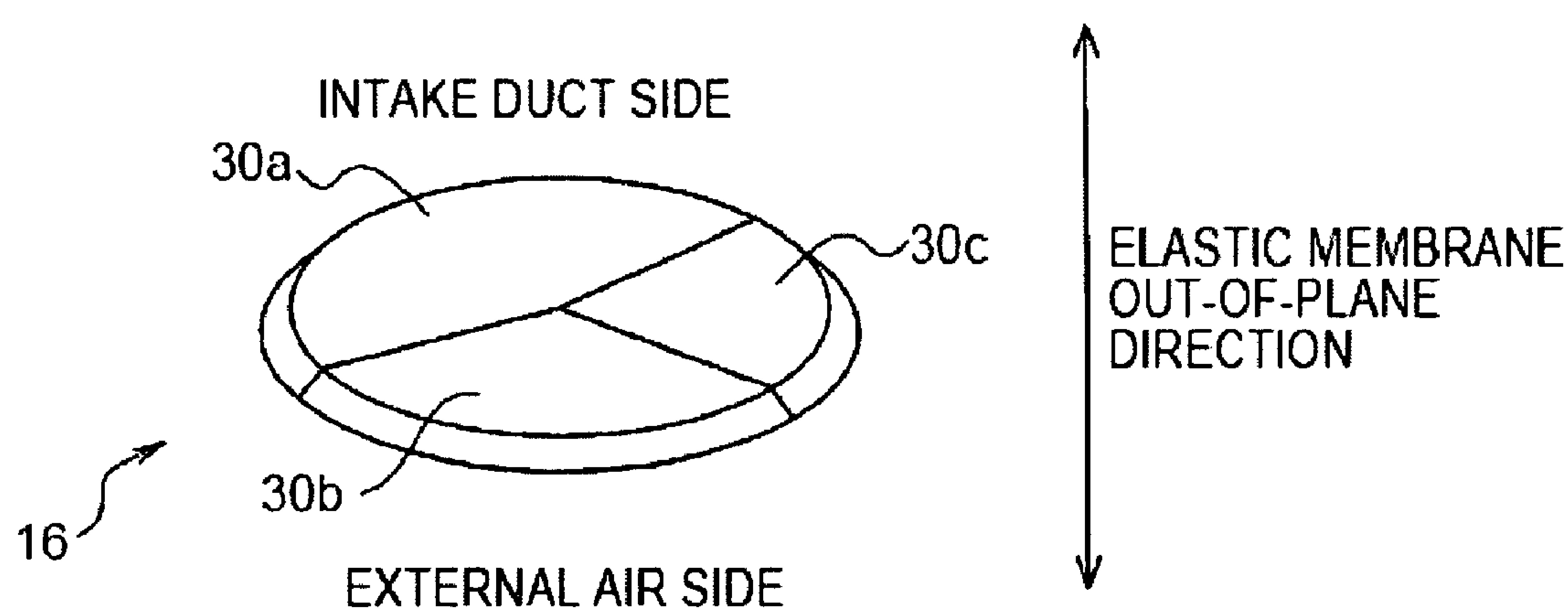


FIG. 16



DEVICE AND METHOD FOR AMPLIFYING SUCTION NOISE

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from Japanese Patent Application Serial No. [2006-155944] *2006-155945* filed Jun. 5, 2006[, the disclosure of which, including its specification, drawings and claims, are incorporated herein by reference in its entirety].

TECHNICAL FIELD

The present disclosure pertains to a type of device for improving the sound quality of a suction noise generated by an intake system of an automobile or the like.

BACKGROUND

Japanese Patent No. 3613665 describes a known device that boosts suction noise. The device described therein is for amplifying suction noise and has plural intake ducts having resonance frequencies that are different from each other, so that it is possible to boost the suction noise at different frequencies, and permits introduction of suction noise into the vehicle passenger compartment.

However, the device for amplifying suction noise described in Japanese Patent No. 3613665 has some disadvantages. First, because the device is constituted with plural intake ducts, there is no leeway in the space required inside the engine compartment. Thus, there are restrictions on the layout, and the device is difficult to install in the engine compartment.

SUMMARY

The present disclosure provides a device to boost the suction noise of a vehicle characterized by the fact that resonance of an elastic membrane, due to variation in pressure of air transmitted into an engine intake port, is allowed to occur at least two different frequencies.

According to the present disclosure, it is possible to boost suction noise at plural frequencies without the need of plural intake ducts, so that it is possible to generate impressive suction noise, and at the same time to improve the freedom of design layout.

One embodiment of the disclosure includes a device for amplifying the suction noise of a vehicle. The embodiment of the device comprises an intake duct, a connecting pipe and a composite membrane. The intake duct is for feeding air to an engine intake port. A connecting pipe is connected to an interior of the intake duct. The composite membrane is positioned within the connecting pipe. The composite member blocks an interior passage formed in the connecting pipe. The composite member further includes at least two elastic membranes with one of masses and rigidities that different from each other. A method is also disclosed.

BRIEF DESCRIPTION OF DRAWINGS

Other features and advantages of the present disclosure will be apparent from the ensuing description, taken in conjunction with the accompanying drawings, in which:

FIG. **1**A is a side elevational view of a vehicle equipped with a device for amplifying a suction noise of a vehicle.

FIG. **1**B is a top plan view of the vehicle of FIG. **1**A.

FIG. **1**C is a front elevational view of the vehicle of FIG. **1**A.

FIG. **2** is a diagram illustrating the structure of the device for amplifying suction noise according to a first embodiment.

FIG. **3** is a diagram illustrating in detail the structure of a composite membrane.

FIG. **4** is a diagram illustrating a vibration state of each elastic membrane in an out-of-plane direction of the composite membrane during a first acceleration mode.

FIG. **5** is a diagram illustrating a vibration state of each elastic membrane in the out-of-plane direction of the composite membrane during a second acceleration mode.

FIG. **6** is a diagram illustrating the vibration state of each elastic membrane in an out-of-plane direction of the composite membrane during a third acceleration mode.

FIG. **7** is a diagram illustrating the structure of a composite membrane of the device for amplifying the suction noise of a vehicle in a second embodiment.

FIG. **8** is a diagram illustrating the structure a composite membrane of the device for amplifying the suction noise of a vehicle in a third embodiment

FIG. **9** is a cross section of the composite membrane taken across X-Y in FIG. **8**.

FIGS. **10**A-**10**C are diagrams illustrating modified examples of the composite membrane of the device for amplifying the suction noise of a vehicle in the third embodiment.

FIG. **11**A-**11**D are diagrams illustrating modified examples of the composite membrane of the device for amplifying the suction noise of a vehicle in the third embodiment.

FIG. **12** is a diagram illustrating the structure of the composite membrane of the device for amplifying the suction noise of a vehicle in a forth embodiment.

FIG. **13** is a cross section of the composite membrane taken across Y-Y in FIG. **12**.

FIGS. **14**A-**14**C are diagrams illustrating modified examples of the composite membrane of the device for amplifying the suction noise of a vehicle the fourth embodiment.

FIGS. **15**A-**15**D are diagrams illustrating modified examples of the composite membrane of the device for amplifying the suction noise of a vehicle in the fourth embodiment.

FIG. **16** is a diagram illustrating the structure of a composite membrane for the device for amplifying the suction noise of a vehicle in a fifth embodiment.

DETAILED DESCRIPTION

While the claims are not limited to the illustrated embodiments, an appreciation of various aspects of the apparatus is best gained through a discussion of various examples thereof. Referring now to the drawings, illustrative embodiments are shown in detail. Although the drawings represent the embodiments, the drawings are not necessarily to scale and certain features may be exaggerated to better illustrate and explain an innovative aspect of an embodiment. Further, the embodiments described herein are not intended to be exhaustive or otherwise limiting or restricting to the precise form and configuration shown in the drawings and disclosed in the following detailed description. Exemplary embodiments of the present invention are described in detail by referring to the drawings as follows.

Embodiment 1

FIGS. **1**A-**1**C includes diagrams illustrating a vehicle C carrying a device **1** for amplifying suction noise according to a first embodiment. FIG. **1**A is a side view of a vehicle C. FIG. **1**B is a top view of vehicle C. And FIG. **1**C is a front view of vehicle C.

As can be seen from FIG. **1**, device **1** that boosts suction noise in the first embodiment is arranged in front of a vehicle passenger compartment **2**. Indeed, device **1** is arranged in an engine compartment **6** that is separated from vehicle passenger compartment **2** by a dash panel **4**. Further, device **1** is arranged on an intake duct **10** that is connected to an engine **8**.

The resonant vibration of air in intake duct **10** takes place in air intake duct **10**. When resonance occurs, pressure variations develop in air in intake duct **10**, and these pressure variations in the air are perceived by humans as noise. The noise accompanying intake is called suction noise. The frequency of the suction noise depends on the frequency of the pressure variations generated due to the resonance phenomenon. The frequency of the pressure variation that takes place due to the resonance phenomenon is determined by the resonance frequency, which depends on the length of the intake duct, etc.

FIG. **2** is a diagram illustrating the structure of device **1** that amplifies the suction noise in the first embodiment. As shown in FIG. **2**, device **1** that amplifies the suction noise in the first embodiment comprises a connecting pipe **12**, an additional pipe **14**, and a composite membrane **16** (represented by dashed lines in FIG. **2**).

In the embodiment shown, connecting pipe **12** is generally cylindrical, and is attached to an outer peripheral surface of intake duct **10**, which may be formed of a draft tube with air inside it. Connecting pipe **12** communicates with intake duct **10**.

Similar to connecting pipe **12**, additional pipe **14** may also be generally cylindrical. A first opening at one end of additional pipe **14** is connected to connecting pipe **12**, and a second opening at the other end of additional pipe **14** opens to external air.

Composite membrane **16** is generally disk-shaped and may be made of, for example, rubber or another elastic material. Composite member **16** is attached on an inner peripheral surface of connecting pipe **12** and extends across an interior of connecting pipe **12** so as to close connecting pipe **12**. Composite membrane **16** undergoes elastic deformation during intake by engine **8**, corresponding to variation in an intake vacuum generated in air inside intake duct **10**, so that vibration of composite membrane **16** occurs in an out-of-plane direction. The detailed structure of composite membrane **16** will be explained later.

The structure of intake duct **10** and the parts related to thereto will now be explained.

Intake duct **10** forms an intake path from the external air to engine **8**, and is comprised of a dust side intake duct **20** and a clean side intake duct **18**.

A first opening at one end of dust side intake duct **20** is connected to an air cleaner **22**, and a second opening at the other end of dust side intake duct **20** opens to the external air.

Clean side intake duct **18** includes a throttle chamber **24**. A first opening at one end of clean side intake duct **18** is connected to air cleaner **22**, and a second opening at the other end of clean side intake duct **18** is connected via a surge tank **26** to various portions of an intake manifold **28** to the various cylinders (not shown in the figure) of engine **8**.

For example, air cleaner **22** includes an oiled filter or other filter part for cleaning air flowing from the second opening at one end of dust side intake duct **10** as it passes through the filter portion.

Throttle chamber **24** is installed between air cleaner **22** and surge tank **26**, and is connected to an accelerator pedal (not shown in the figure). Throttle chamber **24** adjusts the airflow rate from air cleaner **22** to surge tank **26** corresponding to the amount of accelerator pedal depression. When the amount of accelerator pedal depression is reduced, the airflow rate from air cleaner **22** to surge tank **26** is decreased, so that the rotational velocity of engine **8** falls, and at the same time the intake vacuum generated in the air inside intake duct **10** is reduced. On the other hand, when the amount of accelerator pedal depression is increased, the airflow rate from air cleaner **22** to surge tank **26** is increased, so that the rotational velocity of engine **8** rises, and at the same time, the intake vacuum generated in the air in intake duct **10** is increased.

During intake, engine **8** draws air that has flowed from the opening at the second end of dust side intake duct **20** and is present inside clean side intake duct **18** into the various cylinders via surge tank **26** and intake manifold **28**.

Also, in conjunction with the intake operation, engine **8** becomes a pressure source that generates intake pulsation in the air inside intake duct **10**, and this intake pulsation results in suction noise.

Here, the intake pulsation that occurs in conjunction with the intake operation of engine **8** is a pressure variation generated in the air inside intake duct **10**. This pressure variation is composed of plural pressure variations at different frequencies. That is, the intake pulsation that occurs in conjunction with the intake operation of engine **8** is composed of plural intake pulsations at different frequencies. In the first embodiment, engine **8** is assumed to be a 6-cylinder in-line engine. However, engine **8** is not limited to this construction.

FIG. **3** is a diagram illustrating the detailed structure of composite membrane **16**.

Viewed in the thickness direction of composite membrane **16**, as may be seen, composite membrane **16** includes three elastic membranes **30**a-**30**c. Elastic membranes **30**a-**30**c are separated from each other by slots **32** formed in the surface on an intake duct side of composite membrane **16**. In the embodiment shown, and slots **32** are formed in shapes having different areas. More specifically, area Sa of elastic membrane **30**a is larger than area Sb of elastic membrane **30**b, and area Sb of said elastic membrane **30**b is larger than area Sc of elastic membrane **30**c. That is, elastic membranes **30**a-**30**c are formed to satisfy the relationship Sa>Sb>Sc.

Here, because elastic membranes **30**a-**30**c have different areas from each other, their resonance frequencies for vibration in the out-of-plane direction of composite membrane **16** are different from each other.

The resonance frequency is that for vibration at a prescribed frequency detected when an object is allowed to vibration freely. Any object has a natural resonance frequency. Usually, an object has plural resonance frequencies. The resonance frequency depends on the rigidity and mass of the object. More specifically, the higher the rigidity, the higher the resonance frequency, while the larger the mass, the lower the resonance frequency. Here, rigidity refers to the proportionality coefficient between a bending or twisting force applied to the structural body and the deflection of the structural body as a whole.

Consequently, because elastic membranes **30**a-**30**c have different areas, they differ from each other in rigidity and mass. As a result, they have different resonance frequencies.

Compared with elastic membrane **30**c with a smaller area, elastic membrane **30**a with a larger area has a lower resonance frequency for vibration in the out-of-plane direction. Consequently, for said elastic membranes **30**a-**30**c, assuming the resonance frequency of elastic membrane **30**a to be first resonance frequency f**1**, the resonance frequency of elastic membrane **30**b to be second resonance frequency f**2**, and the resonance frequency of elastic membrane **30**c to be third resonance frequency f**3**, the following conditional relationship among them applies: f**1**<f**2**<f**3**.

Also, elastic membranes **30**a-**30**c are appropriately formed such that their resonance frequencies correspond to intake pulsation at a first frequency, intake pulsation at a second frequency and intake pulsation at a third frequency selected from among the intake pulsations at plural frequencies that form the intake pulsation generated in conjunction with the intake operation of engine **8**. More specifically, first resonance frequency f**1** of elastic membrane **30**a matches the first intake pulsation frequency, second resonance frequency f**2** of elastic membrane **30**b matches the second intake pulsation frequency, and third resonance frequency f**3** of elastic membrane **30**c matches the third intake pulsation frequency.

Here, the first frequency is lower than the second frequency and the second frequency is lower than the third frequency. That is, the first frequency, second frequency and third frequency satisfy the following relationship: first frequency<second frequency<third frequency.

The first frequency is the frequency of the intake pulsation generated when the engine rotates at a prescribed rotational velocity R**1**, the second frequency is the frequency of the intake pulsation generated at a prescribed rotational velocity R**2**, and the third frequency is the frequency of the intake pulsation generated at a prescribed rotational velocity R**3**.

Here, R**1** is a rotational velocity lower than R**2** and R**2** is a rotational velocity lower than R**3**. That is, rotational velocities R**1**, R**2**, R**3** satisfy the following relationship: R**1**<R**2**<R**3**.

In addition, each of slots **32** is formed between two adjacent elastic membranes, and they form rigidity changing portions having different rigidities from those of elastic membranes **30**a-**30**c.

The operation of the first embodiment of device **1** that amplifies the suction noise will now be explained.

When engine **8** is started, the intake pulsation generated in conjunction with the intake operation of engine **8** is propagated via intake manifold **28** and surge tank **26** into the air inside intake duct **10** (see FIG. **2**).

While engine **8** is running, as the amount of accelerator pedal depression is increased, the airflow rate from air cleaner **22** to surge tank **26** is increased (hereinafter to be referred to as acceleration mode). As a result, while the rotational velocity of engine **8** is increased, the intake vacuum generated for the air in intake duct **10** rises (see FIG. **2**).

In the following, the operation of elastic membranes **30**a-**30**c in the acceleration mode will be explained in more detail with reference to FIGS. **4**-**6**.

FIGS. **4**-**6** are diagrams illustrating the vibration of elastic membranes **30**a-**30**c in the out-of-plane direction of the composite membrane **16** during the acceleration mode. FIG. **4** is a diagram illustrating the state when the rotational velocity of the engine is R**1**; FIG. **5** is a diagram illustrating the state when the rotational velocity of the engine is R**2**; and FIG. **6** is a diagram illustrating the state when the rotational velocity of the engine is R**3**.

When the rotational velocity of the engine is R**1**, among the plural intake pulsations at different frequencies that form the intake pulsation generated in conjunction with the intake operation of the engine, an intake pulsation at the first frequency is propagated via connecting pipe **12** to composite membrane **16**.

As illustrated in FIG. **4**, because in this case the frequency of the intake pulsation at the first frequency matches first resonance frequency f**1** of elastic membrane **30**a, only elastic membrane **30**a among the elastic membranes **30**a-**30**c vibrates in the out-of-plane direction of composite membrane **16**. When elastic membrane **30**a vibrates in the out-of-plane direction of composite membrane **16**, it causes pressure variations in the air in additional pipe **14** on the side of composite membrane **16** that is open to the external air. There, air pressure variations become noise that is emitted to an external air side, and the suction noise is thereby amplified.

When the amount of accelerator pedal depression is further increased, that is, when the rotational velocity of the engine is at R**2**, among the plural intake pulsations at different frequencies that form the intake pulsation in conjunction with the intake operation of the engine, the intake pulsation at the second frequency is propagated via connecting pipe **12** to composite membrane **16**.

As shown in FIG. **5**, because in this case the frequency of the intake pulsation at the second frequency matches second resonance frequency f**2** of elastic membrane **30**b, only elastic membrane **30**b among elastic membranes **30**a-**30**c vibrates in the out-of-plane direction of composite membrane **16**. When elastic membrane **30**b vibrates in the out-of-plane direction of composite membrane **16**, it causes pressure variations in the air between composite membrane **16** and the second opening of additional pipe **14**, and said air pressure variations become noise that is emitted to the external air side, and the suction noise is thereby amplified.

When the amount of accelerator pedal depression is further increased, that is, when the rotational velocity of the engine is at R**3**, among the plural intake pulsations at different frequencies that form the intake pulsation in conjunction with the intake operation of the engine, the intake pulsation at the third frequency is propagated via connecting pipe **12** to composite membrane **16**.

As shown in FIG. **6**, because in this case the frequency of the intake pulsation at the third frequency matches third resonance frequency f**3** of elastic membrane **30**c, only elastic membrane **30**c among elastic membranes **30**a-**30**c vibrates in the out-of-plane direction of composite membrane **16**. When elastic membrane **30**c vibrates in the out-of-plane direction of composite membrane **16**, it causes pressure variations in the air in additional pipe **14** on the side of composite membrane **16** that is open to the external air, and air pressure variations become noise that is emitted to the external air side, and therefore the suction noise is amplified.

Consequently, in the acceleration mode, elastic membranes **30**a-**30**c with different resonance frequencies vibrate in the out-of-plane direction of the composite membrane according to variation in the rotational velocity of the engine. As a result, the suction noise at the first frequency, the suction noise at the second frequency and the suction noise at the third frequency are amplified, and the amplified suction noise is emitted to the external air side from the second opening at the additional pipe **14** (see FIG. **2**).

When the amplified suction noise is emitted to the external air side from the second opening of additional pipe **14**, the emitted suction noise is propagated via the air into vehicle passenger compartment **2** such that an impressive suction noise is transmitted into vehicle passenger compartment **2** (see FIG. **1**).

Variations of Embodiment 1

For device **1** that amplifies the suction noise in the first embodiment, three elastic membranes **30**a-**30**c are formed to have different resonance frequencies for vibration in the out-of-plane direction of composite membrane **16**. However, it is understood that the present embodiment is not limited to this scheme. Indeed, a scheme may also be adopted in which among three elastic membranes **30**a-**30**c, at least two elastic membranes have resonance frequencies for vibration in the out-of-plane direction of the composite membrane that are different from each other.

Also, for device **1** that amplifies the suction noise in the first embodiment, three elastic membranes **30**a-**30**c are formed to have different resonance frequencies for vibration in the out-of-plane direction of composite membrane **16** by virtue of having different areas. The present embodiment is not limited to this scheme, however. That is, a scheme may also be adopted in which three elastic membranes **30**a-**30**c are formed with the same area, and at the same time, they are formed different from each other with respect to rigidity and/or mass, so that the resonance frequencies for vibration in the out-of-plane direction of the composite membrane are different from each other. Here, to form an elastic membrane **30** having increased rigidity and/or mass, a core member may be arranged inside it, or a processed mass body for forming ribs on elastic membrane **30** may be attached, or the thickness of elastic membrane **30** may be increased. As a result, although elastic membrane **30** has the same area as the other elastic membranes, elastic membrane **30** nevertheless has higher rigidity and/or larger mass than the others. In this case, by selecting the rigidity and/or mass of each elastic membrane **30**a, **30**b, **30**c to meet the required resonance frequency conditions for vibration in the out-of-plane direction of composite membrane **16**, it is possible to set each elastic membrane **30**a, **30**b, **30**c at a desired resonance frequency.

In the first embodiment, device **1** that amplifies the suction noise has a composite membrane **16** composed of three elastic membranes **30**a-**30**c. The present embodiment is not limited to this scheme, however. A scheme can also be adopted in which composite membrane **16** is composed of two elastic membranes **30** or more than three elastic membranes **30**.

Also, in the structure for device **1** that amplifies the suction noise of the present embodiment, device **1** that amplifies the suction noise is set in engine compartment **6** in front of vehicle passenger compartment **2**. However, other locations for device **1** that amplifies the suction noise are contemplated. That is, for example, when vehicle C has an engine compartment **6** arranged behind vehicle passenger compartment **2**, the location for device **1** that amplifies the suction noise can be in engine compartment **6** located behind vehicle passenger compartment **2**. Also, for example, when vehicle C has an engine compartment **6** beneath vehicle passenger compartment **2**, the location for device **1** that amplifies the suction noise can be within engine compartment **6** set beneath vehicle passenger compartment **2**. In any case, the location of device **1** that amplifies the suction noise can be adjusted appropriately according to the configuration of vehicle C, that is, the position of engine compartment **6**.

Viewing the device **1** for amplifying suction noise of the first embodiment in the thickness direction of composite membrane **16**, the composite membrane **16** is composed of three elastic membranes **30**a, **30**b, **30**c. Elastic membranes **30**a, **30**b, **30**c have resonance frequencies for vibrations in the out-of-plane direction of composite membrane **16** that differ from each other.

As a result, in the acceleration mode, the various elastic membranes **30**a, **30**b, **30**c vibrate in the out-of-plane direction of composite membrane **16** corresponding to variation in the rotational velocity of the engine.

Consequently, the intake pulsation at the first frequency, and the suction noises at the second frequency and third frequency are amplified corresponding to variation in the rotational velocity of the engine, and the amplified suction noise is emitted from the second opening of additional pipe **14** on the external air side. The emitted suction noise is propagated via the air into the vehicle passenger compartment, so that an impressive suction noise is transmitted into vehicle passenger compartment **2**.

As a result, it is possible to generate the suction noise at plural frequencies by via composite membrane **16**, and it is possible to generate an impressive suction noise without a requirement of plural intake ducts. Because there is no need for plural intake ducts in this embodiment, freedom of layout is improved, allowing device **1** to be adopted on a variety of vehicles with different constructions, such as vehicles having different body sizes.

Also, viewing the device for amplifying suction noise of the present embodiment in the thickness direction, composite membrane **16** is comprised of three elastic membranes, and these elastic membranes are formed with different areas, so that they have different vibration frequencies in the out-of-plane direction of composite membrane **16**.

Consequently, by selecting the areas of the respective elastic membranes corresponding to resonance frequencies for vibration in the out-of-plane direction of composite membrane **16**, it is possible to set the resonance frequencies of the elastic membranes at the respective desired resonance frequencies.

As a result, it is possible to set the resonance frequencies for vibration in the out-of-plane direction of the various elastic membranes comprising composite membrane **16** at the plural desired frequencies, and it is possible to expand the frequency band range where amplifying the suction noise can be realized. As a result, it is possible to improve the sound quality of the suction noise directed into the vehicle passenger compartment.

Second Embodiment

Turning to FIG. **7**, a second embodiment will be explained. FIG. **7** is a diagram illustrating the structure of composite membrane **16** for device **1** for amplifying the suction noise of a vehicle.

As can be seen from FIG. **7**, the structure of device **1** for amplifying the suction noise of a vehicle C in the second embodiment is the same as that of the first embodiment, except for the structure of composite membrane **16**. That is, composite membrane **16** in the second embodiment is divided by rigidity changing portions **34** formed between every pair of adjacent elastic membranes and having rigidities different from those of said elastic membranes **30**a-**30**d. Viewed in the thickness direction, composite membrane **16** has four elastic membranes **30**a-**30**d.

Rigidity changing portions **34** include an annular rigidity changing portion **36** and radial rigidity changing portions **38**a-**38**c.

Annular rigidity changing portion **36** is formed as a slot arranged in the surface of composite membrane **16** on an intake duct side of composite membrane **16**. Annular rigidity changing portion **36** is shaped to surround a portion of composite membrane **16** that includes the center of composite membrane **16**, and it has an overall circular or elliptical shape. In the second embodiment, the center portion surrounded with annular rigidity changing portion **36** is referred to as elastic membrane **30**d in the following description.

Similar to annular rigidity changing portion **36**, radial rigidity changing portions **38**a-**38**c are formed as slots in the surface of composite membrane **16** on the intake duct side of composite member **16**, and annular rigidity changing portions **38**a-**38**d extend from annular rigidity changing portion **36** towards an outer periphery of composite membrane **16**, so that they divide the portions other than that surrounded by annular rigidity changing portion **36** into plural portions. With regard to radial rigidity changing portions **38**a-**38**c in the second embodiment, an example is explained in which three radial rigidity changing portions **38**a-**38**c are formed extending from annular rigidity changing portion **36** towards the outer periphery of composite membrane **16**. Also, in explanation of the second embodiment, the three elastic membranes **30** divided by said three radial rigidity changing portions **38**a-**38**c are described as elastic membranes **30**a-**30**c, respectively.

Elastic membranes **30**a-**30**d are formed into shapes with different areas by means of rigidity changing portions **34**. More specifically, area Sa of elastic membrane **30**a is larger than area Sb of elastic membrane **30**b; area Sb of elastic membrane **30**b is larger than area Sc of elastic membrane **30**c; and area Sc of elastic membrane **30**c is larger than area Sd of elastic membrane **30**d. That is, elastic membranes **30**a-**30**d are formed to satisfy the following relationship: Sa>Sb>Sc>Sd.

Also, because elastic membranes **30**a-**30**d have different areas, their resonance frequencies in the out-of-plane direction of composite membrane **16** are different from each other. More specifically, assuming the resonance frequency of elastic membrane **30**a to be first resonance frequency f**1**, the resonance frequency of elastic membrane **30**b to be second resonance frequency f**2**, the resonance frequency of elastic membrane **30**c to be third resonance frequency f**3**, and the resonance frequency of elastic membrane **30**d to be fourth resonance frequency f**4**, the following relationship is established: f**1**<f**2**<f**3**<f**4**.

Also, elastic membranes **30**a-**30**d are appropriately shaped such that their resonance frequencies match those of the intake pulsations at the first frequency, the second frequency, the third frequency and the fourth frequency, selected from among the intake pulsations at plural frequencies that form the intake pulsation generated in conjunction with the intake operation of engine **8**. More specifically, first resonance frequency f**1** of elastic membrane **30**a matches the frequency of the intake pulsation at the first frequency, second resonance frequency f**2** of elastic membrane **30**b matches the frequency of the intake pulsation at the second frequency, third resonance frequency f**3** of elastic membrane **30**c matches the frequency of the intake pulsation at the third frequency, and fourth resonance frequency f**4** of elastic membrane **30**d matches the frequency of the intake pulsation at the fourth frequency.

Here, the first frequency is lower than the second frequency, the second frequency is lower than the third frequency, and the third frequency is lower than the fourth frequency. That is, the first frequency, second frequency, third frequency and fourth frequency satisfy the following relationship: first frequency<second frequency<third frequency<fourth frequency.

The first frequency is the frequency of the intake pulsation generated when the engine rotates at a prescribed rotational velocity R**1**, the second frequency is the frequency of the intake pulsation generated at a prescribed rotational velocity R**2**, the third frequency is the frequency of the intake pulsation generated at a prescribed rotational velocity R**3**, and the fourth frequency is the frequency of the intake pulsation generated at a prescribed rotational velocity R**4**.

Here, R**1** is a rotational velocity lower than R**2**, R**2** is a rotational velocity lower than R**3**, and R**3** is a rotational velocity lower than R**4**. That is, rotational velocities R**1**, R**2**, R**3**, R**4** satisfy the following relationship: R**1**<R**2**<R**3**<R**4**.

The remaining structure of composite member **16** and device **1** is substantially the same as that of in the first embodiment.

The operation of device **1** that amplifies the suction noise according to the second embodiment will now be described. In the following description, because the structure of everything besides composite membrane **16** is substantially the same as in the first embodiment, only the operation of different parts will be explained.

When engine **8** is started, the intake pulsation generated in conjunction with the intake operation of engine **8** is propagated via intake manifold **28** and surge tank **26** into the air inside clean-side intake duct **18** (see FIG. **2**).

While engine **8** is running, as the amount of accelerator pedal depression is increased, the airflow rate from air cleaner **22** to surge tank **26** is increased (hereinafter to be referred to as the acceleration mode). As a result, while the rotational velocity of engine **8** is increased, the intake vacuum generated in the air inside intake duct **10** rises (see FIG. **2**).

When the engine is accelerating and the rotational velocity is R**1**, the intake pulsation at the first frequency, among the plural intake pulsations at different frequencies that form the intake pulsation generated in conjunction with the intake operation of engine **8**, is propagated via connecting pipe **12** to the composite membrane **16**.

Because the frequency of the intake pulsation at the first frequency matches first resonance frequency f**1** of elastic membrane **30**a, only elastic membrane **30**a among elastic membranes **30**a-**30**d vibrates in the out-of-plane direction of composite membrane **16**. When elastic membrane **30**a vibrates in the out-of-plane direction of composite membrane **16**, it causes pressure variations in the air in additional pipe **14** on the side of composite membrane **16** that is open to the external air, and these air pressure variations become noise that is emitted to the external air side, such that the suction noise is amplified.

When the amount of accelerator pedal depression is further increased, that is, when the rotational velocity of the engine is at R**2**, from among the plural intake pulsations at different frequencies that form the intake pulsation in conjunction with the intake operation of engine **8**, the intake pulsation at the second frequency is propagated via connecting pipe **12** to the composite membrane **16** (elastic membrane).

Because the frequency of the intake pulsation at the second frequency matches second resonance frequency f**2** of elastic membrane **30**b only elastic membrane **30**b among elastic membranes **30**a-**30**d vibrates in the out-of-plane direction of composite membrane **16**. When elastic membrane **30**b vibrates in the out-of-plane direction of composite membrane **16**, pressure variations result in the air in the region between composite membrane **16** and the end of additional pipe **14** that is open to the external air, and air pressure variations become noise that is emitted to the external air side, thereby amplifying the suction noise.

When the amount of accelerator pedal depression is further increased, that is, when the rotational velocity of the engine is at R**3**, among the plural intake pulsations at different frequencies that form the intake pulsation in conjunction with the intake operation of engine **8**, the intake pulsation at the third frequency is propagated via connecting pipe **12** to composite membrane **16**.

Because the frequency of the intake pulsation at the third frequency matches third resonance frequency f**3** of elastic membrane **30**c, only elastic membrane **30**c among elastic membranes **30**a-**30**d vibrates in the out-of-plane direction of composite membrane **16**. When elastic membrane **30**c vibrates in the out-of-plane direction of composite membrane

16, pressure variations result in the air in the region between composite membrane **16** and the end of additional pipe **14** that is open to the external air, and said air pressure variations become noise that is emitted to the external air side, such that suction noise is amplified.

When the amount of accelerator pedal depression is further increased, that is, when the rotational velocity of the engine is at R**4**, among the plural intake pulsations at different frequencies that form the intake pulsation in conjunction with the intake operation of engine **8**, the intake pulsation at the fourth frequency is propagated via connecting pipe **12** to composite membrane **16** (elastic membrane member).

Because the frequency of the intake pulsation at the fourth frequency matches fourth resonance frequency f**4** of elastic membrane **30**d, only elastic membrane **30**d among elastic membranes **30**a-**30**d vibrates in the out-of-plane direction of composite membrane **16** (elastic membrane member). When elastic membrane **30**d vibrates in the out-of-plane direction of composite membrane **16**, pressure variations result in the air in the region between composite membrane **16** and the end of additional pipe **14** that is open to the external air, and the air pressure variations become noise that is emitted to the external air side, thereby amplifying the suction noise.

Consequently, in the acceleration mode, elastic membranes **30**a-**30**d with different resonance frequencies vibrate in the out-of-plane direction of composite membrane **16** corresponding to the variation in rotational velocity of engine **8**. As a result, the suction noise at the first frequency, the suction noise at the second frequency, the suction noise at the third frequency and the suction noise at the fourth frequency are amplified, and the amplified suction noise is emitted to the external air side from the opening at the second end of additional pipe **14** (see FIG. **2**).

When the amplified suction noise is emitted to the external air side from the second opening of additional pipe **14**, the emitted suction noise is propagated via the air into vehicle passenger compartment **2**, so that an impressive suction noise is transmitted into vehicle passenger compartment **2** (see FIG. **1**).

Variations of the Second Embodiments

Viewing device **1** that amplifies the suction noise in the second embodiment, in the thickness direction of composite membrane **16**, it may be seen that composite membrane **16** is composed of four elastic membranes **30**a-**30**d. However, the second embodiment is not limited to this scheme. That is, viewing in the thickness direction of composite membrane **16**, composite membrane **16** may be composed of five or more elastic membranes. In this case, composite membrane **16** may work with frequencies over a wider range than composite membrane **16** with just four elastic membranes **30**a-**30**d as viewed in the thickness direction of composite membrane **16**.

Viewing the device **1** for amplifying suction noise in the second embodiment in the thickness direction of composite membrane **16**, composite membrane **16** is comprised of four elastic membranes **30**a-**30**d. Elastic membranes **30**a-**30**d are formed with different areas, and their resonance frequencies for vibration in the out-of-plane direction of composite membrane **16** are different from each other.

As a result, by selecting the different areas of elastic membranes **30**a-**30**d according to resonance frequencies of vibration in the out-of-plane direction of composite membrane **16**, it is possible to set the respective resonance frequencies of elastic membranes **30**a-**30**d at the desired resonance frequencies.

Consequently, compared with the device for amplifying the suction noise of a vehicle in the first embodiment, that is, the device for amplifying the suction noise of a vehicle having three elastic membranes as viewed in the thickness direction, it is possible to further expand the frequency range where the suction noise can be amplified, and it is possible to improve the sound quality of the suction noise transmitted into vehicle passenger compartment **2**.

Third Embodiment

Referring to FIGS. **8** and **9**, a third embodiment will be explained. FIGS. **8** and **9** are diagrams illustrating the structure of device **1** that amplifies suction noise in the third embodiment. FIG. **8** is a diagram illustrating the structure of composite membrane **16**, and FIG. **9** is a cross section taken across X-Y in FIG. **8**.

As shown in FIGS. **8** and **9**, the structure of device **1** that amplifies suction noise in the third embodiment is substantially the same as that of the first embodiment except for the structure of composite membrane **16**. That is, the rigidity changing portion for composite membrane **16** in the third embodiment, is formed of convex portions **40** formed on the surface of composite membrane **16** on the intake duct side.

Viewed in the radial direction of composite membrane **16**, convex portions **40** are each generally V-shaped and project toward the intake duct side when composite member **16** is installed in connecting pipe **12**. The thickness of composite membrane **16** where convex portions **40** are formed is substantially equal to the thickness of the remaining portions. That is, composite membrane **16** is formed with a generally uniform thickness throughout. Composite membrane **16** with convex portions **40** formed thereon, may be formed by integral molding using dies.

The remainder of the structure of device **1** is generally the same as that of the first embodiment.

In the following, the operation of device **1** that amplifies the suction noise in the third embodiment will now be explained. Because the structure of everything besides composite membrane **16** is substantially the same as in the first embodiment, only the operation of the different portions will be explained in detail.

When engine **8** is started, the intake pulsation generated in conjunction with the intake operation of engine **8** is propagated via intake manifold **28** and surge tank **26** into the air inside clean-side intake duct **18** (see FIG. **2**).

While engine **8** is running, as the amount of accelerator pedal depression is increased, the airflow rate from air cleaner **22** to surge tank **26** is increased (hereinafter to be referred to as acceleration mode). As a result, while the rotational velocity of engine **8** is increased, the intake vacuum generated for the air in intake duct **10** rises (see FIG. **2**).

In the acceleration mode, when the amount of accelerator pedal depression is changed, the rotational velocity of the engine is changed. As a result, elastic membranes **30**a-**30**c with different resonance frequencies vibrate in the out-of-plane direction of composite membrane **16** corresponding to the change in rotational velocity of engine **8**. As a result, pressure variations occur in the air in the region between composite membrane **16** and the end of additional pipe **14** that is open to the external air. The air pressure variations are emitted as noise to the external air side, so that the suction noise corresponding to the first frequency, the suction noise corresponding to the second frequency, and the suction noise corresponding to the third frequency are amplified (see FIG. **2**).

When the amplified suction noise is emitted to the external air side from the opening at the second end of additional pipe **14**, the emitted suction noise is propagated via the air into vehicle passenger compartment **2**, so that an impressive suction noise is transmitted into vehicle passenger compartment **2** (see FIG. **1**).

Variations of the Third Embodiment

As viewed in the radial direction of composite membrane **16**, device **1** that amplifies the suction noise in the third embodiment has convex portions **40** formed on composite membrane **16**, each being V-shaped and projecting to the intake duct side, and the thickness of composite membrane **16** is substantially uniform throughout when the shape is formed. However, the third embodiment is not limited to this scheme.

For example, as shown in FIG. **10**A, a scheme may also be adopted in which the thickness of the portions of composite membrane **16** where convex portions **40** are positioned is thicker than the remaining portions. Also, as shown in FIG. **10**B, a scheme may also be adopted in which convex portions **40** are each generally U-shaped as viewed in the radial direction of composite membrane **16**, and the thickness of composite membrane **16** is substantially uniform throughout. In addition, for example, as shown in FIG. **10**C, a scheme may be adopted in which convex portions **40** are each U-shaped projecting toward the intake duct side as viewed in the radial direction of composite membrane **16**, and the thickness of composite membrane **16** where convex portions **40** are formed is thicker than the remaining portions.

The rigidity changing portions in device **1** that amplifies suction noise in the present embodiment consist of convex portions **40** formed on the surface of composite membrane **16** on the intake duct side. The third embodiment is not limited to this scheme, however. For example, as shown in FIGS. **11**A and **11**C, the rigidity changing portions may also comprise generally concave portions **42** formed in the surface of composite membrane (elastic membrane member) **16** on the intake duct side. And, as shown in FIGS. **11**B and **11**D, a scheme may also be adopted in which the rigidity changing portions comprise generally convex portions **40** formed on the surface of composite membrane **16** on the external air side.

The device **1** for amplifying the suction noise of a vehicle in the third embodiment has rigidity changing portions that divide composite membrane **16** into plural elastic membranes by convex or concave portions **40**, **42** formed on the surface of composite membrane **16** on the intake duct side. As a result, composite membrane **16** may be formed with plural elastic membranes by means of a simple structure.

As a result, it is possible to prevent increased manufacturing costs for composite membrane **16**, to prevent increased manufacturing costs for the device **1** for amplifying the suction noise of a vehicle, and to improve the producibility of the device for amplifying the suction noise of a vehicle.

Fourth Embodiment

Referring to FIGS. **12** and **13**, a fourth embodiment will be explained. FIGS. **12** and **13** are diagrams illustrating the structure of composite membrane **16** for device **1** that amplifies suction noise in the fourth embodiment. FIG. **13** is a cross section of composite member **16** taken across Y-Y in FIG. **12**.

As shown in FIGS. **12** and **13**, the structure of device **1** that amplifies suction noise in the fourth embodiment is generally the same as that of the first embodiment except for the structure of composite membrane **16**. That is, the rigidity changing portion of composite membrane **16** in the fourth embodiment is formed of convex portions **40** formed on the surface of composite membrane **16** on the intake duct side, and each convex portion **40** has a core member **44**.

Viewed in the radial direction of composite membrane **16**, each convex portion **40** is generally nV-shaped and projects toward the intake duct side. The thickness of the portions of composite membrane **16** where convex portions **40** are formed is substantially equal to the thickness of the remaining portions. That is, thickness of composite membrane **16** is substantially uniform throughout.

Core member **44** is made of a wire material more rigid than composite membrane **16**, and it is arranged on the surface of composite membrane **16** on the external air side.

The remainder of the structure of device **1** is generally the same as that of the first embodiment 1.

In the following description, the operation of device **1** that amplifies suction noise in the fourth embodiment will be explained. Because the structure of everything besides composite membrane **16** is generally the same as in the first embodiment, only the operation of the different portions will be explained in detail.

When engine **8** is started, the intake pulsation generated in conjunction with the intake operation of engine **8** is propagated via intake manifold **28** and surge tank **26** into the air inside clean-side intake duct **18** (see FIG. **2**).

While engine **8** is running, as the amount of accelerator pedal depression is increased, the airflow rate from air cleaner **22** to surge tank **26** is increased (hereinafter to be referred to as acceleration mode). As a result, while the rotational velocity of engine **8** is increased, the intake vacuum generated in the air inside intake duct **10** rises (see FIG. **2**).

In the acceleration mode, when the amount of accelerator pedal depression is changed, the rotational velocity of the engine is changed. As a result, elastic membranes **30**a-**30**c with different resonance frequencies vibrate in the out-of-plane direction of composite membrane **16** corresponding to changes in the rotational velocity of engine **8**. As a result, pressure variations develop in the air in the region between composite membrane **16** and the end of additional pipe **14** open to the external air. The air pressure variations become noise emitted to the external air side, so that the suction noise corresponding to the first frequency, the suction noise corresponding to the second frequency, and the suction noise corresponding to the third frequency are amplified, and the amplified suction noise is emitted to the external air side from the second opening of additional pipe **14** (see FIG. **2**).

When the amplified suction noise is emitted to the external air side from the second opening of additional pipe **14**, the emitted suction noise is propagated via the air into vehicle passenger compartment **2**, so that an impressive suction noise is transmitted into vehicle passenger compartment **2** via dash panel **4** (see FIG. **1**).

Variations of the Fourth Embodiment

Convex portions **40** formed on composite membrane **16** of device **1** that amplifies the suction noise in the present embodiment are each generally V-shaped and project to the intake duct side as viewed in the radial direction of composite membrane **16**. The thickness of composite membrane **16** is substantially uniform throughout when the shape is formed, and core member **44** is arranged on the surface of composite membrane **16** on the external air side. However, the fourth embodiment is not limited to this scheme. For example, as shown in FIG. **14**A, a scheme may also be adopted in which the thickness of composite film **16** where convex portions **40** are set is greater than in the remaining portions, with core member **44** being arranged inside convex portions **40** set on composite membrane **16**. Also, as shown in FIG. **14**B, a scheme may also be adopted in which each convex portion **40** is generally U-shaped as viewed in the radial direction of composite membrane **16**. In addition, for example, as shown in FIG. **14**C, a scheme may also be adopted in which each convex portion **40** of composite film **16** is generally U-shaped and projects toward the intake duct side as viewed from the radial direction of composite membrane **16**, and the composite membrane **16** is formed thicker where convex portions **40** are set than in the remaining portions, with core member **44** being arranged inside the convex portions **40**.

The rigidity changing portions of device **1** that amplifies suction noise in the fourth embodiment comprise convex portions **40** formed on the surface of composite membrane **16** on the intake duct side. However, the fourth embodiment is not limited to this scheme. For example, as shown in FIGS. **15**A and **15**C, the rigidity changing portions can also comprise concave portions **42** formed on the surface of the composite membrane **16** on the intake duct side, and as shown in FIGS. **15**B and **15**D, a scheme may also be adopted in which the rigidity changing portions consist of convex portions **40** formed on the surface of composite membrane **16** on the external air side.

The device **1** for amplifying the suction noise of a vehicle in the fourth embodiment has rigidity changing portions that divide composite membrane **16** into plural elastic membranes by convex portions **40** formed on the surface of the composite membrane on the intake duct side, and the convex portions each have a core member.

Thus composite membrane **16** may be formed with plural elastic membranes with a simple structure, and at the same time, the strength of the convex portions **40** may be increased.

As a result, it is possible to increase the producibility of the device **1** for amplifying the suction noise of a vehicle, and at the same time, the strength of composite membrane **16** may be increased compared to that in the device for amplifying the suction noise of a vehicle in the third embodiment, so that the durability of composite membrane **16** may be improved.

Fifth Embodiment

Referring to FIG. **16**, a fifth embodiment will be explained. FIG. **16** is a diagram illustrating the structure of composite member **16** of device **1** that amplifies suction noise in the present embodiment.

As shown in FIG. **16**, the structure of device **1** that amplifies suction noise in the fifth embodiment is substantially the same as that of the first embodiment except for the structure of composite membrane **16**. That is, elastic membranes **30**a-**30**c of composite membrane **16** in the fifth embodiment are made of materials having different modulus values. Here, the modulus refers to the property representing resistance to deformation of the object per unit volume. When the deformation and stress are proportional to each other, the modulus is the proportionality coefficient, and it depends on the material. Also, rigidity refers to the proportionality coefficient between a bending and twisting force applied to a structural body and the overall change in the structural body. The factors determining rigidity include the modulus of the material, the dimensions, and the shape of the structure. For example, when a material with a higher modulus is used, the rigidity is higher. When a single material is used, the thicker the sheet, the higher the rigidity. Also, the rigidity changes depending on the three-dimensional shape of the member that is obtained by pressing processes.

The modulus of elastic membrane **30**a is lower than the modulus of elastic membrane **30**b, and the modulus of elastic membrane **30**b is lower than the modulus of elastic membrane **30**c. Consequently, rigidity Ra of elastic membrane **30**a is lower than rigidity Rb of elastic membrane **30**b, and rigidity Rb of elastic membrane **30**b is lower than rigidity Rc of elastic membrane **30**c.

That is, the following relationship is established for elastic membranes **30**a-**30**c: $Ra>Rb>Rc$.

Here, because elastic membranes **30**a-**30**c have different rigidities, their resonance frequencies for vibration in the out-of-plane direction of composite membrane **16** are different from each other. Also, elastic membrane **30** with a higher rigidity has a lower resonance frequency for vibration in the out-of-plane direction than does elastic membrane **30** with a lower rigidity. Consequently, for elastic membranes **30**a-**30**c, assuming the resonance frequency of elastic membrane **30**a to be first resonance frequency f**1**, the resonance frequency of elastic membrane **30**b to be second resonance frequency f**2**, and the resonance frequency of elastic membrane **30**c to be third resonance frequency f**3**, the relationship $f1<f2<f3$ is established.

In composite membrane **16** of the fifth embodiment, elastic membranes **30**a-**30**c are made of materials having different modulus values. As a result, the structure is divided into three elastic membranes **30**a-**30**c without providing slots or other rigidity changing portions on the intake duct side of composite membrane **16**.

The remaining features of the structure of the device **1** are substantially the same as those in the first embodiment.

In the following, the operation of device **1** that amplifies the suction noise in the fifth embodiment will be explained. Because the structure of everything besides composite membrane **16** is substantially the same as that in the first embodiment, only the operation of the different portions will be explained in detail.

When engine **8** is started, the intake pulsation generated in conjunction with the intake operation of engine **8** is propagated via intake manifold **28** and surge tank **26** into the air inside clean-side intake duct **18** (see FIG. **2**).

While engine **8** is running, as the amount of accelerator pedal depression is increased, the airflow rate from air cleaner **22** to surge tank **26** is increased (hereinafter to be referred to as acceleration mode). As a result, while the rotational velocity of engine **8** is increased, the intake vacuum generated in the air inside intake duct **10** rises (see FIG. **2**).

In this case, because said elastic membranes **30**a-**30**c have different rigidity values, their resonance frequencies for vibration in the out-of-plane direction of composite membrane **16** are different from each other.

As a result, in the acceleration mode, as the amount of accelerator pedal depression is changed, the rotational velocity of the engine is changed. As a result, elastic membranes **30**a-**30**c with different resonance frequencies vibrate in the out-of-plane direction of composite membrane **16** corresponding to changes in the rotational velocity of engine **8**.

As a result, the intake pulsation at the first frequency, the intake pulsation at the second frequency and the intake pulsation at the third frequency are amplified, and the amplified suction noise is emitted to the external air side from additional pipe **14** (see FIG. **2**).

When the amplified suction noise is emitted to the external air side from the opening at the other end of additional pipe **14**, the emitted suction noise is propagated via the air into vehicle passenger compartment **2**, so that an impressive suction noise is transmitted into vehicle passenger compartment **2** via dash panel **4** (see FIG. **1**).

Variations of the Fifth Embodiment

In the fifth embodiment, elastic membranes **30**a-**30**c of device **1** that amplifies the suction noise have rigidities different from each other, so that their resonance frequencies for vibration in the out-of-plane direction of composite membrane **16** are different from each other. However, the fifth embodiment is not limited to this scheme. That is, a scheme may also be adopted in which elastic membranes **30**a-**30**c are made of materials having different mass values, so that they have different resonance frequencies for vibration in the out-of-plane direction of composite membrane **16**. Also, one may adopt a scheme in which elastic membranes **30**a-**30**c are made of materials different from each other with respect to their modulus and/or mass, so that they have different resonance frequencies for vibration in the out-of-plane direction of composite membrane **16**.

For composite membrane **16** in the fifth embodiment, elastic membranes **30**a-**30**c are made of materials having different modulus values. As a result, the structure is provided with three divided elastic membranes **30**a-**30**c without setting slots or other rigidity changing portions on the intake duct side of composite membrane **16**. However, the fifth embodiment is not limited to this scheme. For example, a scheme may also be adopted in which composite membrane **16** is composed of three separated elastic membranes **30**a-**30**c by forming slots or other rigidity changing portions on the surface of composite membrane (elastic membrane member) **16** on the intake duct side, just as in any of the previous embodiments.

Viewed in the thickness direction of composite membrane **16**, composite membrane **16** of the device **1** for amplifying the suction noise of a vehicle in the fifth embodiment is composed of three elastic membranes. Because the elastic membranes have different rigidity values, their resonance frequencies for vibration in the out-of-plane direction of composite membrane **16** are different from each other.

As a result, in the acceleration mode, the various elastic membranes vibrate in the out-of-plane direction of composite membrane **16** corresponding to changes in the rotational velocity of engine **8**.

Consequently, the intake pulsation at the first frequency, the intake pulsation at the second frequency and the intake pulsation at the third frequency are amplified corresponding to changes in the rotational velocity of engine **8**, and the amplified suction noise is emitted to the external air side from the second opening of the additional pipe. The emitted suction noise is propagated via dash panel **4** into vehicle passenger compartment **2**, and an impressive suction noise is transmitted into vehicle passenger compartment **2**.

As a result, it is possible to generate plural resonance frequencies with a single composite membrane **16**, and an impressive suction noise may be generated without the need of plural intake ducts. Also, because the structure does not need plural intake ducts, the freedom of layout design may be improved, and device **1** may be adopted for vehicles with different body sizes or different structures.

Also, as viewed in the thickness direction, composite membrane **16** of the device **1** for amplifying suction noise in the fifth embodiment is composed of three elastic membranes, and these elastic membranes are made of materials with different modulus values, so that they have different frequencies for vibration in the out-of-plane direction of composite membrane **16**.

Consequently, by selecting the modulus values of the elastic membranes corresponding to the respective resonance frequencies for vibration in the out-of-plane direction of composite membrane **16**, it is possible to set the resonance frequencies of the elastic membranes at the respective desired resonance frequencies.

As a result, it is possible to set the resonance frequencies of the various elastic membranes for vibration in the out-of-plane direction of composite membrane **16** at plural desired frequencies, and it is possible to expand the range of frequency bands where amplification of the suction noise may be realized. As a result, it is possible to improve the sound quality of the suction noise transmitted into vehicle passenger compartment **2**.

Also, because composite membrane **16** in the device **1** for amplifying the suction noise of a vehicle in the fifth embodiment has elastic membranes made of materials having different modulus values, composite membrane **16** is constituted as three separated elastic membranes without the provision of slots or other rigidity changing portions on the surface of composite membrane **16** on the intake duct side.

Consequently, the durability of composite membrane **16** is improved due to the lack of rigidity changing portions with thicknesses different from other portions set at the boundaries between adjacent elastic membranes of composite membrane **16**.

The preceding description has been presented only to illustrate and describe exemplary embodiments of the oil return device according to the claimed invention. It is not intended to be exhaustive or to limit the invention to any precise form disclosed. It will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. The invention may be practiced otherwise than is specifically explained and illustrated without departing from its spirit or scope. The scope of the invention is limited solely by the following claims.

What is claimed is:

1. A method for amplifying the suction noise of a vehicle, comprising:

passing variations in air pressure transmitted into an engine intake port through a pipe that is connected to an engine, the variations in air pressure resulting in intake pulsations having one of at least two different frequencies;

resonating a first elastic member of a composite membrane at one of the at least two different frequencies;

resonating a second elastic member of the composite membrane at the other one of the at least two different frequencies; and

varying the air pressure transmitted to an external air side in response to one of the resonated first elastic member and the resonated second elastic member.

2. A device for amplifying the suction noise of a vehicle, comprising:

an intake duct for feeding air to an engine intake port,

a connecting pipe connected to an interior of the intake duct, and

a composite membrane positioned within the connecting pipe, wherein the composite membrane blocks an interior passage formed in the connecting pipe, wherein the composite membrane includes at least two elastic membranes with one of masses and rigidities that differ from each other, each of the at least two elastic membranes vibrating in response to a different intake pulsation frequency.

3. The device for amplifying the suction noise of a vehicle described in claim **2**, wherein the composite membrane further comprises a rigidity changing portion formed between the at least two elastic membranes, with the rigidity of the rigidity changing portion being different from that of the at least two elastic membranes.

4. The device for amplifying the suction noise of a vehicle described in claim **3**, wherein the rigidity changing portion is one of a convex portion and concave portion formed on the surface of the composite membrane.

5. The device for amplifying the suction noise of a vehicle described in claim **3**, wherein the rigidity changing portion further comprises a core member with a rigidity higher than that of the elastic membranes.

6. The device for amplifying the suction noise of a vehicle described in claim **3**, wherein the rigidity changing portion further comprises:

at least an annular rigidity changing portion of one of a circular and elliptical shape and arranged inward of an outer periphery of the composite membrane, and

radial rigidity changing portions that extend from said annular rigidity changing portion to the outer periphery of the composite membrane, and

which divide the region between the portion surrounded by the annular rigidity changing portion and the outer periphery of the composite membrane into at least two portions.

7. The device for amplifying the suction noise of a vehicle described claim **3** wherein the at least two elastic membranes have different areas from each other.

8. The device for amplifying the suction noise of a vehicle described claim **7** wherein the rigidity changing portion refers to one of a convex portion and concave portion formed on a surface of the composite membrane.

9. The device for amplifying the suction noise of a vehicle described in claim **7** wherein the rigidity changing portion further comprises a core member with a rigidity higher than that of the elastic membranes.

10. The device for amplifying the suction noise of a vehicle described in claim **7** wherein the rigidity changing portion further comprises:

at least an annular rigidity changing portion of one of a generally circular and elliptical shape that is arranged inward of an outer periphery of the composite membrane, and

radial rigidity changing portions that extend from the annular rigidity changing portion to the outer periphery of the composite membrane, and

which divide the region between the portion surrounded by the annular rigidity changing portion and the outer periphery of the compo site membrane into at least two portions.

11. The device for amplifying the suction noise of a vehicle described in claim **2**, wherein at least two elastic membranes are made of materials having one of different moduli and densities from each other.

12. The device for amplifying the suction noise of a vehicle described in claim **11** wherein:

the composite membrane has a rigidity changing portion formed between the at least two elastic membranes, with the rigidity of the rigidity changing portion being different from that of the at least two elastic membranes.

13. The device for amplifying the suction noise of a vehicle described in claim **12**, wherein the rigidity changing portion is one of a convex portion and concave portion formed on the surface of the composite membrane.

14. The device for amplifying the suction noise of a vehicle described in claim **12** wherein the rigidity changing portion further comprises a core member with a rigidity higher than that of the elastic membranes.

15. The device for amplifying the suction noise of a vehicle described in claim **12** wherein the rigidity changing portion further comprises:

at least an annular rigidity changing portion of one of a generally circular and elliptical shape that is arranged inward of an outer periphery of the composite membrane, and

radial rigidity changing portions that extend from the annular rigidity changing portion to the outer periphery of the composite membrane, and

which divide the region between the portion surrounded by the annular rigidity changing portion and the outer periphery of the composite membrane into at least two portions.

16. The device for amplifying the suction noise of a vehicle described in claim **12** wherein the at least two elastic membranes have different thicknesses from each other.

17. The device for amplifying the suction noise of a vehicle described in claim **16** wherein the composite membrane further comprises a rigidity changing portion formed between the at least two elastic membranes, with the rigidity of the rigidity changing portion being different from that of the at least two elastic membranes.

18. The device for amplifying the suction noise of a vehicle described in claim **17** wherein the rigidity changing portion is one of a convex portion and concave portion formed on a surface of the compo site membrane.

19. The device for amplifying the suction noise of a vehicle described in claim **17** wherein the rigidity changing portion further comprises a core member with a rigidity higher than that of the elastic membranes.

20. The device for amplifying the suction noise of a vehicle described in claim **17** wherein the rigidity changing portion further comprises:

at least an annular rigidity changing portion of one of a generally circular or elliptical shape and arranged inward of an outer periphery of the composite membrane, and

radial rigidity changing portions that extend from the annular rigidity changing portion to the outer periphery of the composite membrane, and

which divide the region between the portion surrounded by the annular rigidity changing portion and the outer periphery of the composite membrane into at least two portions.

21. A device for amplifying the suction noise of a vehicle, comprising:

intake means for feeding air to an engine intake port,

pipe means fluidly connected to the intake means, and

composite membrane means positioned within the pipe means, wherein the composite membrane means blocks an interior passage formed in the pipe means, wherein the composite membrane means includes at least two elastic membranes with one of masses and rigidities that differ from each other, each of the at least two elastic membranes adapted to vibrate in response to a different intake pulsation frequency.

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