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(54) **CATALYTIC CONVERTER**

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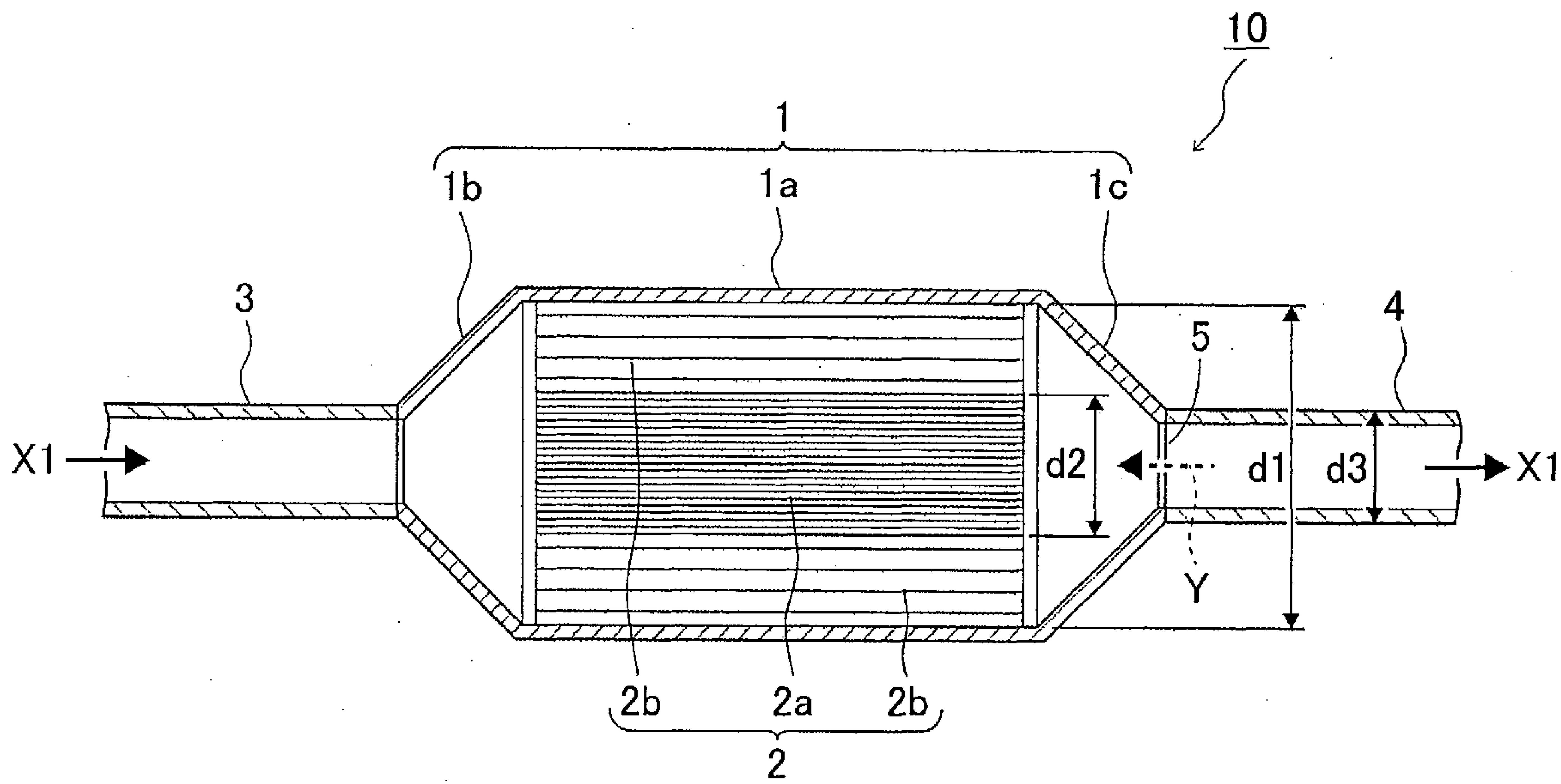
(57) **ABSTRACT**

A catalytic converter (**10**) includes i) an outer tube (**1**) that includes a cylindrical portion (**1***a*), an upstream-side cone portion (**1***b*), and a downstream-side cone portion (**1***c*), and ii) a substrate (**2**) having a cell structure that is arranged in the cylindrical portion (**1***a*) of the outer tube (**1**). The substrate (**2**) has a center region (**2***a*) where a cell density is relatively high and a peripheral region (**2***b*) where the cell density is relatively low, in a cross-section that is orthogonal to a length direction of the substrate (**2**). A projection portion when a connecting portion (**5**) of the exhaust duct (**4**) and the downstream-side cone portion (**1***c*) is projected onto the substrate (**2**) is within the center region (**2***a*).



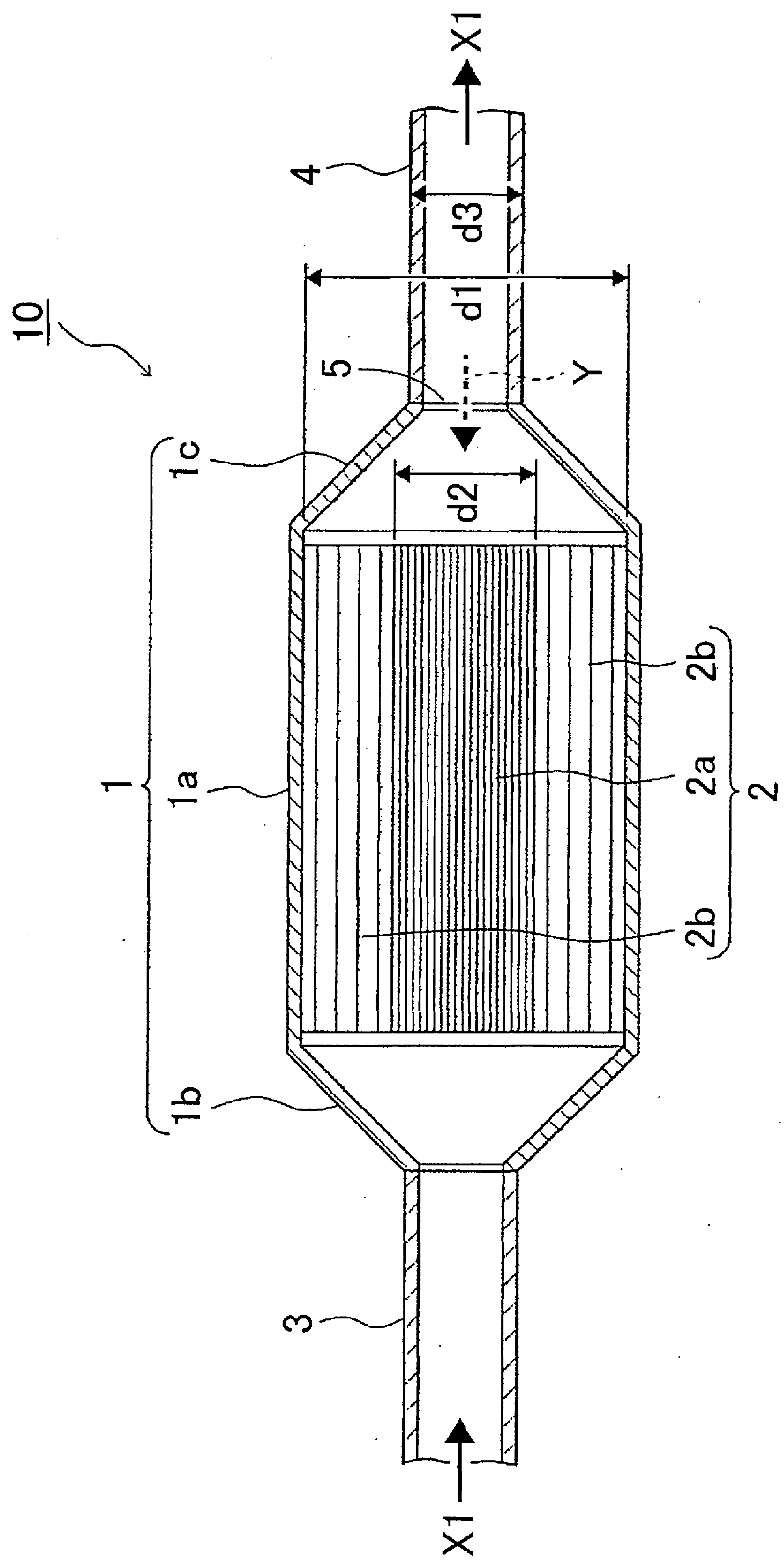


FIG. 1

FIG. 2

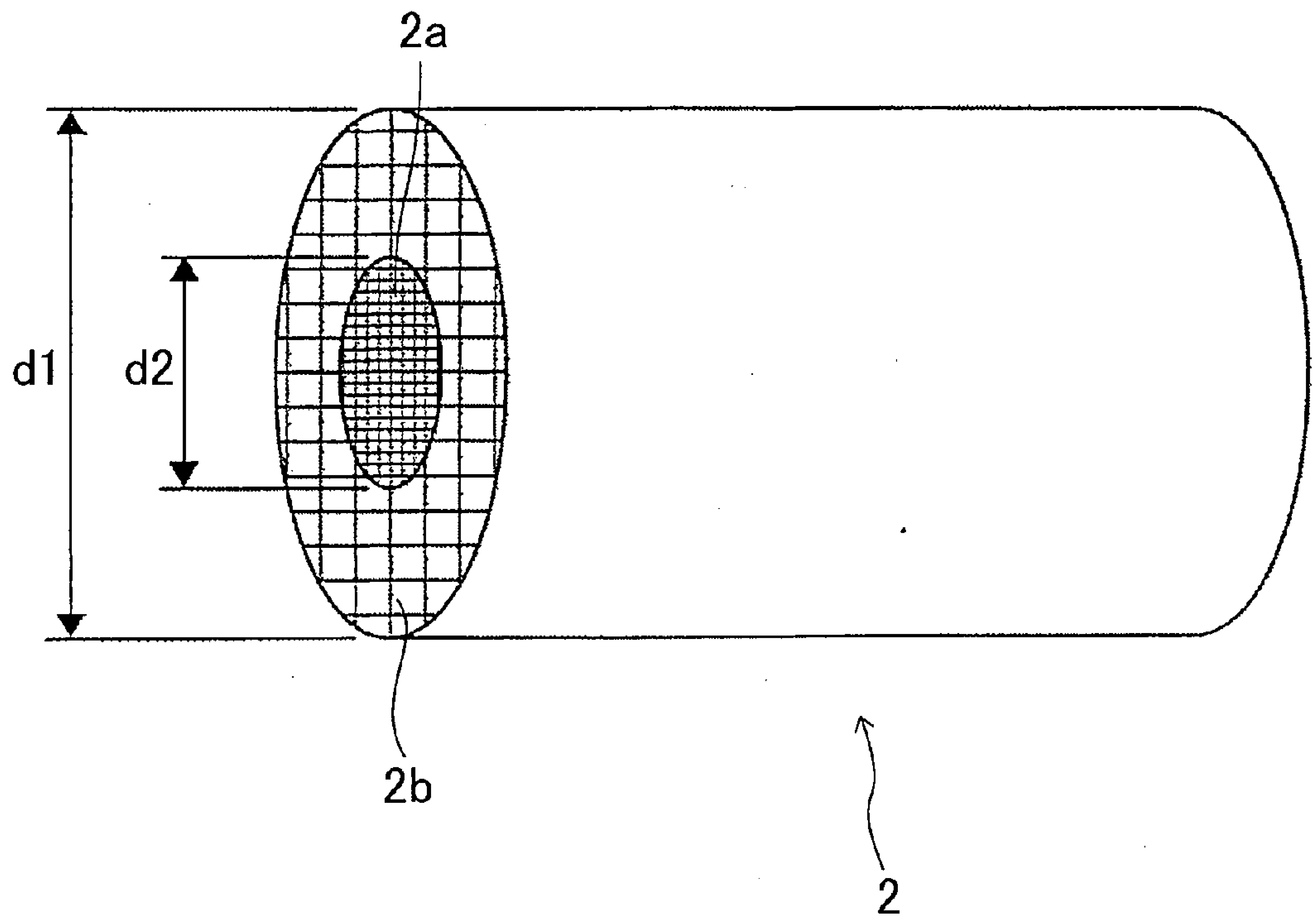


FIG. 3A

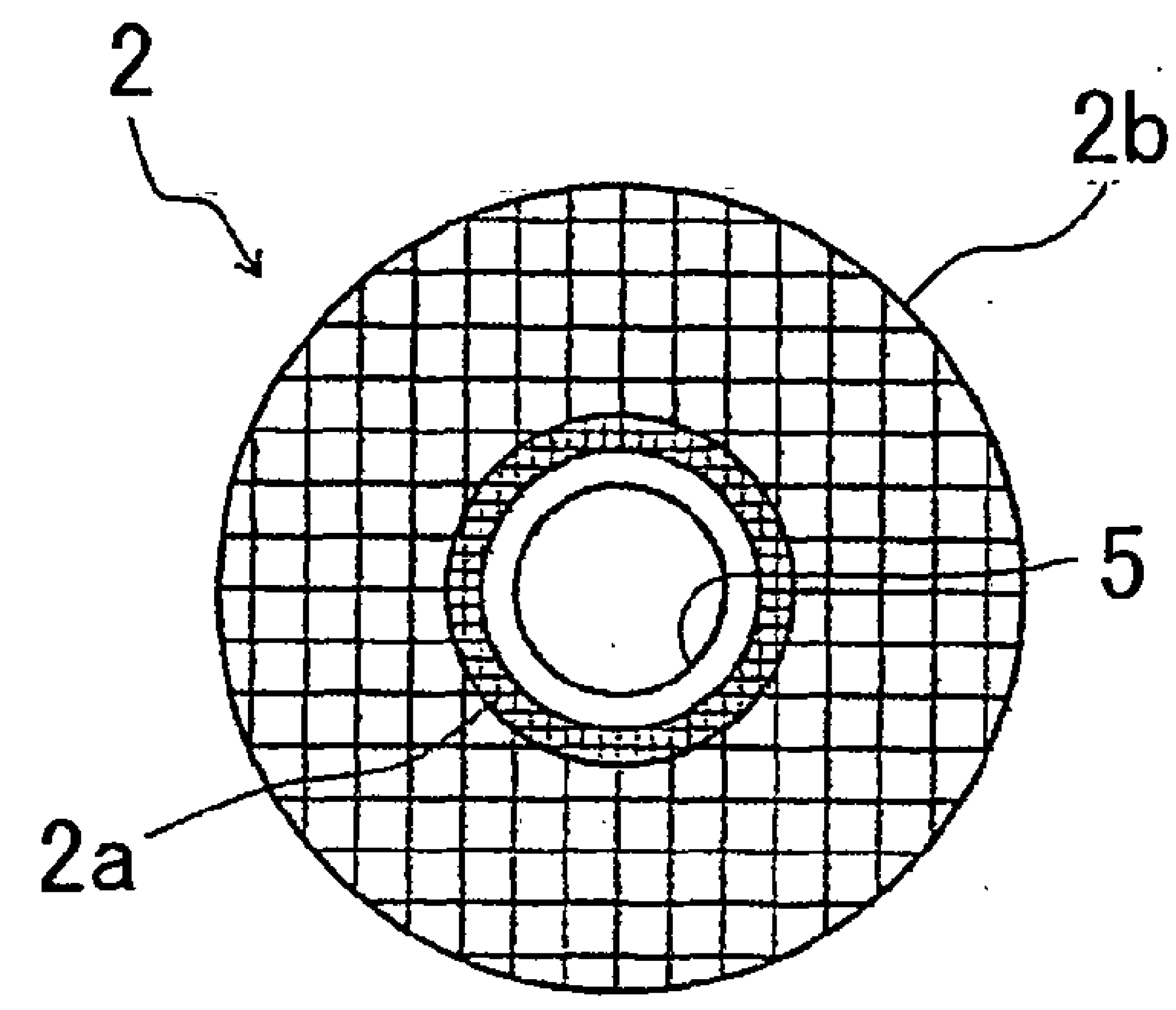


FIG. 3B

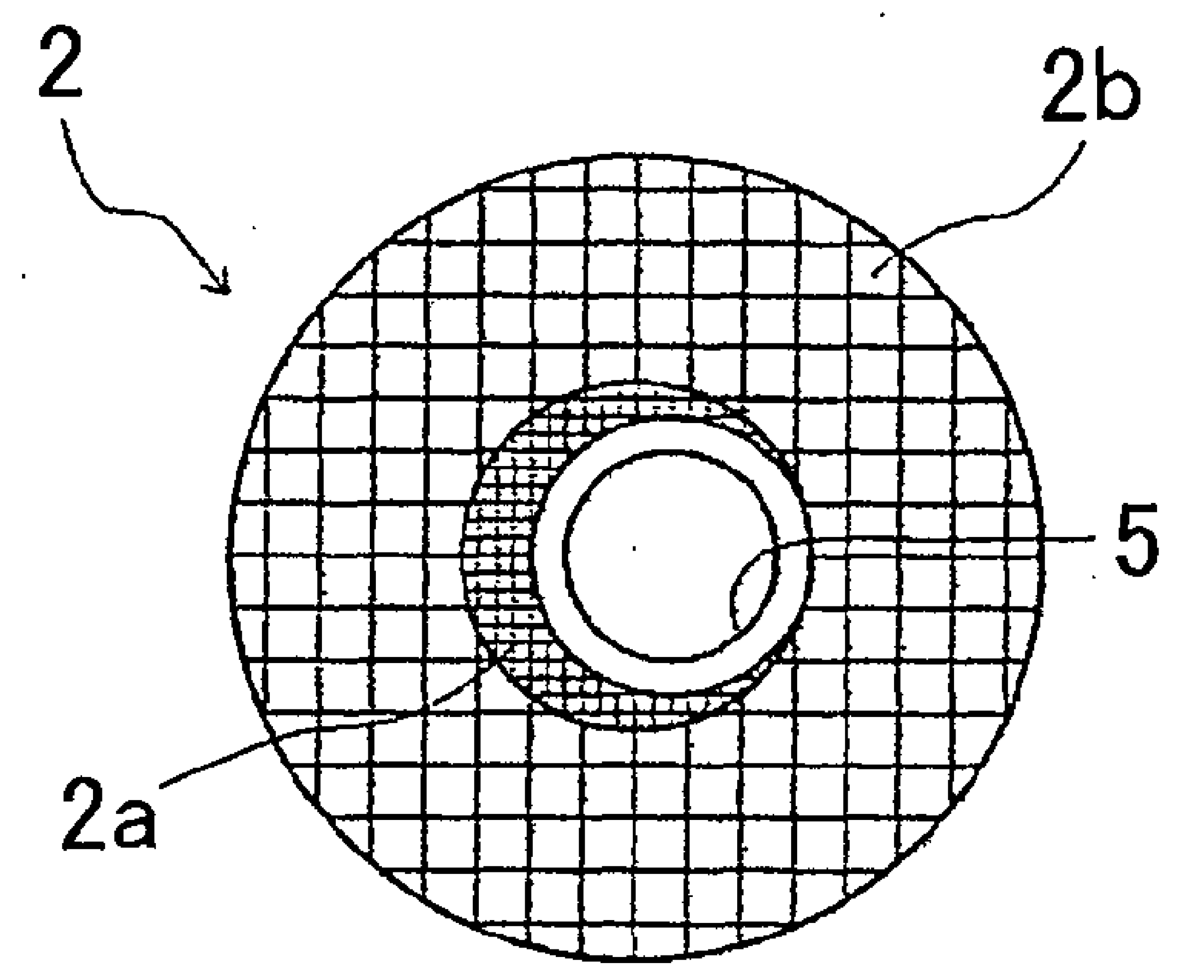


FIG. 3C

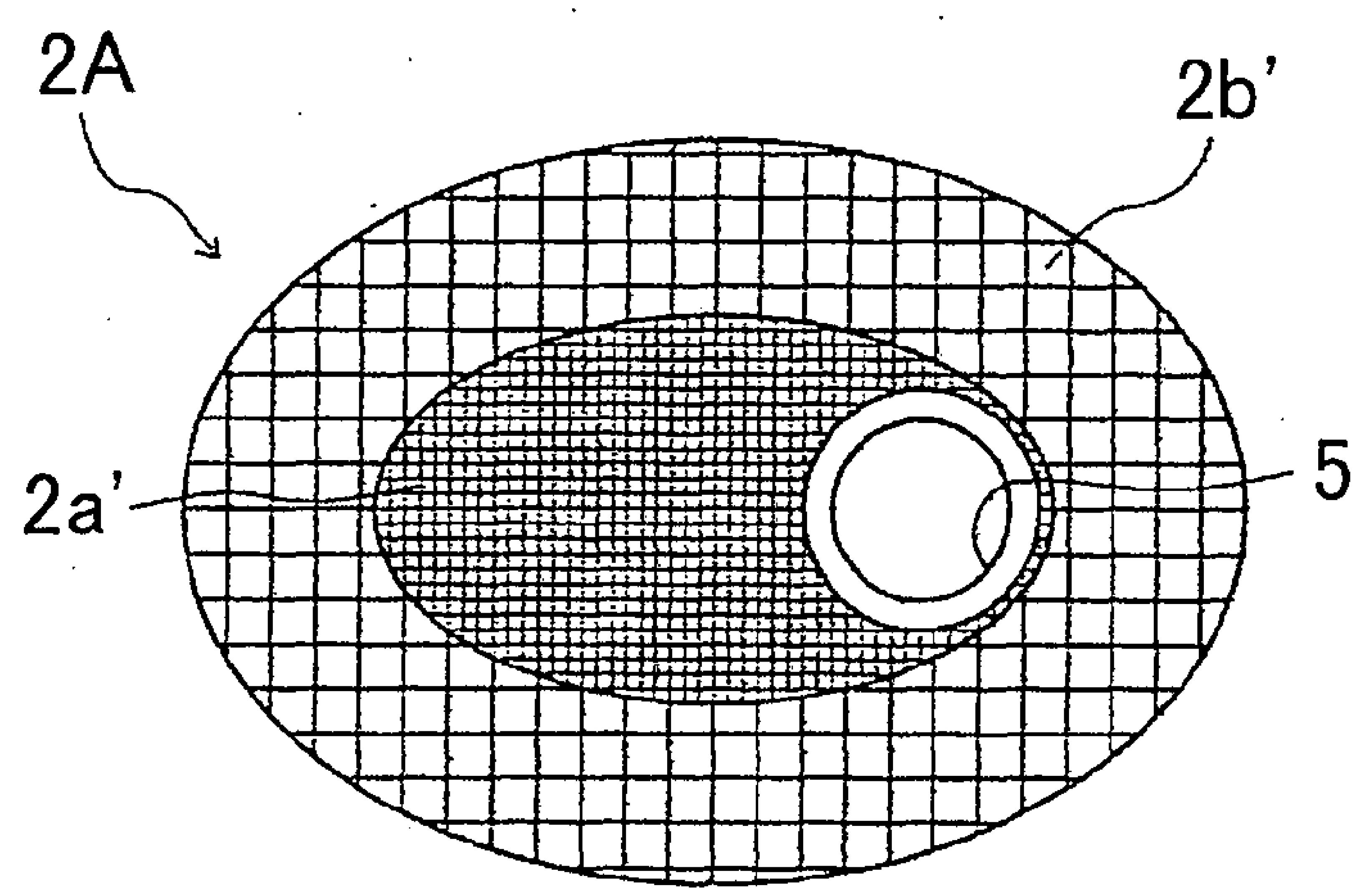


FIG. 4

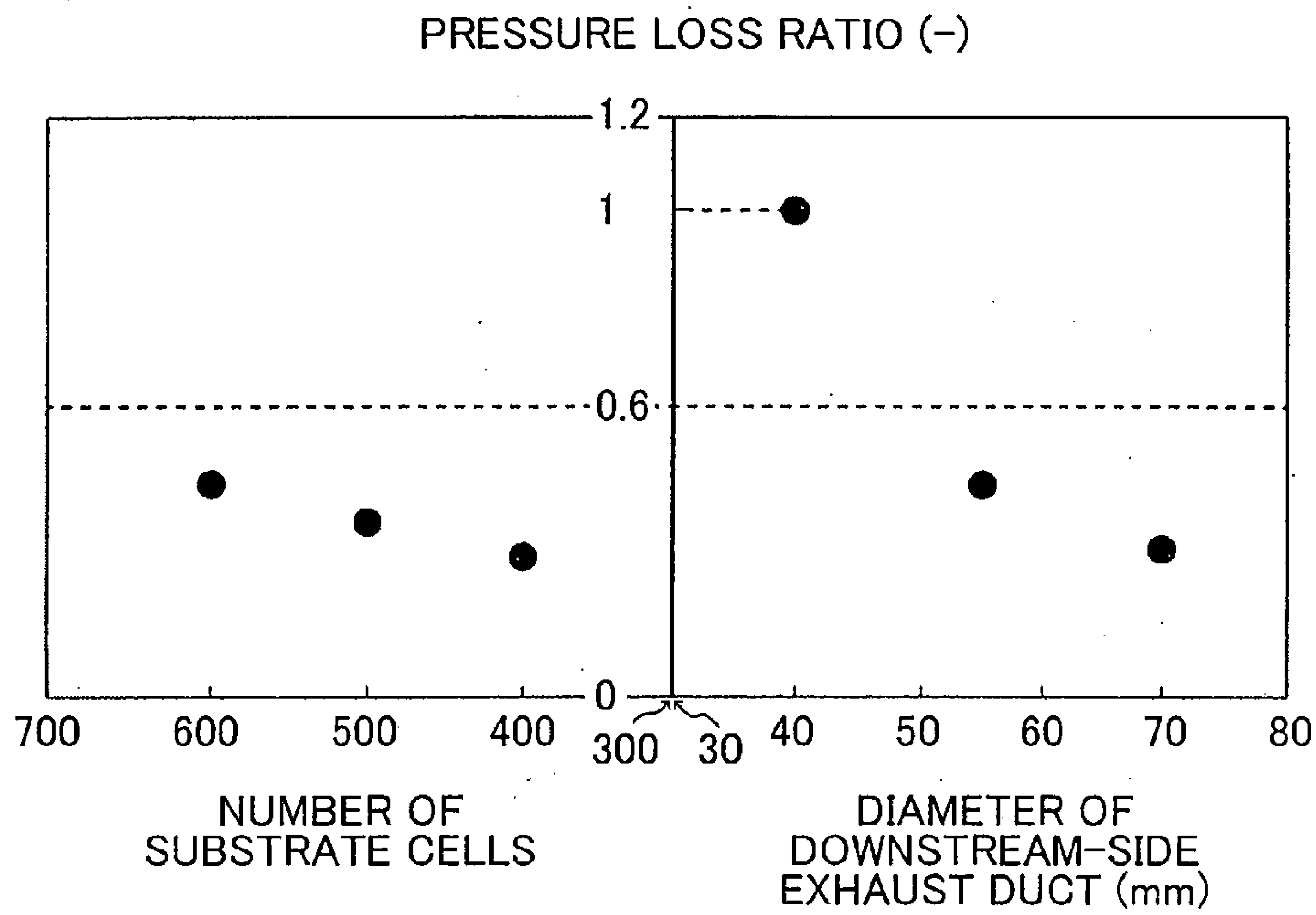
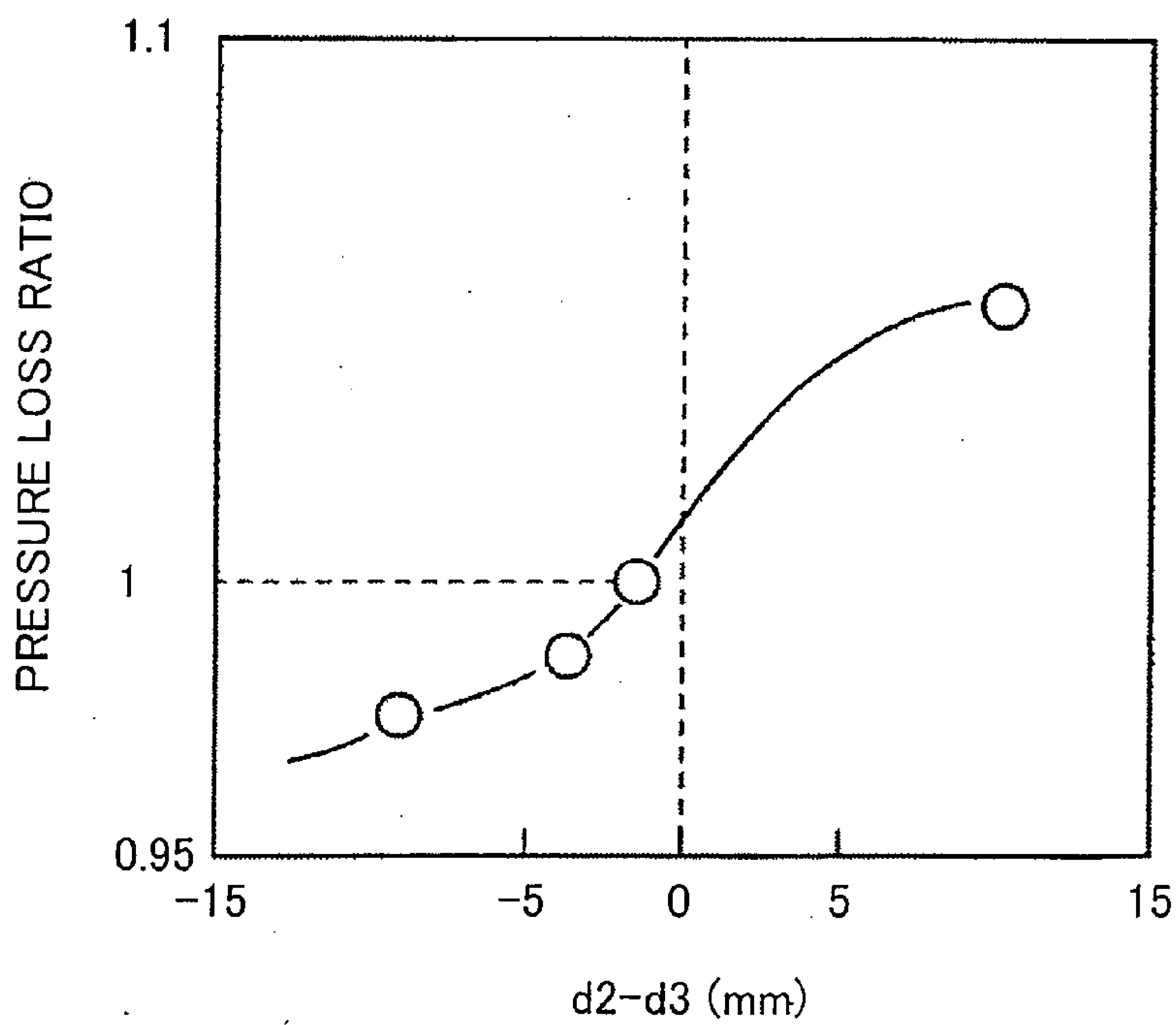

PRESSURE LOSS RATIO (-)
1.2
1
0.6
0
700
600
500
400
300
30
40
50
60
70
80
NUMBER OF SUBSTRATE CELLS
DIAMETER OF DOWNSTREAM-SIDE EXHAUST DUCT (mm)

FIG. 5


1.1
PRESSURE LOSS RATIO
1
0.95
−15
−5
0
5
15
d2−d3 (mm)

F I G . 6

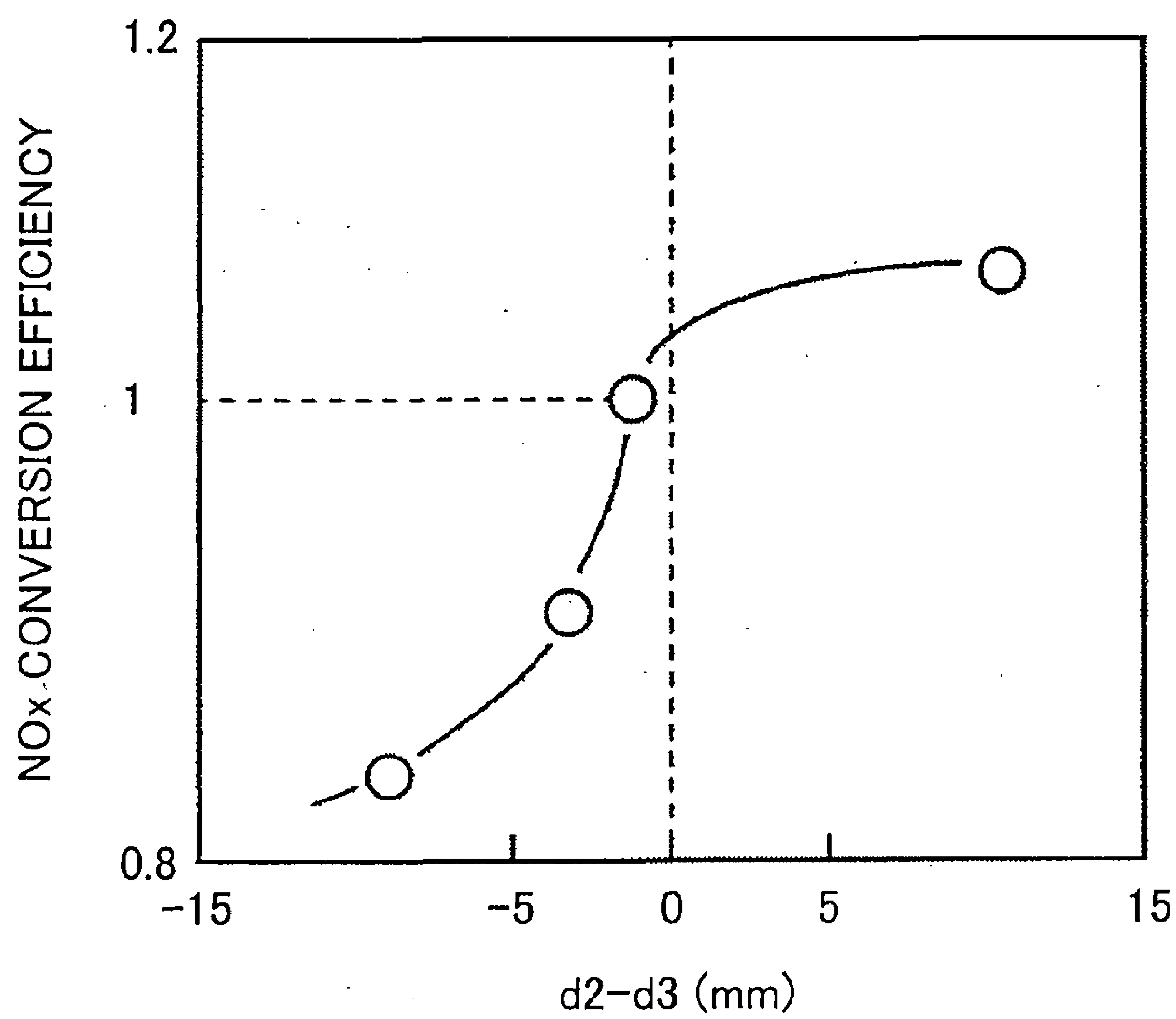
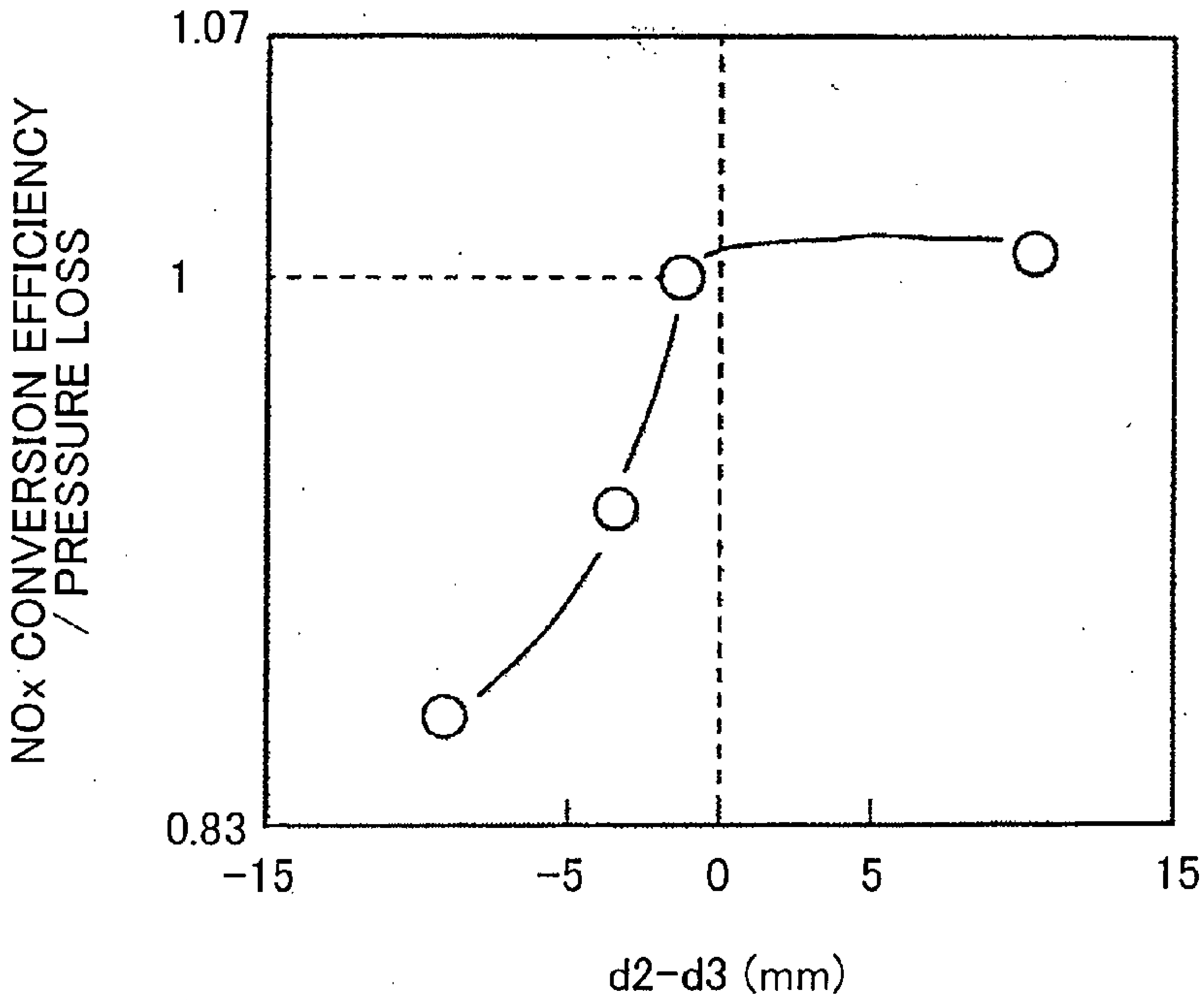


FIG. 7


1.07
1
0.83
NOx CONVERSION EFFICIENCY / PRESSURE LOSS
−15
−5
0
5
15
d2−d3 (mm)

CATALYTIC CONVERTER

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a catalytic converter that forms an exhaust system for exhaust gas.

[0003] 2. Description of Related Art

[0004] In various industries, various efforts to reduce the environmental impact are being made on a worldwide scale. Among these, on a daily basis in the automotive industry efforts are being made to popularize so-called eco-cars such as hybrid vehicles and electric vehicles, and of course, gasoline engine vehicles with excellent fuel efficiency performance, and developments are being made to further improve the performance of these vehicles.

[0005] A catalytic converter for purifying exhaust gas is typically arranged in an exhaust system for exhaust gas that connects a vehicle engine to a muffler.

[0006] The engine discharges toxic substances such as unburned HC and VOC. In order to convert these toxic substances into allowable substances, a catalyst layer formed by a precious metal catalyst such as palladium or platinum is formed on a cell wall surface of a substrate that includes multiple cells. More specifically, a catalyst layer is formed in the length direction of the substrate, i.e., along a direction in which the exhaust gas flows, on the cell wall surface of the multiple cells. When the exhaust gas passes through the catalytic converter provided with the substrate having this kind of structure, CO is consequently converted to CO_2, NOx is converted to N_2 and O_2, and VOC is combusted to produce CO_2 and H_2O.

[0007] In a typical catalytic converter, the cell density of the substrate is uniform with a substrate provided with cells having a honeycomb structure, for example. Because a flow rate distribution of the exhaust gas in a sectional center region of the substrate is higher than it is in a sectional peripheral region, the catalyst layer of the entire substrate is unable to be sufficiently utilized.

[0008] Therefore, taking this kind of exhaust gas flow rate distribution into consideration, a difference in flow rate distribution in a cross-section of the substrate is able to be reduced as quickly as possible, by making the catalytic converter have a higher cell density in the center region than in the sectional peripheral region of the substrate, so exhaust gas purification that effectively utilizes the catalyst layer of the entire catalytic converter becomes possible.

[0009] Also, changing the cell density in the cross-section of the substrate in this way enables pressure loss in the catalytic converter to also be reduced, which also contributes to improved exhaust gas purification performance.

[0010] The relationship between the catalytic converter and an exhaust duct on the downstream side where purified exhaust gas flows out from this catalytic converter is also extremely important in improving the exhaust gas conversion efficiency of the entire catalytic converter and reducing pressure loss. It is necessary to comprehensively design a catalytic converter, including the exhaust duct on the downstream side of the catalytic converter.

[0011] Japanese Patent Application Publication No. 2008-18370 (JP 2008-18370 A) focuses on the relationship between a catalytic converter and an exhaust duct on the upstream side, and describes a ceramic catalyst body in which an aperture ratio of a substrate portion corresponding to a projection portion with respect to the substrate of the exhaust duct on the upstream side is smaller than the aperture ratio of a substrate portion corresponding to a portion to the outside of this projection portion.

[0012] The ceramic catalyst body described in JP 2008-18370 A focuses on the relationship between the exhaust duct on the upstream side of the catalytic converter and the cell density of the substrate that forms the catalytic converter. The exhaust gas purification performance is also able to be increased by this ceramic catalyst body However, the inventors have discovered that the relationship between the substrate that forms the catalytic converter and the exhaust duct on the downstream side of this catalytic converter is even more important to the exhaust gas purification performance than the relationship between the exhaust duct on the upstream side of the catalytic converter and the substrate that forms this catalytic converter is.

SUMMARY OF THE INVENTION

[0013] The invention thus provides a catalytic converter having excellent exhaust gas purification performance, by specifying a relationship between a substrate that forms the catalytic converter and an exhaust duct on a downstream side of the catalytic converter.

[0014] The catalytic converter according to the invention includes an outer tube that is connected to an exhaust duct through which exhaust gas flows. This outer tube includes a cylindrical portion, an upstream-side cone portion that extends from one end of the cylindrical portion in such a manner that a cross-section thereof becomes smaller in diameter, and that is connected to the exhaust duct on an upstream side with respect to an exhaust gas flow, and a downstream-side cone portion that extends from the other end of the cylindrical portion in such a manner that a cross-section thereof becomes smaller in diameter, and that is connected to the exhaust duct on a downstream side with respect to the exhaust gas flow. The catalytic converter also includes a substrate having a cell structure that is arranged inside of the cylindrical portion of the outer tube. A catalyst layer in which a precious metal catalyst is carried on a carrier is formed on a cell wall surface of the substrate. The substrate is configured such that a cell density at a center region is different than a cell density at a peripheral region, in a cross-section that is orthogonal to a length direction of the substrate, the cell density of the center region being higher than the cell density of the peripheral region. The substrate is such that a projection portion when a cross-section of a connecting portion of the exhaust duct and the downstream-side cone portion is projected onto the substrate falls within the center region.

[0015] The catalytic converter of the invention includes a substrate with a catalyst layer having a cell structure arranged in a hollow interior of a metal outer tube formed by a cylindrical portion that is between an upstream-side cone portion at one end and a downstream-side cone portion at the other end, both of which become smaller in diameter toward the outside. Providing the substrate with the center region where the cell density is relatively high and the peripheral region where the cell density is relatively low enables a difference in the exhaust gas flow rate distribution between the center region and the peripheral region to be smaller than it is with a substrate in which the cell density is uniform.

[0016] In addition, a projection portion formed when the connecting portion of the exhaust duct on the downstream side and the downstream-side cone portion of the outer tube in which the sectional area is smaller than that of the substrate is projected onto the substrate may fall within the center region. As a result, the exhaust gas purification performance is able to be increased.

[0017] The purified exhaust gas that flows out on the downstream side from the catalytic converter passes through the downstream-side cone portion of the outer tube and out into the exhaust duct on the downstream side. Therefore, even if an attempt is made to equalize the flow rate distribution of the entire cross-section by making the cell density in the center region different from that in the peripheral region in a cross-section of the substrate, the flow rate of the exhaust gas at a substrate portion corresponding to the projection portion when the cross-section of the exhaust duct on the downstream side where the exhaust gas flows out is projected onto the substrate is actually faster than it is at another substrate portion.

[0018] Therefore, by placing this projection portion inside the center region (i.e., the region where the cell density is high) of the substrate, the exhaust gas is able to be made to effectively flow through the center region where the cell density is high and the catalyst quantity is large, so purification of this exhaust gas is able to be promoted. As a result, the exhaust gas purification performance of the overall catalytic converter is able to be improved.

[0019] Here, the substrate having the cell structure may be made of ceramic material such as cordierite or silicon carbine. A so-called honeycomb structure that includes multiple cells with lattice profiles that are square, hexagonal, or octagonal or the like, may be applied to the substrate having the cell structure.

[0020] Also, a porous oxide is one possible example of the carrier that forms the catalyst layer that is formed on the cell wall surface of the substrate. A catalyst layer in which one or two or more types of precious metal catalysts such as rhodium, palladium, and platinum are carried on this carrier may be formed.

[0021] The catalytic converter of the invention has a cordierite honeycomb carrier having excellent thermal shock resistance, but it may alternatively be an electrically heated catalytic converter (EHC: electrically heated converter). This electrically heated catalytic converter is provided with a pair of electrodes that are attached to a honeycomb catalyst, for example. The honeycomb catalyst is heated by energizing the electrodes, which in turn increases the activity of the honeycomb catalyst, such that the exhaust gas that passes through this is purified. By applying the electrically heated catalytic converter to an exhaust system for exhaust gas that connects a vehicle engine to a muffler, the catalyst can be activated by electric heating, thus enabling the exhaust gas to be purified when it is cold, in addition to purifying exhaust gas at normal temperature.

[0022] As described above, according to the catalytic converter of the invention, exhaust gas purification is able to be promoted, thus enabling the exhaust gas purification performance of the entire catalytic converter to be improved, by passing exhaust gas having a high flow rate through a center region where the cell density is high and the catalyst quantity is large, while effectively utilizing the catalyst in the peripheral region of the substrate to purify exhaust gas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

[0024] FIG. **1** is a view showing a frame format of one example embodiment of a catalytic converter according to the invention, together with exhaust ducts on an upstream side and a downstream side;

[0025] FIG. **2** is a perspective view of a substrate that forms the catalytic converter;

[0026] FIG. **3**A is a view from a Y direction in FIG. **1**, of a connecting portion of an exhaust duct on a downstream side and a downstream-side cone portion projected onto a cross-section of the substrate;

[0027] FIG. **3**B is a view of another example embodiment of the projection view in FIG. **3**A;

[0028] FIG. **3**C is a view of yet another example embodiment of the projection view in FIG. **3**A;

[0029] FIG. **4** is a view showing analysis results related to a pressure loss ratio when the number of substrate cells and the diameter of the downstream-side exhaust duct are changed;

[0030] FIG. **5** is a view of test results identifying a relationship between a difference in a diameter d**2** of a center region of the substrate and a diameter d**3** of the connecting portion, and the pressure loss in the catalytic converter;

[0031] FIG. **6** is a view of test results identifying a relationship between the difference in the diameter d**2** of the center region of the substrate and the diameter d**3** of the connecting portion, and a NOx purification amount of the catalytic converter; and

[0032] FIG. **7** is a view of test results identifying a relationship between the difference in the diameter d**2** of the center region of the substrate and the diameter d**3** of the connecting portion, and a ratio of the NOx purification amount to the pressure loss (i.e., NO purification amount/pressure loss).

DETAILED DESCRIPTION OF EMBODIMENTS

[0033] Example embodiments of a catalytic converter of the invention will now be described with reference to the accompanying drawings.

[0034] (Example Embodiments of the Catalytic Converter)

[0035] FIG. **1** is a view showing a frame format of one example embodiment of the catalytic converter according to the invention, together with exhaust ducts on an upstream side and a downstream side. FIG. **2** is a perspective view of a substrate that forms the catalytic converter. Also, FIG. **3**A is a view from a Y direction in FIG. **1**, of a connecting portion of a downstream-side cone portion and the downstream-side exhaust duct projected on a cross-section of the substrate

[0036] First, an overview of an exhaust system for exhaust gas, in which a catalytic converter **10** of the invention is interposed will be described. The exhaust system for exhaust gas to which the catalytic converter of the invention is applied includes an engine, a catalytic converter, a three-way catalytic converter, a sub muffler, and a main muffler, all of which are connected together by an exhaust duct. Exhaust gas produced by the engine flows through each portion via the exhaust duct, so as to be discharged. In FIG. **1**, the catalytic converter **10**, an exhaust duct **3** on an upstream side of the catalytic converter **10** (hereinafter also referred to as the "upstream-side exhaust duct **3**"), and an exhaust duct **4** on a downstream side of the catalytic converter **10** (hereinafter also referred to as the "downstream-side exhaust duct **4**")are shown.

[0037] The catalytic converter **10** includes a metal outer tube **1**, and a substrate **2** arranged inside the outer tube **1**. The outer tube **1** is formed, for example, by a cylindrical portion **1***a* having a uniform cross-section, an upstream-side cone portion **1***b* that extends from one end of the cylindrical portion **1***a* such that the cross-section narrows in diameter, and that connects the exhaust duct **3** on the upstream side with respect to the exhaust gas flow, and a downstream-side cone portion **1***c* that extends from the other end of the cylindrical portion **1***a* such that the cross-section narrows in diameter, and that connects the exhaust duct **3** on the downstream side with respect to the exhaust gas flow.

[0038] The substrate **2** arranged inside the outer tube **1** is formed by a cylindrical member having multiple cells, with a catalyst layer, not shown, formed on a cell wall surface. Possible examples of material used to form the substrate **2** include ceramic material such as silicon carbine or cordierite made of a composite oxide of silicon dioxide, aluminum oxide, and magnesium oxide, and material other than ceramic material such as metal material.

[0039] Also, a possible example of a carrier that forms the catalyst layer formed on the cell wall surface of the substrate **2** is an oxide having at least one of CeO_2, ZrO_2, and Al_2O_3 as the main component, which is a porous oxide. Possible examples include an oxide formed from one of ceria (CeO_2), zirconia (ZrO_2), and alumina (Al_2O_3), and a composite oxide formed from two or more of these (i.e., ceria (CeO_2), zirconia (ZrO_2), and alumina (Al_2O_3)) (a so-called CeO_2—ZrO_2 compound that is CZ material, or an Al_2O_3—CeO_2—ZrO_2 ternary composite oxide (ACZ material) into which Al_2O_3 has been introduced as a diffusion barrier). Also, the entire catalyst layer is formed by one or two or more of Pd, Pt, and Rh that are precious metal catalysts being carried on these carriers.

[0040] The substrate **2** is formed by a honeycomb structure that includes multiple cells with lattice profiles that are square, hexagonal, or octagonal or the like, such that exhaust gas flows through the inside of each of the cells (in direction X**1**).

[0041] Moreover, the substrate **2** is has two regions, i.e., a center region **2***a* where the cell density is relatively high, and a peripheral region **2***b* where the cell density is relatively low.

[0042] By providing the center region **2***a* and the peripheral region **2***b* having different cell densities in this way, exhaust gas that has flowed through from the upstream-side exhaust duct **3** effectively flows into the peripheral region **2***b* where the cell density is relatively low which facilitates the flow. As a result, the difference in the flow rate distribution between the center region **2***a* and the peripheral region **2***b* decreases, so exhaust gas purification that effectively utilizes the entire catalyst layer of the catalytic converter **10** can be performed.

[0043] As shown in the drawing, when the diameter of the substrate **2** is d**1**, the diameter of the center region that forms the substrate **2** is d**2**, and the diameter of the connecting portion **5** of the downstream-side exhaust duct **4** and the downstream-side cone portion **1***c* is d**3**, the catalytic converter **10** illustrated has a relationship of d1>d2≥d3. Further, the catalytic converter **10** and the downstream-side exhaust duct **4** are formed such that a projection portion formed by projecting the connecting portion **5** onto a cross-section of the substrate **2** is within the center region **2***a,* as shown in FIG. **3**A.

[0044] The mode in which the projection portion formed by projecting the connecting portion **5** onto a cross-section of the substrate **2** exists in the center region **2***a* includes both a mode in which a true circle cross section of the connecting portion **5** and a true circle cross section of the center region **2***a* have the same circle center as shown in FIG. **3**A, a mode in which the circle centers of both of the true circle cross sections are offset from one another as shown in FIG. **3**B. Moreover, when a substrate **2**A having an oblong sectional shape is applied as shown in FIG. **3**C, in a center region **2***a*' having an oblong sectional shape and a peripheral region **2***b*' around this center region **2***a*', the true circle cross section of the connecting portion **5** is in the center region **2***a*' having this oblong shape. In a case in which the substrate and the center region thereof are polygonal and a case in which the downstream-side exhaust duct is oblong or polygonal (and therefore a case in which the projection portion of the connecting portion is also oblong or polygonal) as well, the structure of the invention is satisfied as long as the projection portion of the connecting portion is in the center region of the substrate.

[0045] [Analysis related to pressure loss ratio when the number of substrate cells and the diameter of the downstream-side exhaust duct are changed, and results thereof]

[0046] The inventors used a computer to simulate a catalytic converter with three different numbers of substrate cells and downstream-side exhaust duct diameters as parameters, an performed an analysis to obtain the pressure loss ratio in each of these catalytic converters. Thermo-fluid analysis (software: STAR-CD by IDAJ Co., LTD.) was used in the analysis.

[0047] The downstream-side exhaust duct diameter was set to 55 mm as a condition when analyzing the relationship between the number of substrate cells and the pressure loss ratio. Meanwhile, the number of substrate cells was set to 600 as a condition when analyzing the relationship between the downstream-side exhaust duct diameter and the pressure loss ratio. The analysis results are shown in FIG. **4**.

[0048] Upon verifying the degree to which each of the factors contributes to pressure loss in the catalytic converter, the inventors found that an increase in the downstream-side exhaust duct diameter contributes significantly to a decrease in pressure loss, as is also evident from FIG. **4**.

[0049] As described above, it is evident that when reducing the pressure loss in the catalytic converter, the cross-section diameter of the downstream-side exhaust duct that is connected to the outer tube that forms the catalytic converter has a greater effect than the constituent elements that directly make up the catalytic converter. The relationship between the constituent elements of the catalytic converter and the downstream-side exhaust duct is specified based on this verification result.

[0050] Because the purified exhaust gas that has flowed out to the downstream side from the catalytic converter **10** passes through the downstream-side cone portion **1***c* of the outer tube **1**, and then flows out to the downstream-side exhaust duct **4**, the cell density in the center region **2***a* is made different from the cell density in the peripheral region **2***b* in the substrate **2** in an attempt to equalize the flow rate distribution of the entire cross-section. In this case, the flow rate of the exhaust gas at a substrate portion corresponding to a projection portion when a cross section of the downstream-side exhaust duct **4** where the exhaust gas flows out is projected onto the substrate **2** is actually faster than it is at another substrate portion. Therefore, by providing this projection portion in the center region **2***a* of the substrate **2** as shown in FIG. **3**A, the exhaust gas can be made to effectively flow through the center region **2***a* where the cell density is high and there are a large amount catalysts, so purification can be promoted.

As a result, the exhaust gas purification performance of the overall catalytic converter **10** is able to be improved.

[0051] [Test to identify the relationship between the difference in the diameter d**2** of the center region of the substrate and the diameter d**3** of the connecting portion, and the pressure loss of the catalytic converter, the relationship between that difference and the NOx purification amount of the catalytic converter, the relationship between that difference and the NOx purification amount/the pressure loss, as well as the results of these]

[0052] The inventors conducted a test to identify the relationship between the difference in the diameter d**2** of the center region of the substrate and the diameter d**3** of the connecting portion of the downstream-side exhaust duct and the downstream-side cone portion, and the pressure loss of the catalytic converter, the relationship between that difference and the NOx purification amount of the catalytic converter, the relationship between that difference and the NOx purification amount/the pressure loss.

[0053] The test conditions were such that the diameter dl (sectional diameter=103 mm) of the substrate and the diameter d**2** of the center region were set, and the diameter d**3** of the downstream-side exhaust duct was changed to four dimensions, i.e., 41.2 mm, 52.7 mm, 55 mm, and 60.5 mm. The ratio of the area of the center region to the total sectional area of the substrate was 25%. Also, when measuring the pressure loss, a 2.5 liter gasoline engine was used, and the intake air amount Ga was 100 g/s. Further, when measuring the NOx purification amount as well, a 2.5 liter gasoline engine was used, and the intake air amount Ga was 20 g/s.

[0054] The test results are shown in FIGS. **5** to **7**. Here, FIG. **5** is a view of test results related to the pressure loss. FIG. **6** is a view of test results related to the NOx purification amount. FIG. **7** is a view of test results related to the NO purification amount/the pressure loss). In each of the drawings, an approximate curve is created based on the plotted test results.

[0055] From FIG. **5** it is evident that the pressure loss increases as the diameter of the downstream-side exhaust duct decreases.

[0056] Also, from FIG. **6** it is evident that the amount of change in the conversion efficiency decreases as the diameter of the downstream-side exhaust duct becomes smaller than the diameter of the center region.

[0057] In this way, the pressure loss increases as the diameter of the downstream-side exhaust duct becomes smaller, while the amount of change in the conversion efficiency decreases as the diameter of the downstream-side exhaust duct decreases. This is thought to be because exhaust gas having a fast flow rate flows into the center region where the cell density is high, so exhaust gas purification is efficiently performed in the center region where the catalyst quantity is large and the exhaust gas purification performance is high.

[0058] Based on the results in FIGS. **5** and **6**, it is evident that a high exhaust gas conversion efficiency is able to be maintained in a range in which the difference is equal to or greater than zero, i.e., in a region where the diameter of the center region is larger than the diameter of the downstream-side exhaust duct.

[0059] While the invention has been described in detail with reference to the foregoing example embodiments, the invention is not limited to the example embodiments, but may also include design modifications and the like without departing from the scope of the invention.

1. A catalytic converter comprising:

an outer tube that is connected to an exhaust duct through which exhaust gas flows, the exhaust duct including an upstream-side exhaust duct and a downstream-side exhaust duct with respect to a direction of an exhaust-gas flow, the outer tube including a cylindrical portion, an upstream-side cone portion connected to the upstream-side exhaust duct, and a downstream-side cone portion connected to the downstream-side exhaust duct, the upstream-side cone portion extending from an upstream-side end of the cylindrical portion in such a manner that a cross-section diameter of the upstream-side cone portion decreases toward the upstream-side exhaust duct, the downstream-side cone portion extending from a downstream-side end of the cylindrical portion in such a manner that a cross-section diameter of the downstream-side cone portion decreases toward the downstream-side exhaust duct; and

a substrate having a cell structure and being arranged inside of the cylindrical portion of the outer tube, wherein

a catalyst layer in which a precious metal catalyst is carried on a carrier is formed on a cell wall surface of the substrate,

the substrate has a center region and a peripheral region in a cross-section orthogonal to a length direction of the substrate,

a cell density of the center region is higher than a cell density of the peripheral region,

a projection portion when a projection of a cross-section of a connecting portion of the exhaust duct and the downstream-side cone portion on the substrate falls within the center region,

a downstream-side surface of the substrate is directly opposite to an opening of the downstream-side exhaust duct, and

a diameter of the center region is larger than a diameter of the connecting portion of the exhaust duct and the downstream-side cone portion.

* * * * *