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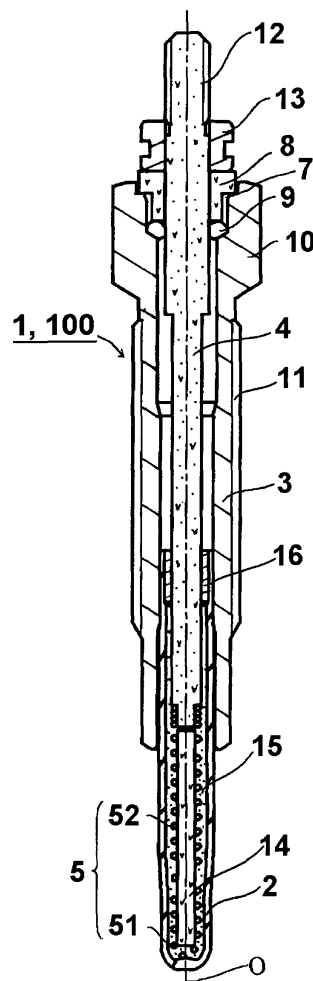
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(54) **Glow plug**

(57) A glow plug 1 includes a metallic tube 3 having a closed distal end and extending axially, a rod-like insulator 14 disposed within the metallic tube 3 in such a manner as to form a clearance therebetween, a coil member 5 disposed in such a manner as to encircle an outer circumferential surface of the insulator 14, and insulating powder 15 charged into the metallic tube 3 in such a manner as to fill the interior of the metallic tube 3, wherein the insulator 14 is formed of a material having thermal conductivity lower than that of the insulating powder 15. By rendering thermal conductivity in the inside of the coil member 5 lower than thermal conductivity in a region between the coil member 5 and the metallic tube 3, conduction of heat generated by the coil member 5 to the inside of the coil member 5 is suppressed, so that the heat is effectively conducted to the metallic tube 3.

Fig. 1



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Description

[0001] The present invention relates to a glow plug for preheating the interior of a cylinder of a diesel engine, as well as to a glow plug for preheating water.

[0002] A conventional glow plug includes a metallic tube having a closed distal end and extending axially; a rod-like insulator disposed within the metallic tube in such a manner as to form a clearance therebetween; a coil member disposed in such a manner as to encircle an outer circumferential surface of the insulator; and insulating powder charged into the metallic tube in such a manner as to fill the interior of the metallic tube; see for example Japanese Patent Application Laid-Open (*kokai*) No. 57-58017 at page 1 (referred to herein as Patent Document 1).

[0003] In the glow plug of Patent Document 1, the rod-like insulator is inserted into an internal space of the coil member so as to prevent contact between the coil member and the metallic tube, which could otherwise result from bending of the coil member in the process of drawing the metallic tube, and to prevent variations in heating characteristics among glow plugs, which could otherwise result from occurrence of uneven pitch spacings between turns of the coil member. Also, when only the insulating powder is used as a filler for the metallic tube, voids are formed between powder particles even after drawing. Insertion of the rod-like insulator lessens a space into which the insulating powder is charged, whereby the effect of charging is enhanced through reduction of void space.

[0004] However, in the glow plug of Patent Document 1, heat generated by the coil member cannot be effectively conducted to the metallic tube. This is because heat generated by the coil member is conducted not only to the metallic tube to thereby directly preheat the interior of a cylinder of a diesel engine or to thereby directly preheat water, but also from the coil member to the insulator located in the inside of the coil member. As a result, the glow plug may fail to function as an effective heat source.

[0005] The present invention has been accomplished in view of the above problem, and an object of the invention is to provide a glow plug in which heat generated by the coil member can be effectively conducted to the metallic tube.

[0006] To achieve the above object, the present invention provides a glow plug comprising a metallic tube having a closed distal end and extending axially, a rod-like insulator disposed within the metallic tube in such a manner as to form a clearance therebetween, a coil member disposed in such a manner as to encircle an outer circumferential surface of the insulator, and insulating powder charged into the metallic tube in such a manner as to fill the interior of the metallic tube, wherein the insulator is formed of an insulating material having thermal conductivity lower than that of the insulating powder.

[0007] In the glow plug of the present invention, the insulator to be inserted into the coil member is formed of an insulating material having thermal conductivity lower than that of the insulating powder, which is to be charged into the metallic tube in such a manner as to fill the interior of the metallic tube. By rendering thermal conductivity in the inside of the coil member lower than thermal conductivity in a region between the coil member and the metallic tube, conduction of heat generated by the coil member to the metallic tube increases, so that the heat is effectively conducted to the metallic tube. Thus, the glow plug can function as an effective heat source.

[0008] Generally, in order to preheat an internal combustion engine, a glow plug is maintained at a predetermined temperature. In order to maintain the glow plug at the predetermined temperature, predetermined current must be continuously supplied to a coil member. As a result, the coil member involves danger of breaking.

[0009] However, since the glow plug of the present invention is configured such that the insulator inserted into the coil member is formed of an insulating material having thermal conductivity lower than that of the insulating powder, heat generated by the coil member is effectively conducted to the metallic tube, so that the heat that the coil member must generate in order to maintain the glow plug at a predetermined temperature can be reduced as compared with the case of a conventional glow plug. As a result, predetermined current that flows to the coil member decreases, whereby the durability of the coil member can be enhanced.

[0010] Preferably, the glow plug of the present invention is configured such that $A \geq 0.6B$, where A is the diameter of the insulator, and B is the inside diameter of the coil member. This feature allows the insulator to occupy a greater space in the inside of the coil member, so that thermal conductivity in the inside of the coil member can be effectively lowered. Notably, the inside diameter B of the coil member is the inside diameter of a projected image of the coil member when the coil member is axially projected.

[0011] Preferably, the glow plug of the present invention is configured such that the insulating powder is of magnesium oxide, and the insulating material is alumina. When the insulating powder is of magnesium oxide, and the insulating material is alumina, heat can be more effectively conducted from the coil member to the metallic tube.

[0012] A further aspect of the present invention provides a glow plug comprising a metallic tube having a closed distal end and extending axially, a rod-like insulator formed of an insulating material and disposed within the metallic tube in such a manner as to form a clearance therebetween, a coil member disposed in such a manner as to encircle an outer circumferential surface of the insulator, and insulating powder charged into the metallic tube in such a manner as to fill the interior of the metallic tube, wherein, as viewed on a cross section taken perpendicularly to an axis, the insulating powder present in a clearance between the metallic tube and the coil member is greater in an occupancy

rate per unit area than the insulating material in the insulator.

[0013] The glow plug of this aspect of the present invention is configured such that the occupancy rate (packing density) of the insulating powder in the clearance between the metallic tube and the coil member is greater than that of the insulating material in the insulator. Since void space in a region of the clearance between the metallic tube and the coil member becomes less than that in the insulator, the thermal conductivity of the insulating powder can be rendered higher than that of the insulator, so that heat generated by the coil member can be effectively conducted to the metallic tube. Notably, the occupancy rate is measured per unit area on a cross section taken perpendicularly to the axis of the glow plug.

[0014] Since the glow plug of the present invention is configured such that the occupancy rate of the insulating powder present in the clearance between the metallic tube and the coil member is greater than that of the insulating material in the insulator, heat generated by the coil member is effectively conducted to the metallic tube, so that the heat that the coil member must generate in order to maintain a predetermined temperature can be reduced as compared with the case of a conventional glow plug. As a result, predetermined current that flows to the coil member decreases, whereby the durability of the coil member can be enhanced.

[0015] Preferably, the glow plug of the present invention is configured such that an average particle size of the insulating powder is smaller than that of the insulating material. This feature enables the insulating powder present in the clearance between the metallic tube and the coil member to have an occupancy rate greater than that of the insulating material in the insulator, so that heat generated by the coil member can be effectively conducted to the metallic tube.

[0016] Preferably, the insulating material has thermal conductivity lower than that of the insulating powder. By rendering thermal conductivity in the inside of the coil member lower than thermal conductivity in a region between the coil member and the metallic tube, conduction of heat generated by the coil member to the metallic tube increases, so that the heat is effectively conducted to the metallic tube. Thus, the glow plug can function as a more effective heat source.

[0017] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

Fig. 1 is a vertical sectional view of a glow plug 1 according to an embodiment of the present invention; and

Fig. 2 is an enlarged sectional view of a distal end portion of the glow plug according to an embodiment of the present invention.

[0018] Reference numerals are used to identify items shown in the drawings as follows:

- 1, 100 ... glow plug
- 2 ... metallic tube
- 3 ... metallic shell
- 4 ... center rod
- 5 ... coil member
- 51 ... heating coil
- 52 ... control coil
- 8 ... insulation ring
- 9 ... O-ring
- 13 ... round nut
- 14 ... insulator
- 15 ... insulating powder
- 16 ... elastic packing

[0019] Embodiment 1 of the present invention will next be described in detail with reference to the drawings.

[0020] Fig. 1 shows the internal structure of a glow plug 1, which is an example of the present invention; and Fig. 2 is an enlarged view showing the internal structure of a distal end portion of the glow plug 1. The glow plug 1 includes a tubular metallic shell 3 extending in the direction of an axis O; a metallic tube 2 fixedly attached to a distal end portion of the metallic shell 3, extending in the direction of the axis O, and having a closed distal end; and center rod 4, which serves as an electrode. The metallic tube 2 is formed of stainless steel, such as SUS310S. The center rod 4 extends along the axis of the metallic shell 3 and reaches the interior of the metallic tube 2. The bottom of the metallic tube 2 and a distal end portion of the center rod 4 are electrically connected together via a coil member 5. The coil member 5 consists of a front-end-side heating coil 51, and a rear-end-side control coil 52. The heating coil 51 is formed of a material having a R20 (resistivity at 20°C of) of 80 $\mu\Omega\cdot\text{cm}$ to 200 $\mu\Omega\cdot\text{cm}$, and an R1000/R20 value of 0.8 to 3, where R1000 is resistivity at 1,000°C. Specific examples of the material include an Fe-Cr-A1 alloy, an Ni-Cr alloy, and an

Fe-Cr alloy. The control coil 52 is formed of a material having a R20 (resistivity at 20°C of) of $5\ \mu\Omega\cdot\text{cm}$ to $20\ \mu\Omega\cdot\text{cm}$, an R1000/R20 value of 6 or more, where R1000 is resistivity at 1,000°C. Specific examples of the material include a Co-Ni-Fe alloy and a Co-Fe alloy. In the present embodiment, the center rod 4 and the heating coil 51 are indirectly connected via the control coil 52. However, the heating coil 51 and the center rod 4 may be directly connected together without provision of the control coil 52.

[0021] A rod-like insulator 14 formed of an insulating material, such as aluminum oxide (alumina) or zirconium oxide (zirconia), is inserted into the coil member 5 accommodated within the metallic tube 2. Insulating powder 15 formed of a magnesium oxide (magnesia) powder or the like is charged into the metallic tube 2 in such a manner as to fill the interior of the metallic tube 2. In this embodiment, the insulating material and the insulating powder both have an average particle size of 80 μm , and both have an occupancy rate of 96%. An elastic packing 16 is disposed between the metallic tube 2 and a front end portion of the center rod 4 so as to seal against the metallic tube 2 and the center rod 4, and the elastic packing 16 closes the metallic tube 2. As in the case of the above combination of alumina and magnesia, the insulator 14 is formed of an insulating material having thermal conductivity lower than that of the insulating powder 15. As a result, thermal conductivity in the inside of the coil member 5 is rendered lower than thermal conductivity in a region between the coil member 5 and the metallic tube 2, so that conduction of heat generated by the coil member 5 to the metallic tube 2 increases, and thus the heat is effectively conducted to the metallic tube 2. Therefore, the glow plug 1 can function as an effective heat source.

[0022] Even in the case where, in order to preheat an internal combustion engine, the glow plug 1 is maintained at a predetermined temperature, heat generated by the coil member 5 is effectively conducted to the metallic tube 2, so that the heat that the coil member 5 must generate in order to maintain the glow plug 1 at the predetermined temperature can be reduced as compared with the case of a conventional glow plug. As a result, predetermined current that flows to the coil member 5 decreases, whereby the durability of the coil member 5 can be enhanced.

[0023] Furthermore, the diameter A of the insulator 14 is substantially equal to the inside diameter B of the coil member 5. When $A \geq 0.6B$, where A is the diameter of the insulator 14, and B is the inside diameter of the coil member 5, thermal conductivity in the inside of the coil member 5 decreases, so that heat can be effectively conducted from the coil member 5 to the metallic tube 2.

[0024] A stepped hole 7 is formed at the upper end of the metallic shell 3. A bush-like insulation ring 8 fitted into the stepped hole 7 supports an upper portion of the center rod 4 in such a manner as to dispose the upper portion at the center of the metallic shell 3, and electrically insulates the upper portion from the metallic shell 3. A clearance is formed between the stepped hole 7 and the center rod 4 and filled with an O-ring 9.

[0025] A hexagonal tool engagement portion 10 is externally formed on an upper end portion of the metallic shell 3. A male-threaded portion 11 is formed below the tool engagement portion 10 and used for connection to a diesel engine (not shown) or the like. A male-threaded portion 12 is formed on an upper end portion of the center rod 4. A round nut 13 is screw-engaged with the male-threaded portion 12 and presses the insulation ring 8. In the present embodiment, the center rod 4 and a power cable are directly connected together so as to establish electrical connection therebetween. However, the present invention is not limited thereto. For example, an alternative form of connection may be such that a terminal electrode (not shown) is fixedly attached to the center rod 4 in such a manner as to cover a top portion of the center rod 4, and is connected to a power cable.

[0026] A method for manufacturing the glow plug 1 will next be described. First, the insulator 14 is inserted into the coil member 5, which is formed by welding the control coil 52 and the heating coil 51 together. A rear end portion (of the control coil 52) of the coil member 5 is joined to the center rod 4 by means of, for example, resistance welding. The coil member 5 is inserted, from the heating coil 51, into the metallic tube 2. A distal end portion of the heating coil 51 is joined to the distal end of the metallic tube 2 by means of, for example, arc welding. Then, the insulating powder 15 is charged into the metallic tube 2 in such a manner as to fill the interior of the metallic tube 2. Furthermore, the elastic packing 16 is inserted into a rear end portion of the metallic tube 2.

[0027] A rear end portion of the metallic tube 2 is swaged so as to crimp the elastic packing 16. Furthermore, the entire metallic tube 2 is subjected to swaging from its rear end side toward its distal end side so as to assume predetermined dimensions. Subsequently, the resultant assembly is inserted, from a rear end portion of the center rod 4, into the metallic shell 3 on its distal end side. A rear end portion of the metallic tube 2 is interference-fitted; for example, press-fitted, into the metallic shell 3. Then, a rear end portion of the metallic shell 3 is sealed with the O-ring 9. Subsequently, the insulation ring 8 and the round nut 13 are sequentially fitted to the center rod 4, thereby completing the glow plug 1.

[0028] Next, embodiment 2 of the present invention will be described.

[0029] A glow plug 100 of embodiment 2 is similar to the above-described glow plug 1 except that the insulating powder 15 and the insulator 14 differ from each other in material and/or average particle size. Since the configuration of the glow plug 100 is identical with that of the glow plug 1 of embodiment 1, the insulating powder 15 and the insulator 14 are mainly described with reference to Figs. 1 and 2 while identical structural features are denoted by common reference numerals.

[0030] The rod-like insulator 14, which is formed of an insulating material, such as magnesium oxide (magnesia), is inserted into the coil member 5 of the glow plug 100 of embodiment 2. The insulating powder 15, which is formed of the same insulating material as that of the insulator 14, such as a magnesium oxide (magnesia) powder, is charged into the metallic tube 2 in such a manner as to fill the interior of the metallic tube 2. The insulating powder 15 of the glow plug 100 has an average particle size of 80 μm , whereas the insulating material for the insulator 14 has an average particle size of 120 μm . By rendering the average particle size of the insulating powder 15 smaller than that of the insulating material for the insulator 14, the occupancy rate of the insulating powder 15 present in the clearance between the metallic tube 2 and the coil member 5 can become greater than that of the insulating material in the insulator 14 as observed on the cross section of the glow plug 100 taken perpendicular to the axis. Since void space in a region of the clearance between the metallic tube 2 and the coil member 5 becomes less than that in the insulator 14, the thermal conductivity of the insulating powder 15 can be rendered higher than that of the insulator 14, so that heat generated by the coil member 5 can be effectively conducted to the metallic tube 2.

Example 1

[0031] The results of experiments conducted to confirm the effect of the present invention will be described below. Samples of the glow plug 1 shown in Fig. 1 were fabricated by the above-described method. The coil member 5 had a diameter of 0.35 mm and a length of 22 mm; the metallic tube 2 had a length of 42 mm, a diameter of 4.5 mm as measured at its distal end portion and 5 mm as measured at its rear end portion, and a wall thickness of 0.75 mm; and the materials shown in Table 1 were used to form the insulator 14 and the insulating powder 15. The surface temperature was the maximum temperature that the metallic tube 2 could generate; and the generated heat was calculated by measuring current and applied voltage. Also, the number of voltage application cycles until the coil member 5 broke was measured—each voltage application cycle consists of 5-minute application of 13 VDC and subsequent 1-minute suspension of voltage application. The test results are shown in Table 1. Sample Nos. 1, 4, and 5 are of Comparative Examples, and Sample Nos. 2 and 3 are examples of the present invention. In all of samples 1 to 5 the average particle size of the insulating powder and insulating material is 80 μm and the occupancy rate is 96%.

Table 1

Sample No.	Insulating Powder	Insulator	Generated Heat (W)	Surface Temp. ($^{\circ}\text{C}$)	Durability
1	MgO	MgO	80	900	10,000
2	MgO	Al_2O_3	80	930	10,000
3	MgO	Al_2O_3	70	900	13,000
4	Al_2O_3	Al_2O_3	80	850	10,000
5	Al_2O_3	Al_2O_3	120	900	3,000

[0032] As shown in Table 1, in comparing Sample Nos. 1, 2, and 4, in which the voltage was controlled to exhibit a generated heating of 80 W, Sample Nos. 1 and 4 exhibited a surface temperature of 900 $^{\circ}\text{C}$ and 850 $^{\circ}\text{C}$, respectively, whereas Sample No. 2 exhibited a surface temperature of 930 $^{\circ}\text{C}$. This indicates that, by using magnesium oxide as the insulating powder 15 and alumina as an insulating material for the insulator 14, heat generated by the coil member 5 is effectively conducted to the metallic tube 2.

[0033] Among Sample Nos. 1, 3, and 5, in which the voltage was controlled to exhibit a surface temperature of 900 $^{\circ}\text{C}$, Sample Nos. 1 and 5 exhibit a durability of 10,000 cycles and 3,000 cycles, respectively, whereas Sample No. 3 exhibits a durability of 13,000 cycles. This indicates that the heat that the coil member 5 must generate in Sample No. 3 in order to maintain the glow plug 1 at a predetermined temperature (in this case, 900 $^{\circ}\text{C}$) is reduced, so that the durability of the coil member 5 can be enhanced.

Example 2

[0034] Samples of the glow plug 100 shown in Fig. 1 were fabricated. The coil member 5 had a diameter of 0.35 mm and a length of 22 mm; the metallic tube 2 had a length of 42 mm, a diameter of 4.5 mm as measured at its distal end portion and 5 mm as measured at its rear end portion, and a wall thickness of 0.75 mm; and magnesium oxide was used to form the insulator 14 and the insulating powder 15. A DC voltage of 11 V was applied to the samples, and the surface temperature of each metallic tube 2 and the generated heat were measured after elapse of 60 seconds. The surface temperature was the maximum temperature that the metallic tube 2 could generate; and the generated heat was calculated by measuring current and applied voltage 60 seconds after start of application of the voltage. Also, the

number of voltage application cycles until the coil member 5 broke was measured—each voltage application cycle consists of 5-minute application of 13 VDC and subsequent 1-minute suspension of voltage application. Each of the samples was cut at a position located 5 mm rearward from its distal end so as to obtain a cross section at the position; and an image of 0.3 square millimeter was obtained, through image processing, from the cross section with respect to each of the insulator 14 and the region of the clearance between the metallic tube 2 and the coil member 5, and the occupancy rate of the insulating material and the occupancy rate of the insulating powder 15 were obtained from the respective images. The test results are shown in Table 2. Sample No. 6 is a comparative example glow plug 100 similar to Sample No. 1, and Sample Nos. 7 and 8 are examples of the present invention. In Sample No. 6, the average particle sizes of both the insulating powder and insulating material are 80 μm , whereas in Sample Nos. 7 and 8 the insulating powder has an average particle size of 80 μm , but the insulating material of the insulator has an average particle size of 120 μm . The occupancy rates resulting from these particle sizes are given in Table 2.

Table 2

Sample No.	Insulating Powder Occupancy Rate	Insulator Occupancy Rate	Generated Heat (W)	Surface Temp. ($^{\circ}\text{C}$)	Durability
6	96%	96%	80	900	10,000
7	96%	90%	80	920	10,000
8	96%	90%	75	900	12,000

[0035] As shown in Table 2, in comparing Sample Nos. 6 and 7, in which the voltage was controlled to exhibit a heating of 80 W, Sample No. 6 exhibited a surface temperature of 900 $^{\circ}\text{C}$, whereas Sample No. 7 exhibited a surface temperature of 920 $^{\circ}\text{C}$. This indicates that, when the occupancy rate of the insulating powder 15 present in the clearance between the metallic tube 2 and the coil member 5 is greater than that of the insulating material in the insulator 14, the surface temperature increases, and heat generated by the coil member 5 is more effectively conducted to the metallic tube 2.

[0036] In comparing Sample Nos. 6 and 8, in which the voltage is controlled to exhibit a surface temperature of 900 $^{\circ}\text{C}$, Sample No. 6 had a durability of 10,000 cycles, whereas Sample No. 8 had a durability of 12,000 cycles. This indicates that the heat that the coil member 5 of Sample 8 must generate in order to maintain the glow plug 100 at a predetermined temperature (in this case, 900 $^{\circ}\text{C}$) is reduced, so that the durability of the coil member 5 can be enhanced.

[0037] While the present invention has been described with reference to embodiments, the present invention is not limited thereto, but may be embodied in various other forms without departing from the scope of the invention. For example, the above embodiments are described while mentioning the glow plug 1, 100; however, the present invention may be usable as a water heater for heating water.

[0038] This application is based on Japanese Patent Application No. 2003-118961 filed 23 April 2003, and Japanese Patent Application No. 2004-10149 filed 19 January 2004, incorporated herein by reference in their entirety.

Claims

1. A glow plug (1) comprising a metallic tube (2) having a closed distal end and extending axially, a rod-like insulator (14) disposed within the metallic tube (2) so as to form a clearance between the insulator (14) and the metallic tube (2), a coil member (5) encircling an outer circumferential surface of the insulator (14), and insulating powder (15) charged into the metallic tube (2) which fills the interior of the metallic tube (2),
wherein the insulator (14) is formed of an insulating material having a thermal conductivity lower than that of the insulating powder (15).
2. A glow plug according to claim 1, wherein $A \geq 0.6B$, where A is a diameter of the insulator (14), and B is an inside diameter of the coil member (5).
3. A glow plug according to claim 1 or 2, wherein the insulating powder (15) comprises magnesium oxide, and the insulating material comprises alumina.
4. A glow plug (100) comprising a metallic tube (2) having a closed distal end and extending axially, a rod-like insulator (14) formed of an insulating material and disposed within the metallic tube (2) so as to form a clearance between the insulator (14) and the metallic tube (2), a coil member (5) encircling an outer circumferential surface of the insulator (14), and insulating powder (15) charged into the metallic tube (2) which fills the interior of the metallic

tube (2),

wherein, as viewed on a cross-section perpendicular to a longitudinal axis (O) of the glow plug (100), the insulating powder (15) present in a clearance between the metallic tube (2) and the coil member (5) has a greater occupancy rate per unit area than the insulating material of the insulator (14).

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5. A glow plug according to claim 4, wherein an average particle size of the insulating powder (15) is smaller than that of the insulating material.

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6. A glow plug according to claim 4 or 5, wherein the insulating material has a thermal conductivity lower than that of the insulating powder (15).

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Fig. 1

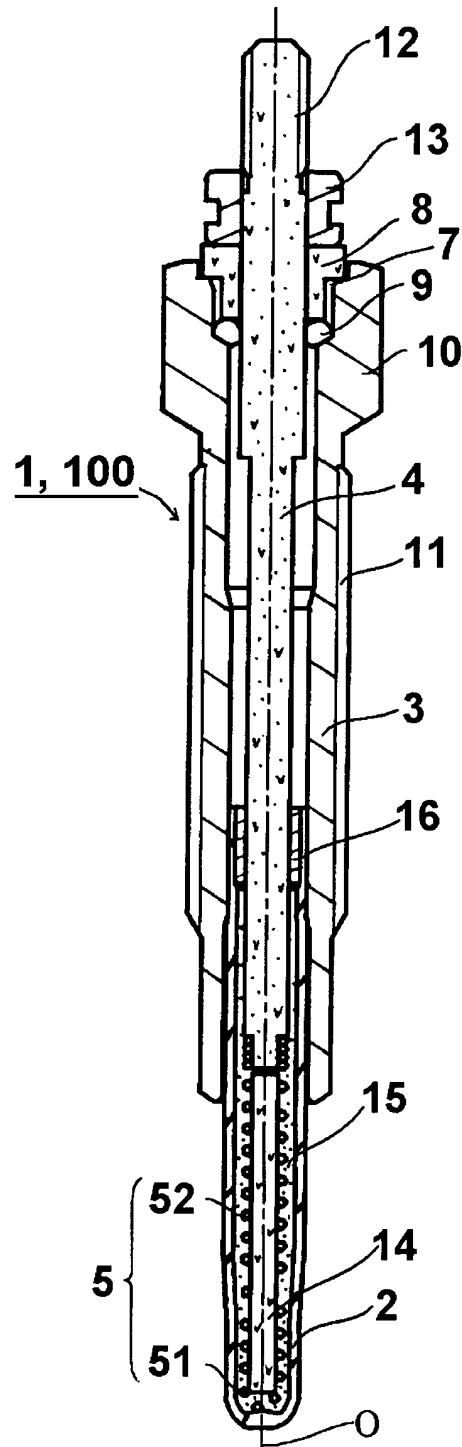
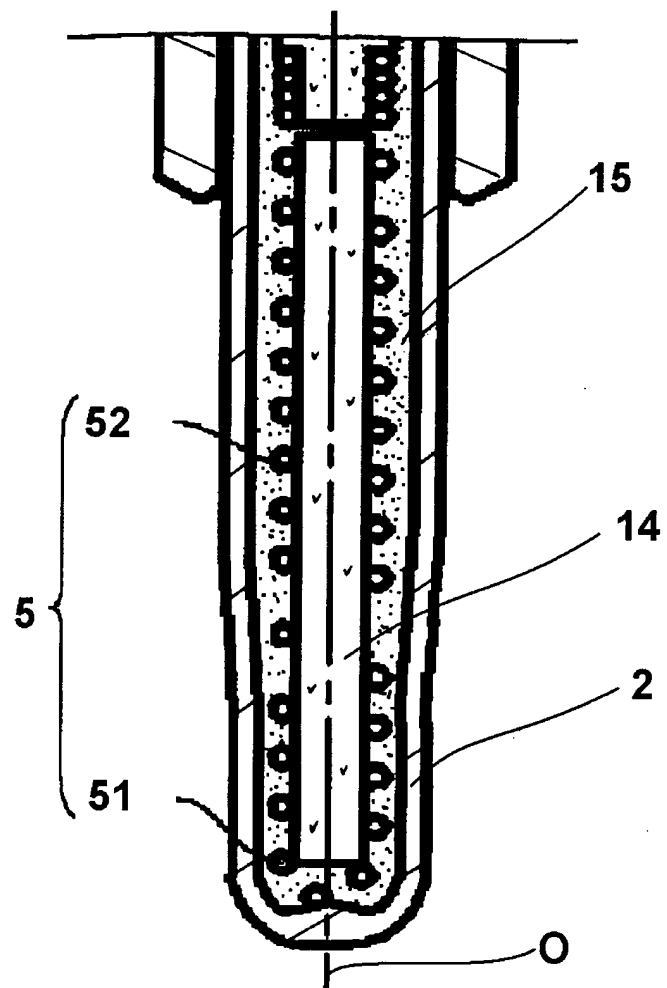


Fig. 2





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 04 25 2379

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	GB 859 659 A (BOSCH GMBH ROBERT) 25 January 1961 (1961-01-25) * page 2, line 35 - line 68; figures *	1-6	F23Q7/00
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A	PATENT ABSTRACTS OF JAPAN vol. 0061, no. 34 (M-144), 21 July 1982 (1982-07-21) & JP 57 058017 A (NGK SPARK PLUG CO LTD), 7 April 1982 (1982-04-07) * abstract *	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		20 August 2004	Vanheusden, J
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 04 25 2379

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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20-08-2004

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