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(54) **Glow plug**

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Description

[Technical Field]

[0001] The present invention relates to a glow plug.

[Background Art]

[0002] Among glow plugs, a sheath-type glow plug which uses a sheath heater is known. The sheath heater of the glow plug includes a sheath tube (a tubular member) whose forward end is closed, and a heat-generating coil (a heat-generating element) provided within the sheath tube. The sheath tube of the glow plug is formed of a material having excellent resistance to heat and oxidation; generally, a nickel-based alloy which predominantly contains nickel (Ni), or stainless steel which contains nickel (Ni).

[0003] A heat-generating coil of the glow plug is generally formed of an Fe-Cr-Al alloy which contains iron (Fe), chromium (Cr), and aluminum (Al). In recent years, in order to improve heat resistance of the glow plug, there has been proposed use of the following materials higher in melting point than an Fe-Cr-Al alloy for forming the heat-generating coil: a substantially pure metal of tungsten (W) or molybdenum (Mo), or an Ni-W alloy which contains nickel (Ni) in a predominant amount and tungsten (W) (refer to, for example, Patent Documents 1 and 2).

[Prior Art Documents]

[Patent Documents]

[0004]

> [Patent Document 1] International Publication No. WO2011/162074
> [Patent Document 2] Japanese Patent Application Laid-Open (*kokai*) No. 2012-57820

[Summary of the Invention]

[Problem to be Solved by the Invention]

[0005] In the glow plug of Patent Document 1, when the heat-generating coil which is substantially formed of tungsten (W) or molybdenum (Mo) is welded to the sheath tube which contains nickel (Ni), a fusion zone formed, by welding, between the sheath tube and the heat-generating coil contains a W-Ni alloy or a Mo-Ni alloy which is lower in melting point than W or Mo; therefore, the fusion zone fails to exhibit sufficient heat resistance, potentially resulting in a failure to secure sufficient durability of the glow plug. Such a problem caused by lack of heat resistance in the fusion zone has not been studied; i.e., such a problem is new. In the glow plug of Patent Document 2, since the heat-generating coil is formed of an Ni-W alloy, the heat-generating coil lacks heat resistance as compared with a heat-generating coil formed substantially of W or Mo; as a result, the glow plug may potentially fail to exhibit sufficient durability.

[Means for Solving the Problem]

[0006] The present invention has been conceived to solve the above problem and can be embodied in the following modes.

[0007] In order to solve the aforementioned problem, the present invention proposes a glow plug having the features as defined in claim 1.
In this glow plug the heat resistance of the fusion zone can be improved. As a result, the durability of the glow plug can be improved.

[0008] Further preferred embodiments of the invention are defined in the dependent claims.

> (2) Preferably, in the above-mentioned glow plug, the connection portion has at least either of a portion which is formed primarily of iron (Fe) and contains chromium (Cr) and a portion which is formed primarily of chromium (Cr). According to this mode, a first fusion zone which does not contain nickel (Ni) can be formed in that portion of the connection portion which extends up to at least 20 μm from the interface with the heat-generating element.
>
> (3) Preferably, in the above-mentioned glow plug, the tubular member is formed primarily of nickel (Ni) or iron (Fe) containing nickel (Ni), and a forward end portion of the tubular member has a chromium (Cr) content of 13% by mass or more as measured at a portion which is located on a center axis of the tubular member and extends 100 μm from an outside periphery of the tubular member. According to this mode, the forward end portion can have sufficient resistance to oxidation. As a result, the durability of the glow plug can be sufficiently improved.
>
> (4) Preferably, in the above-mentioned glow plug, the tubular member is formed primarily of nickel (Ni) or iron (Fe) containing nickel (Ni), and a forward end portion of the tubular member has a chromium (Cr) content of 18% by mass or more as measured at a portion which is located on a center axis of the tubular member and extends 100 μm from an outside periphery of the tubular member. According to this mode, the forward end portion can have sufficiently high resistance to oxidation. As a result, the durability of the glow plug can be far more improved.

[0009] The present invention can be embodied in various forms other than a glow plug. For example, the present invention can be embodied in an internal combustion engine having the above-mentioned glow plug, a heat-generating apparatus having the above-mentioned tubular member and heat-generating element, and a method of manufacturing the above-mentioned glow plug.

[Brief Description of the Drawings]

[0010]

[FIG. 1] Explanatory view showing the configuration of a glow plug.
[FIG. 2] Explanatory view showing the detailed configuration of a sheath heater of the glow plug.
[FIG. 3] Explanatory view showing the detailed configuration of a connection portion in the sheath heater.
[FIG. 4] Explanatory view showing a fragmentary section of a rear-end fusion zone.
[FIG. 5] Explanatory view showing a modified sheath heater, which is helpful for understanding the present invention
[FIG. 6] Flowchart showing a method of manufacturing the glow plug.
[FIG. 7] Explanatory views showing a procedure of forming the sheath heater in manufacture of the glow plug.
[FIG. 8] Table showing the results of evaluation of the durability of glow plugs having a heat-generating coil formed primarily of tungsten (W).
[FIG. 9] Table showing the results of evaluation of the durability of glow plugs having a heat-generating coil formed primarily of molybdenum (Mo).
[FIG. 10] Explanatory view showing another modified sheath heater.
[FIG. 11] Explanatory view showing a further modified sheath heater.
[FIG. 12] Explanatory view showing a still further modified sheath heater.
[FIG. 13] Explanatory view showing yet another modified sheath heater.

[Modes for Carrying out the Invention]

A. Embodiment

A1. Configuration of Glow Plug

[0011] FIG. 1 is an explanatory view showing the configuration of a glow plug 10. FIG. 1 shows the external appearance of a glow plug 10 on the right side with respect to a center axis SC of the glow plug 10, and the section of the glow plug 10 on the left side. In the description of the present embodiment, the lower side of the glow plug 10 on paper on which FIG. 1 appears is referred to as the "forward side," and the upper side on paper is referred to as the "rear side."

[0012] The glow plug 10 functions as a heat source for assisting ignition at start-up of internal combustion engines (not shown) including a diesel engine. The glow plug 10 includes a center rod 200, a metallic shell 500, and a sheath heater 800. In the present embodiment, the center axis SC of the glow plug 10 coincides with the center axes of the center rod 200, the metallic shell 500, and the sheath heater 800.

[0013] The center rod 200 of the glow plug 10 is an electrically conductive member provided in the metallic shell 500. In the present embodiment, the center rod 200 is a circular columnar electrically conductive member which is formed of metal and whose center axis coincides with the center axis SC. The center rod 200 relays electricity to the sheath heater 800.

[0014] The center rod 200 includes a forward end portion 210 formed on a forward end side thereof and a rear end portion 290 formed on a rear end side thereof. The forward end portion 210 of the center rod 200 is inserted into the sheath heater 800 joined to the forward end of the metallic shell 500. The rear end portion 290 of the center rod 200 protrudes from the rear end of the metallic shell 500. In the present embodiment, the rear end portion 290 is externally threaded. An O-ring 110, which is an annular member formed of an electrically insulating resin, an insulating bush 120, which is a tubular member formed of an electrically insulating resin, a ring 130, which is a tubular member formed of metal, and a nut 140 formed of metal are sequentially attached to the rear end portion 290.

[0015] The metallic shell 500 of the glow plug 10 is a cylindrical electrically conductive member which is formed of metal and whose center axis coincides with the center axis SC. In the present embodiment, the metallic shell 500 is formed of low carbon steel and plated with nickel. In another embodiment, the metallic shell 500 may be formed of low carbon steel and plated with zinc or may be formed of low carbon steel and unplated.

[0016] The metallic shell 500 includes an axial hole 510, a tool engagement portion 520, and a threaded portion 540. The axial hole 510 of the metallic shell 500 is a through hole whose center axis coincides with the center axis SC. The sheath heater 800 is press-fitted into a forward end portion of the axial hole 510 to thereby be joined to the metallic shell 500. The inside diameter of the axial hole 510 is greater than the outside diameter of the center rod 200. The center rod 200 is held in the axial hole 510. An air gap is formed between the center rod 200 and the wall of the axial hole 510. The tool engagement portion 520 of the metallic shell 500 has such a perimetric shape (e.g., hexagonal shape) as to be engaged with a tool (not shown) used to attach or remove the glow plug 10. The threaded portion 540 of the metallic shell 500 is externally threaded so as to be threadingly engaged with a counterpart of an internal combustion engine (not shown).

[0017] FIG. 2 shows the detailed configuration of the sheath heater 800 in the glow plug 10. The sheath heater 800 is a heat-generating device for generating heat. The sheath heater 800 includes a sheath tube 810, a connection portion 830, a heat-generating coil 850, and an insulating powder 870.

[0018] The sheath tube 810 of the sheath heater 800 is a tubular-shaped tubular member whose forward end is closed. The sheath tube 810 includes a forward end portion 811 disposed on the forward end side and a rear end portion 819 disposed on the rear end side. The forward end portion 811 of the sheath tube 810 is closed. The heat-generating coil 850 is connected to the inside of the forward end portion 811 through the connection portion 830. The rear end portion 819 of the sheath tube 810 is open. The center rod 200 is inserted into the rear end portion 819. The center rod 200 and the rear end portion 819 are electrically insulated from each other by a packing 600, which is a tubular member formed of an electrically insulating resin. The outer surface of the rear end portion 819 is in contact with the wall of the axial hole 510 of the metallic shell 500.

[0019] In the present embodiment, the sheath tube 810 has an outside diameter of 3.5 mm (millimeters). In the present embodiment, the sheath tube 810 has a wall thickness of about 0.5 mm at the forward end portion 811 and at the side wall.

[0020] In the present embodiment, the sheath tube 810 is formed primarily of nickel (Ni) such that the Ni content is highest (preferably, 50% by mass or more) in the sheath tube 810. Specifically, the sheath tube 810 is formed of a nickel-based alloy (INCONEL 601 ("INCONEL" is a registered trademark)) which contains nickel (Ni) as a main component, chromium (Cr) in an amount of 23% by mass, iron (Fe) in an amount of 14% by mass, and aluminum (Al) in an amount of 1.4% by mass.

[0021] In another embodiment, the sheath tube 810 may be formed primarily of iron (Fe) and contains nickel (Ni) as well. The Fe content can be the highest (preferably, 50% by mass or more) in the sheath tube 810. Specifically, the sheath tube 810 may be formed of stainless steel (SUS310s) which contains iron (Fe) as a main component, chromium (Cr) in an amount of 26% by mass, and nickel (Ni) in an amount of 22% by mass.

[0022] The heat-generating coil 850 of the sheath heater 800 is a heat-generating element provided within the sheath tube 810 and generating heat upon energization. The heat-generating coil 850 includes a forward end portion 851 disposed on the forward end side and a rear end portion 859 disposed on the rear end side. The forward end portion 851 of the heat-generating coil 850 is connected to the forward end portion 811 of the sheath tube 810 through the connection portion 830. The rear end portion 859 of the heat-generating coil 850 is connected to the center rod 200.

[0023] The heat-generating coil 850 contains substantially no nickel (Ni). In the present embodiment, the heat-generating coil 850 is formed primarily of tungsten (W). The W content is the highest (preferably, 99% by mass or more) in the heat-generating coil 850. That is, the heat-generating coil 850 is formed substantially of tungsten (W). Specifically, the material of the heat-generating coil 850 is a pure metal of tungsten (W).

[0024] In another embodiment, the heat-generating coil 850 may be formed primarily of molybdenum (Mo) such that the Mo content is highest (preferably, 99% by mass or more) in the heat-generating coil 850. That is, the heat-generating coil 850 may be formed substantially of molybdenum (Mo). Specifically, the material of the heat-generating coil 850 may be a pure metal of molybdenum (Mo).

[0025] The insulating powder 870 of the sheath heater 800 is electrically insulating powder. In the present embodiment, the insulating powder 870 is formed primarily of magnesium oxide (MgO). The insulating powder 870 is charged into the sheath tube 810 to fill clearances between the center rod 200, the sheath tube 810, the connection portion 830, and the heat-generating coils 850 for providing electrical insulation.

[0026] FIG. 3 shows the detailed configuration of the connection portion 830 in the sheath heater 800. The connection portion 830 is provided within the sheath tube 810 and provides a connection between the forward end portion 811 of the sheath tube 810 and the forward end portion 851 of the heat-generating coil 850. The connection portion 830 includes a rear-end fusion zone 831, a forward-end fusion zone 832, and a wire portion 835. The rear-end fusion zone 831 of the connection portion 830 is a first fusion zone formed as a result of welding between the heat-generating coil 850 and a wire used to form the connection portion 830. The forward-end fusion zone 832 of the connection portion 830 is a second fusion zone formed as a result of welding between the sheath tube 810 and the wire used to form the connection portion 830. The wire portion 835 of the connection portion 830 is that portion of a wire used to form the connection portion which remains unfused in welding the wire to the sheath tube 810 and to the heat-generating coil 850.

[0027] A wire used to form the connection portion 830 contains substantially no nickel (Ni). In the present embodiment, the wire used to form the connection portion 830 is of an alloy formed primarily of iron (Fe) and containing chromium (Cr). In another embodiment, the wire used to form the connection portion 830 may be of an alloy formed primarily of chromium (Cr) or of a pure metal of chromium (Cr).

[0028] Because of material of the wire used to form the connection portion 830, the connection portion 830 has at least one of a portion formed primarily of iron (Fe) and containing chromium (Cr) and a portion formed primarily of chromium (Cr). In the present embodiment, a portion of the rear-end fusion zone 831 located toward the forward end, a portion of the forward-end fusion zone 832 located toward the rear end, and the entire wire portion 835 are formed primarily of iron (Fe) and contain chromium (Cr). In another embodiment, a portion of the rear-end fusion zone 831 located toward the forward end, a portion of the forward-end fusion zone 832 located toward the rear end, and the entire wire portion 835 may be formed primarily of chromium (Cr).

[0029] A distance Dtm shown in FIG. 3 is a distance along the center axis SC from a forward end A of the sheath tube 810 to the rear-end fusion zone 831. In the present embodiment, the distance Dtm is about 1.0 mm.

[0030] The forward-end fusion zone 832 of the connection portion 830 constitutes at least a portion of the forward end portion 811 of the sheath tube 810. The forward end portion 811 of the sheath tube 810 and the forward-end fusion zone 832 of the connection portion 830 contain substantially no tungsten (W) and no molybdenum (Mo).

[0031] Position B shown in FIG. 3 indicates a position on that portion of the forward end portion 811 which is located on the center axis SC, and is located 100 μm away along the center axis SC from the forward end A on the outside periphery of the sheath tube 810. A chromium (Cr) content CT_Cr of that portion of the forward end portion 811 which is located on the center axis SC between the forward end A and the position B is preferably 13% by mass or more, more preferably 18% by mass or more. The content CT_Cr is an average of chromium contents detected, by use of an electron probe microanalyzer (EPMA) which utilizes a wavelength dispersive X-ray spectrometer (WDS), from 100 analysis regions (diameter: 1 μm) located at 1 μm intervals between the forward end A and the position B in the section of the sheath tube 810 taken along the center axis SC.

[0032] FIG. 4 is an explanatory view showing a fragmentary section of the rear-end fusion zone 831. An interface 839 between the connection portion 830 and the heat-generating coil 850 intervenes between the rear-end fusion zone 831 of the connection portion 830 formed through fusion and subsequent solidification in welding of the connection portion 830 and the heat-generating coil 850 to each other, and the forward end portion 851 of the heat-generation coil 850 which remains unfused in welding of the connection portion 830 and the heat-generating coil 850 to each other. In an example shown in FIG. 4, the interface 839 extends between a position C and a position D. An imaginary line L1 shown in FIG. 4 indicates a position located 20 μm (micrometers) away from the interface 839 in the rear-end fusion zone 831.

[0033] Preferably, that portion of the rear-end fusion zone 831 which extends up to at least 20 μm from the interface 839 with the heat-generating coil 850 does not contain nickel (Ni). The expression "does not contain nickel (Ni)" means that an average of nickel contents detected, by use Of EPMA which utilizes WDS, from 20 analysis regions (diameter: 1 μm) located at 1 μm intervals between the interface 839 and the imaginary line L1 in the rear-end fusion zone 831 is 0.1 at% (atomic percent) or less; i.e., substantially no Ni is contained.

[0034] FIG. 5 is an explanatory view showing a modified sheath heater 800B, outside the scope of the the present invention. The modified sheath heater 800B is similar to the sheath heater 800 of the above-described embodiment except that a connection portion 830B replaces the connection portion 830. The connection portion 830B is similar to the connection portion 830 of the above-described embodiment except that the rear-end fusion zone 831 and the forward-end fusion zone 832 are adjacent to each other. In an example shown in FIG. 5, the wire portion 385 does not exist between the rear-end fusion zone 831 and the forward-end fusion zone 832. In another modified sheath heater, the wire portion 835 may partially exist between the rear-end fusion zone 831 and the forward-end fusion zone 832.

A2. Method of Manufacturing Glow Plug

[0035] FIG. 6 is a flowchart showing a method of manufacturing the glow plug 10. FIG. 7 is a set of explanatory views showing a procedure of forming the sheath heater in manufacture of the glow plug 10.

[0036] In manufacture of the glow plug 10, a manufacturer prepares various members which constitute the glow plug 10 (step P110). In the present embodiment, the manufacturer prepares, as members of the sheath heater 800, the sheath tube 810 having an opening 811h in the forward end thereof, a wire 835p used to form the connection portion 830, and the heat-generating coil 850 unjoined to other members.

[0037] After preparing various members (step P110), the manufacturer welds the wire 835p to the forward end of the heat-generating coil 850 (step P120). As a result of this welding, the rear-end fusion zone 831 is formed between the wire 835p and the heat-generating coil 850 (see FIG. 7(A)).

[0038] After welding the wire 835p to the heat-generating coil 850 (step P120), the manufacturer inserts the heat-generating coil 850 to which the wire 835p is welded, into the sheath tube 810 from the rear end of the sheath tube 810 (step P130). As a result of this insertion, the wire 835p protrudes from the opening 811h of the sheath tube 810 (see FIG. 7(B)).

[0039] After inserting the heat-generating coil 850 into the sheath tube 810 (step P130), the manufacturer welds the wire 835p to the forward end of the sheath tube 810 (step P140). As a result of this welding, at the forward end of the sheath tube 810, while the opening 811h of the sheath tube 810 is closed, the forward-end fusion zone 832 is formed, whereby the forward end portion 811 of the sheath tube 810 is formed (see FIG. 7(C)).

[0040] After welding the wire 835p to the sheath tube 810 (step P140), the manufacturer charges the insulating powder 870 into the sheath tube 810 (step P150). Through execution of these steps, the sheath heater 800 is completed.

[0041] After charging the insulating powder 870 into the sheath tube 810 (step P150), the manufacturer attaches various members (e.g., the center rod 200 and the metallic shell 500) to the sheath heater 800 (step P160). Through execution of these steps, the glow plug 10 is completed.

A3. Evaluation of Glow Plug

[0042] FIG. 8 is a table showing the results of evaluation of the durability of glow plugs having the heat-generating coil 850 formed primarily of tungsten (W). FIG. 9

is a table showing the results of evaluation of the durability of glow plugs having the heat-generating coil 850 formed primarily of molybdenum (Mo).

[0043] A tester prepared six kinds of samples A1 to A6 of glow plugs having the heat-generating coil 850 formed primarily of tungsten (W), and six kinds of samples B1 to B6 of glow plugs having the heat-generating coil 850 formed primarily of molybdenum (Mo). In samples A1 to A6 and samples B1 to B6, the sheath tube 810 is formed of a nickel alloy (INCONEL601).

[0044] In samples A1 to A6 and samples B1 to B6, the material of the wire 835p used to form the connection portion 830 is as follows.

- Samples A1 and B1: stainless steel (SUS430) which contains iron (Fe) as a main component and chromium (Cr) in an amount of 18% by mass.
- Samples A2 and B2: stainless steel (SUH21) which contains iron (Fe) as a main component, chromium (Cr) in an amount of 18% by mass, and aluminum (Al) in an amount of 3% by mass.
- Samples A3 and B3: stainless steel (SUS403) which contains iron (Fe) as a main component and chromium (Cr) in an amount of 12% by mass.
- Samples A4 and B4: stainless steel which contains iron (Fe) as a main component and chromium (Cr) in an amount of 10% by mass.
- Samples A5 and B5: nickel-based alloy (INCONEL601) which contains nickel (Ni) as a main component, chromium (Cr) in an amount of 23% by mass, iron (Fe) in an amount of 14% by mass, and aluminum (A1) in an amount of 1.4% by mass.
- Samples A6 and B6: stainless steel (SUS310s) which contains iron (Fe) as a main component, chromium (Cr) in an amount of 26% by mass, and nickel (Ni) in an amount of 22% by mass.

[0045] The tester cut a portion of each sample extending from the rear-end fusion zone 831 of the connection portion 830 to the forward end portion 851 of the heat-generating coil 850, and measured a nickel (Ni) content CT_Ni10 in that portion of the rear-end fusion zone 831 which extends up to 10 μm from the interface 839 with the heat-generating coil 850 as well as a nickel (Ni) content CT_Ni20 in that portion of the rear-end fusion zone 831 which extends up to 20 μm from the interface 839 with the heat-generating coil 850. The content CT_Ni10 is an average of nickel contents detected, by use of EPMA which utilizes WDS, from 10 analysis regions (diameter: 1 μm) located at 1 μm intervals in that portion of the rear-end fusion zone 831 which extends up to 10 μm from the interface 839. The content CT_Ni20 is an average of nickel contents detected, by use of EPMA which utilizes WDS, from 20 analysis regions (diameter: 1 μm) located at 1 μm intervals in that portion of the rear-end fusion zone 831 which extends up to 20 μm from the interface 839. In measuring the content CT_Ni10 and the content CT_Ni20, the tester judged that at an average nickel content of 0.1 at% or less, nickel (Ni) was not detected from the measured portion of the rear-end fusion zone 831; i.e., the measured portion of the rear-end fusion zone 831 did not contain nickel (Ni).

[0046] The tester cut the sheath tube 810 of each sample along the center axis SC and measured the chromium (Cr) content CT_Cr of a portion of the sheath tube 810 located on the center axis SC between the forward end A and the position B. The content CT_Cr is an average of chromium contents detected, by use of EPMA which utilizes WDS, from 100 analysis regions (diameter: 1 μm) located at 1 μm intervals between the forward end A and the position B.

[0047] In the evaluation test, the tester performed test cycles on the samples, each cycle consisting of the following steps 1 to 3, and checked the samples for the number of cycles (number of wire-breaking cycles) at which the connection portion 830 was broken.

(Step 1) Electricity is applied to a glow plug sample such that the temperature rises to 1,200°C at position ML located 2 mm away along the center axis SC from the forward end A on the outer surface of the sheath tube 810.

(Step 2) After the temperature rises to 1,200°C at the position ML of the sheath tube 810, application of electricity to the glow plug is continued for maintaining a temperature of 1,200°C for 10 minutes at the position ML of the sheath tube 810.

(Step 3) After the temperature is maintained at 1,200°C for 10 minutes at the position ML of the sheath tube 810, application of electricity to the glow plug is shut off; then, the sheath tube 810 is cooled for two minutes by blowing the sheath tube 810 with air.

[0048] The tester evaluated the durability of the samples on the following evaluation criteria.

A (excellent): 10,000 ≤ the number of wire-breaking cycles

B (good): 8,000 ≤ the number of wire-breaking cycles < 10,000

C (fair): 6,000 ≤ the number of wire-breaking cycles < 8,000

F (failure): the number of wire-breaking cycles < 6,000

[0049] As is known from comparison between samples A1 to A4 and samples A5 and A6, the samples' heat-generating coils 850 being formed of tungsten (W), if no nickel (Ni) is detected from that portion of the rear-end fusion zone 831 which extends up to 20 μm from the interface 839, the durability of a glow plug can be sufficiently secured. In samples A5 and A6, conceivably, a tungsten (W)-nickel (Ni) alloy whose melting point is lower than that of tungsten (W) exists in the rear-end fusion zone 831; as a result, the melting point of the rear-end fusion zone 831 drops to less than 1,500°C, so that the durability of the glow plugs deteriorates as compared with samples A1 to A4.

[0050] According to comparison among samples A1 to A4, in view of improvement of the durability of a glow plug, the sheath tube 810 has preferably a chromium (Cr) content CT_Cr of 13% by mass or more, more preferably 18% by mass or more. Conceivably, this is for the following reason: chromium (Cr) ensures resistance to oxidation of the forward-end fusion zone 832 formed as a result of welding of the wire 835p formed of an iron (Fe)-chromium (Cr) alloy.

[0051] As is known from comparison between samples B1 to B4 and samples B5 and B6, the samples' heat-generating coils 850 being formed of molybdenum (Mo), if no nickel (Ni) is detected from that portion of the rear-end fusion zone 831 which extends up to 20 μm from the interface 839, the durability of a glow plug can be sufficiently secured. In samples B5 and B6, conceivably, a molybdenum (Mo)-nickel (Ni) alloy whose melting point is lower than that of molybdenum (Mo) exists in the rear-end fusion zone 831; as a result, the melting point of the rear-end fusion zone 831 drops to less than 1,500°C, so that the durability of the glow plugs deteriorates as compared with samples B1 to B4.

[0052] According to comparison among samples B1 to B4, in view of improvement of the durability of a glow plug, the sheath tube 810 has preferably a chromium (Cr) content CT_Cr of 13% by mass or more, more preferably 18% by mass or more. Conceivably, this is for the following reason: chromium (Cr) ensures resistance to oxidation of the forward-end fusion zone 832 formed as a result of welding of the wire 835p formed of an iron (Fe)-chromium (Cr) alloy.

A4. Effects

[0053] According to the above-described embodiment, the heat-generating coil 850 is formed primarily of tungsten (W) or molybdenum (Mo), and that portion of the rear-end fusion zone 831 which extends up to at least 20 μm from the interface 839 with the heat-generating coil 850 does not contain nickel (Ni), so that heat resistance of the rear-end fusion zone 831 can be improved. As a result, the durability of the glow plug 10 can be improved.

[0054] Also, since the connection portion 830 has at least one of a portion formed primarily of iron (Fe) and containing chromium (Cr) and a portion formed primarily of chromium (Cr), there can be implemented the rear-end fusion zone 831 containing no nickel (Ni) at its portion which extends up to at least 20 μm from the interface 839 with the heat-generating coil 850.

[0055] The sheath tube 810 is formed primarily of nickel (Ni) or iron (Fe), and, in the case where the forward end portion 811 of the sheath tube 810 has a chromium (Cr) content CT_Cr of 13% by mass or more, resistance to oxidation of the forward end portion 811 can be sufficiently secured. As a result, the durability of the glow plug 10 can be sufficiently improved. Furthermore, in the case where the forward end portion 811 of the sheath tube 810 has a chromium (Cr) content CT_Cr of 18% by mass or more, resistance to oxidation of the forward end portion 811 can be far more reliably secured. As a result, the durability of the glow plug 10 can be improved to a far greater extent.

B. Other Embodiments

[0056] The present invention is not limited to the above-described embodiment and modifications, but may be embodied in various other forms without departing from the spirit of the invention. For example, in order to solve, partially or entirely, the above-mentioned problem or yield, partially or entirely, the above-mentioned effects, technical features of the embodiment and modifications corresponding to technical features of the modes described in the section "Summary of the Invention" can be replaced or combined as appropriate. Also, the technical feature(s) can be eliminated as appropriate unless the technical feature(s) is specified as an indispensable one(s) in the present specification.

[0057] FIG. 10 is an explanatory view showing another modified sheath heater 800C. The modified sheath heater 800C is similar to the sheath heater 800 of the above-described embodiment except that a connection portion 830C replaces the connection portion 830. The connection portion 830C connects the sheath tube 810 and the heat-generating coil 850. The connection portion 830C includes a rear-end fusion zone 831C, a forward-end fusion zone 832C, and a rivet portion 835C. A rivet used to form the connection portion 830C is similar to a wire used to form the connection portion 830 of the above-described embodiment except that the rivet assumes the form of a disk.

[0058] The rear-end fusion zone 831C of the connection portion 830C is similar to the rear-end fusion zone 831 of the above-described embodiment except that the rear-end fusion zone 831C is a first fusion zone formed as a result of welding between the heat-generating coil 850 and the rivet used to form the connection portion 830C. The rear-end fusion zone 831C is formed at the center of the rear end surface of the disklike rivet portion 835C.

[0059] The forward-end fusion zone 832C of the connection portion 830C is similar to the forward-end fusion zone 832 of the above-described embodiment except that the forward-end fusion zone 832C is a second fusion zone formed as a result of welding between the sheath tube 810 and the rivet used to form the connection portion 830C. The forward-end fusion zone 832C is formed along the entire circumferential surface of the disklike rivet portion 835C.

[0060] The rivet portion 835C of the connection portion 830C is that portion of a rivet used to form the connection portion 830C which remains unfused in welding the rivet to the sheath tube 810 and to the heat-generating coil

850. The rivet portion 835C assumes the form of a disk, and the forward end surface of the rivet portion 835C is exposed to the ambient atmosphere.

[0061] According to the modified embodiment shown in FIG. 10, similar to the case of the above-described embodiment, the durability of the glow plug 800C can be improved.

[0062] FIG. 11 is an explanatory view showing a further modified sheath heater 800D. The modified sheath heater 800D is similar to the sheath heater 800 of the above-described embodiment except that a connection portion 830D replaces the connection portion 830. The connection portion 830D connects the sheath tube 810 and the heat-generating coil 850. The connection portion 830D includes a rear-end fusion zone 831D, a forward-end fusion zone 832D, and a rivet portion 835D. A rivet used to form the connection portion 830D is similar to a wire used to form the connection portion 830 of the above-described embodiment except that the rivet assumes the form of a circular column stepped such that a forward portion is thin, whereas a rear portion is thick.

[0063] The rear-end fusion zone 831D of the connection portion 830D is similar to the rear-end fusion zone 831 of the above-described embodiment except that the rear-end fusion zone 831D is a first fusion zone formed as a result of welding between the heat-generating coil 850 and the rivet used to form the connection portion 830D. The rear-end fusion zone 831D is formed on the side surface of a rear portion of the rivet portion 835D, which has the form of a stepped circular column.

[0064] The forward-end fusion zone 832D of the connection portion 830D is similar to the forward-end fusion zone 832 of the above-described embodiment except that the forward-end fusion zone 832D is a second fusion zone formed as a result of welding between the sheath tube 810 and the rivet used to form the connection portion 830D. The forward-end fusion zone 832D is formed along the entire circumferential surface of a forward portion of the rivet portion 835D having the form of a stepped circular column.

[0065] The rivet portion 835D of the connection portion 830D is that portion of a rivet used to form the connection portion 830D which remains unfused in welding the rivet to the sheath tube 810 and to the heat-generating coil 850. The rivet portion 835D assumes the form of a stepped circular column, and the forward end surface of the rivet portion 835D is exposed to the ambient atmosphere.

[0066] According to the modified embodiment shown in FIG. 11, similar to the case of the above-described embodiment, the durability of the glow plug 800D can be improved.

[0067] FIG. 12 is an explanatory view showing a still further modified sheath heater 800E. The modified sheath heater 800E is similar to the sheath heater 800 of the above-described embodiment except that a connection portion 830E replaces the connection portion 830. The connection portion 830E connects the sheath tube 810 and the heat-generating coil 850. The connection portion 830E includes a rear-end fusion zone 831E, a forward-end fusion zone 832E, and a rivet portion 835E. A rivet used to form the connection portion 830E is similar to that used to form the connection portion 830D in the modified embodiment shown in FIG. 11.

[0068] The rear-end fusion zone 831E of the connection portion 830E is similar to the rear-end fusion zone 831D of the connection portion 830D in the modified embodiment shown in FIG. 11.

[0069] The forward-end fusion zone 832E of the connection portion 830E is similar to the forward-end fusion zone 832D of the connection portion 830D in the modified embodiment shown in FIG. 11 except that the forward-end fusion zone 832E is formed up to the center of a forward portion of a rivet used to form the connection portion 830E.

[0070] The rivet portion 835E of the connection portion 830E is that portion of a rivet used to form the connection portion 830E which remains unfused in welding the rivet to the sheath tube 810 and to the heat-generating coil 850. The rivet portion 835E assumes the form of a stepped circular column, and the forward end of the rivet portion 835D is adjacent to the forward-end fusion zone 832E.

[0071] According to the modified embodiment shown in FIG. 12, similar to the case of the above-described embodiment, the durability of the glow plug 800E can be improved.

[0072] FIG. 13 is an explanatory view showing yet another modified sheath heater 800F. The modified sheath heater 800F is similar to the sheath heater 800 of the above-described embodiment except that a connection portion 830F replaces the connection portion 830. The connection portion 830F connects the sheath tube 810 and the heat-generating coil 850. The connection portion 830F includes a rear-end fusion zone 831F, a forward-end fusion zone 832F, and a rivet portion 835F. A rivet used to form the connection portion 830F is similar to that used to form the connection portion 830D in the modified embodiment shown in FIG. 11.

[0073] The rear-end fusion zone 831F of the connection portion 830F is similar to the rear-end fusion zone 831D of the connection portion 830D in the modified embodiment shown in FIG. 11.

[0074] The forward-end fusion zone 832F of the connection portion 830F is similar to the forward-end fusion zone 832D of the connection portion 830D in the modified embodiment shown in FIG. 11 except that the forward-end fusion zone 832F is formed at the entire forward portion of a rivet used to form the connection portion 830F and further extends, beyond a step between the forward portion and a rear portion of the rivet, into the rear portion.

[0075] The rivet portion 835F of the connection portion 830F is that portion of a rivet used to form the connection portion 830F which remains unfused in welding the rivet to the sheath tube 810 and to the heat-generating coil 850. The rivet portion 835F assumes the form of a circular column, and the forward end of the rivet portion 835D is adjacent to the forward-end fusion zone 832E.

[0076] According to the modified embodiment shown in FIG. 13, similar to the case of the above-described embodiment, the durability of the glow plug 800F can be improved.

[Description of Reference Numerals]

[0077]

10:	glow plug
110:	O-ring
120:	insulating bush
130:	ring
140:	nut
200:	center rod
210:	forward end portion
290:	rear end portion
500:	metallic shell
510:	axial hole
520:	tool engagement portion
540:	threaded portion
600:	packing
800, 800B-800F:	sheath heater
810:	sheath tube
811:	forward end portion
811h:	opening
819:	rear end portion
830, 830B-830F:	connection portion
831, 831C-831F:	rear-end fusion zone
832, 832C-832F:	forward-end fusion zone
835:	wire portion
835C-835F:	rivet portion
835p:	wire
839:	interface
850:	heat-generating coil
851:	forward end portion
859:	rear end portion
870:	insulating powder

Claims

1. A glow plug (10) comprising:

a tubular member (810) having a tubular shape, said tubular member (810) containing nickel (Ni),
a heat-generating element (850) disposed within the tubular member (810) and adapted to generate heat through application of electricity thereto; wherein the heat-generating element (850) is formed primarily of tungsten (W) or molybdenum (Mo), **characterized by**:

a connection portion (830, 830C, 830D, 830F) which includes a forward end fusion zone (832, 832C, 832D, 832F), a rear end fusion zone (831, 831C, 831 D, 831 F) and a portion (835, 835C, 835D, 835F) which remains unfused,
wherein the connection portion (830, 830C, 830D, 830F) connects the tubular member (810) and the heat-generating element (850), and the forward end fusion zone (832, 832C, 832D, 832F) is formed as a result of welding to the tubular member (810), and the rear end fusion zone (831, 831C, 831 D, 831 F) is formed as a result of welding to the heat-generating element (850),
wherein a portion of the rear end fusion zone (831, 831C, 831 D, 831 F) which extends up to at least 20 μm from an interface with the heat-generating element (850) does not contain nickel (Ni), and the portion (835, 835C, 835D, 835F) which remains unfused contains substantially no nickel (Ni).

2. A glow plug (10) according to claim 1, wherein the wherein the portion (835, 835C, 835D, 835F) which remains unfused is at least either formed primarily of iron (Fe) which contains chromium (Cr) or primarily of chromium (Cr).

3. A glow plug (10) according to claim 1 or 2, wherein

the tubular member (810) is formed primarily of nickel (Ni) or iron (Fe) containing nickel (Ni), and a forward end portion (811) of the tubular member (810) has a chromium (Cr) content of 13% by mass or more as measured at a portion which is located on a center axis (SC) of the tubular member (810) and extends 100 μm along the center axis (SC) from an outside periphery of the tubular member (810).

4. A glow plug (10) according to claim 1 or 2, wherein

the tubular member (810) is formed primarily of nickel (Ni) or iron (Fe) containing nickel (Ni), and a forward end portion (811) of the tubular member (810) has a chromium (Cr) content of 18% by mass or more as measured at a portion which is located on a center axis (SC) of the tubular member (810) and extends 100 μm along the center axis (SC) from an outside periphery of the tubular member (810).

Patentansprüche

1. Glühkerze (10) enthaltend:

ein rohrförmiges Element (810) mit einer rohrförmigen Form, das Ni enthält;

ein wärmeerzeugendes Element (850), das innerhalb des rohrförmigen Elements (810) angeordnet ist und dazu ausgelegt ist, durch Zuführung von Elektrizität Wärme zu erzeugen;
wobei das wärmeerzeugende Element (850) hauptsächlich aus Wolfram (W) oder Molybdän (Mo) gebildet ist,
gekennzeichnet durch
einen Verbindungsabschnitt (830, 830C, 830D, 830F), der eine vorderendige Schmelzzone (832, 832C, 832D, 832F), eine hinterendige Schmelzzone (831, 831C, 831 D, 831 F) und einen Abschnitt (835, 835C, 835D, 835F) umfasst, der ungeschmolzen bleibt,
wobei der Verbindungsabschnitt (830, 830C, 830D, 830F) das rohrförmige Element (810) und das wärmeerzeugende Element (850) verbindet, und die vorderendige Schmelzzone (832, 832C, 832D, 832F) als ein Ergebnis des Verschweißens mit dem rohrförmigen Element (810) ausgebildet ist, und die hinterendige Schmelzzone (831, 831C, 831 D, 831 F) als ein Ergebnis des Verschweißens mit dem wärmeerzeugenden Element (850) ausgebildet ist,
wobei ein Abschnitt der hinterendigen Schmelzzone (831, 831C, 831 D, 831 F), der sich bis zu mindestens 20 μm von einer Grenzfläche zu dem wärmeerzeugenden Element (850) erstreckt, kein Nickel (Ni) enthält, und der Abschnitt (835, 835C, 835D, 835F), der ungeschmolzen bleibt, im wesentlichen kein Nickel (Ni) enthält.

2. Glühkerze (10) nach Anspruch 1, wobei der Abschnitt (835, 835C, 835D, 835F), der ungeschmolzen bleibt, zumindest hauptsächlich aus Eisen (Fe) gebildet ist, welches Chrom (Cr) enthält oder hauptsächlich Chrom (Cr) enthält.

3. Glühkerze (10) nach Anspruch 1 oder 2, wobei das rohrförmige Element (810) hauptsächlich aus Nickel (Ni) gebildet ist, oder Eisen (Fe), welches Nickel (Ni) enthält, und
ein vorderer Endabschnitt (811) des rohrförmigen Elements (810) einen Chromgehalt (Cr) von 13 Massen-% oder mehr aufweist, gemessen an einem Abschnitt, der sich auf einer Mittelachse (SC) des rohrförmigen Elements (810) befindet, und der sich von einem Außenumfang des röhrenförmigen Elements (810) 100 μm entlang der Mittelachse (SC) erstreckt.

4. Glühkerze (10) nach Anspruch 1 oder 2, wobei das rohrförmige Element (810) hauptsächlich aus Nickel (Ni) gebildet ist, oder Eisen (Fe), das Nickel (Ni) enthält, und
ein vorderer Endabschnitt (811) des rohrförmigen Elements (810) einen Chromgehalt (Cr) von 18 Massen-% oder mehr aufweist, gemessen an einem Abschnitt, der sich auf einer Mittelachse (SC) des rohrförmigen Elements (810) befindet, und der sich von einem Außenumfang des röhrenförmigen Elements (810) 100 μm entlang der Mittelachse (SC) erstreckt.

Revendications

1. Bougie de préchauffage (10) comprenant :

un organe tubulaire (810) ayant une forme tubulaire, ledit organe tubulaire (810) contenant du nickel (Ni) ;
un élément générateur de chaleur (850) disposé à l'intérieur l'organe tubulaire (810) et apte à générer de la chaleur à partir de l'électricité qui lui est appliquée ; où l'élément générateur de chaleur (850) est principalement composé de tungstène (W) ou de molybdène (Mo),

caractérisée par :

une partie de connexion (830, 830C, 830D, 830F) qui inclut une zone de fusion d'extrémité avant (832, 832C, 832D, 832F), une zone de fusion d'extrémité arrière (831, 831C, 831D, 831F) et une partie (835, 835C, 835D, 835F) qui reste à l'état non fondu,
où la partie de connexion (830, 830C, 830D, 830F) connecte l'élément tubulaire (810) et l'élément générateur de chaleur (850) et la zone de fusion d'extrémité avant (832, 832C, 832D, 832F) est formée par soudage sur l'organe tubulaire (810) et la zone de fusion d'extrémité arrière (831, 831C, 831D, 831F) est formée par soudage sur l'élément générateur de chaleur (850),

où
une partie de la zone de fusion d'extrémité arrière (831, 831C, 831D, 831F) qui s'étend jusqu'à au moins 20 μm d'une interface avec l'élément générateur de chaleur (850) ne contient pas de nickel (Ni) et la partie (835, 835C, 835D, 835F) qui reste à l'état non fondu ne contient substantiellement pas de nickel (Ni).

2. Bougie de préchauffage (10) selon la revendication 1, où la partie (835, 835C, 835D, 835F) qui reste à l'état non fondu est au moins composée soit principalement de fer (Fe) contenant du chrome (Cr) soit principalement de chrome (Cr).

3. Bougie de préchauffage (10) selon la revendication 1 ou 2, où

l'organe tubulaire (810) est principalement composé de nickel (Ni) ou de fer (Fe) contenant du

nickel (Ni), et
une partie d'extrémité avant (811) de l'organe tubulaire (810) a une teneur en chrome (Cr) de 13% en masse ou plus mesurée au niveau d'une partie située sur un axe central (SC) de l'organe tubulaire (810) et s'étendant sur 100 μm le long de l'axe central (SC) à partir d'une périphérie extérieure de l'organe tubulaire (100).

4. Bougie de préchauffage (10) selon la revendication 1 ou 2, où

l'organe tubulaire (810) est principalement composé de nickel (Ni) ou de fer (Fe) contenant du nickel (Ni), et
une partie d'extrémité avant (811) de l'organe tubulaire (810) a une teneur en chrome (Cr) de 18% en masse ou plus mesurée au niveau d'une partie située sur un axe central (SC) de l'organe tubulaire (810) et s'étendant sur 100 μm le long de l'axe central (SC) à partir d'une périphérie extérieure de l'organe tubulaire (100).

FIG. 1

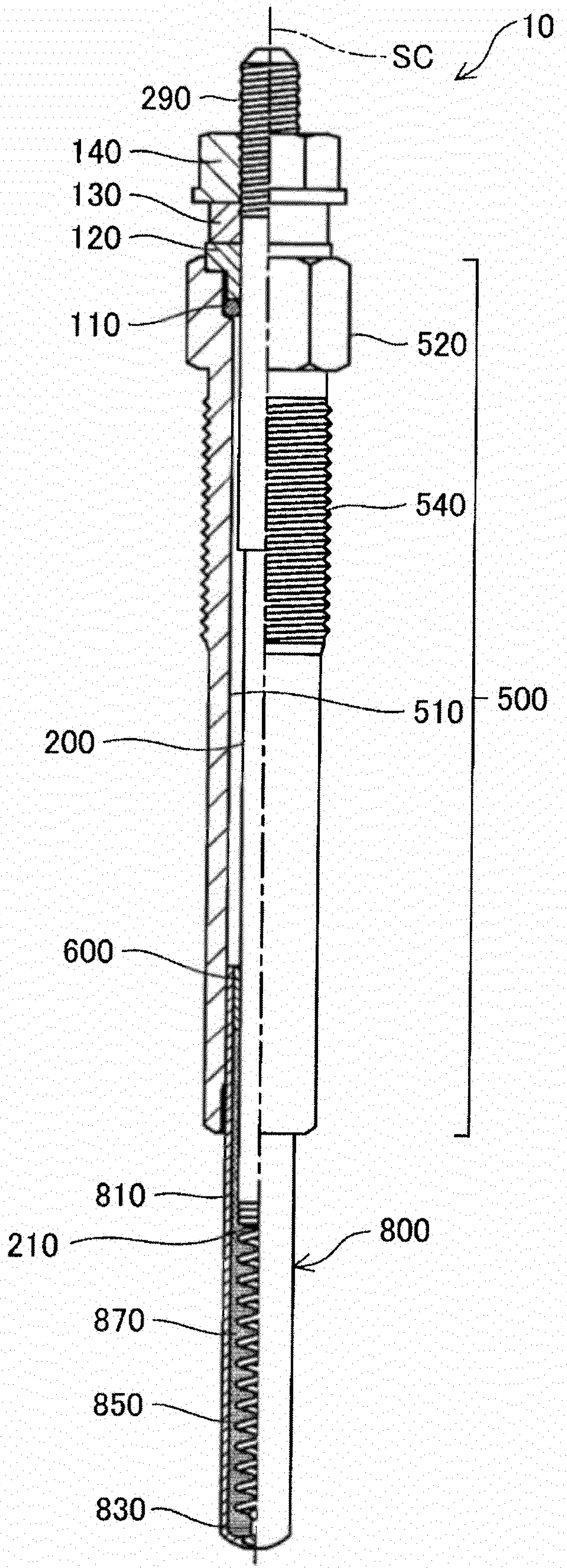

SC
10
290
140
130
120
110
520
540
510
500
200
600
810
210
800
870
850
830

FIG. 2

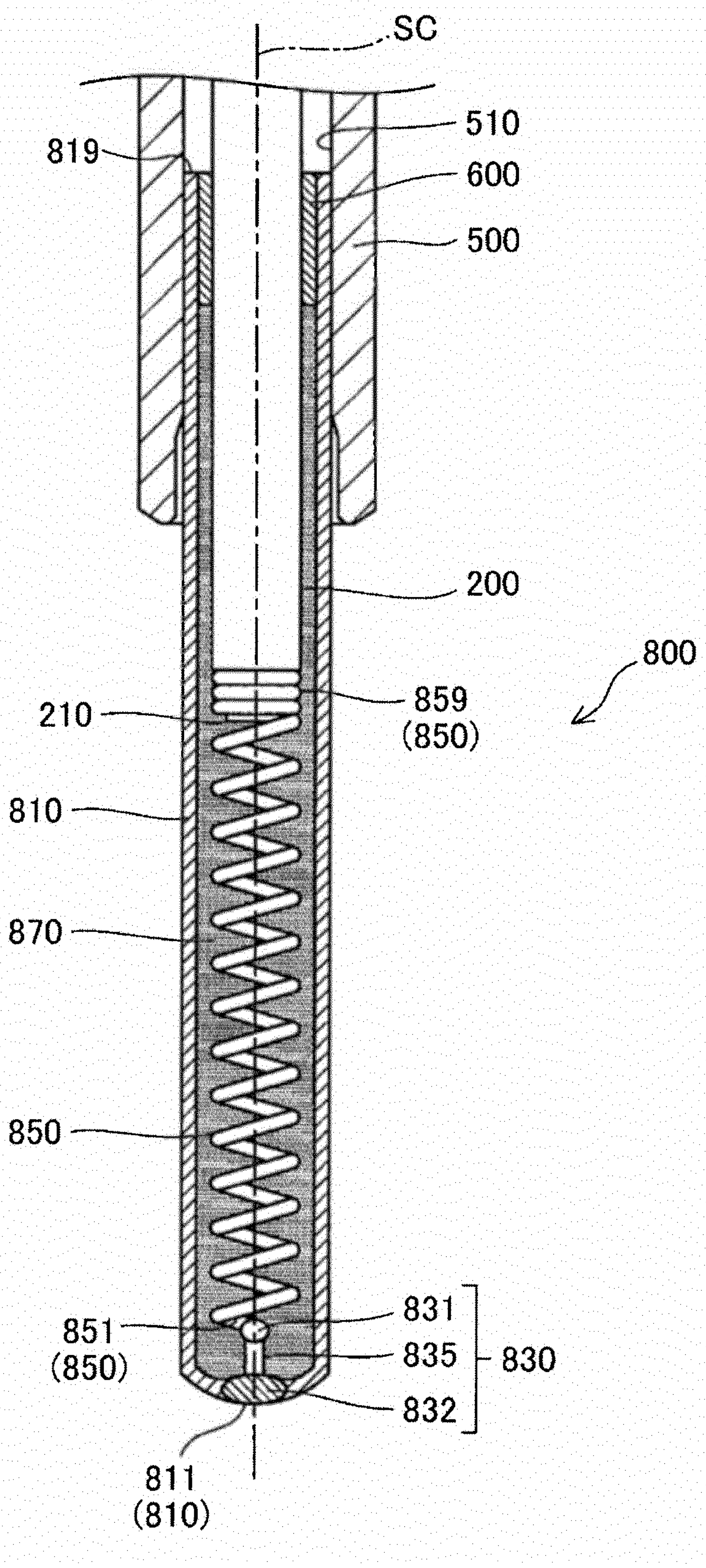

SC
510
819
600
500
200
800
859
(850)
210
810
870
850
831
851
(850)
835
830
832
811
(810)

FIG. 3

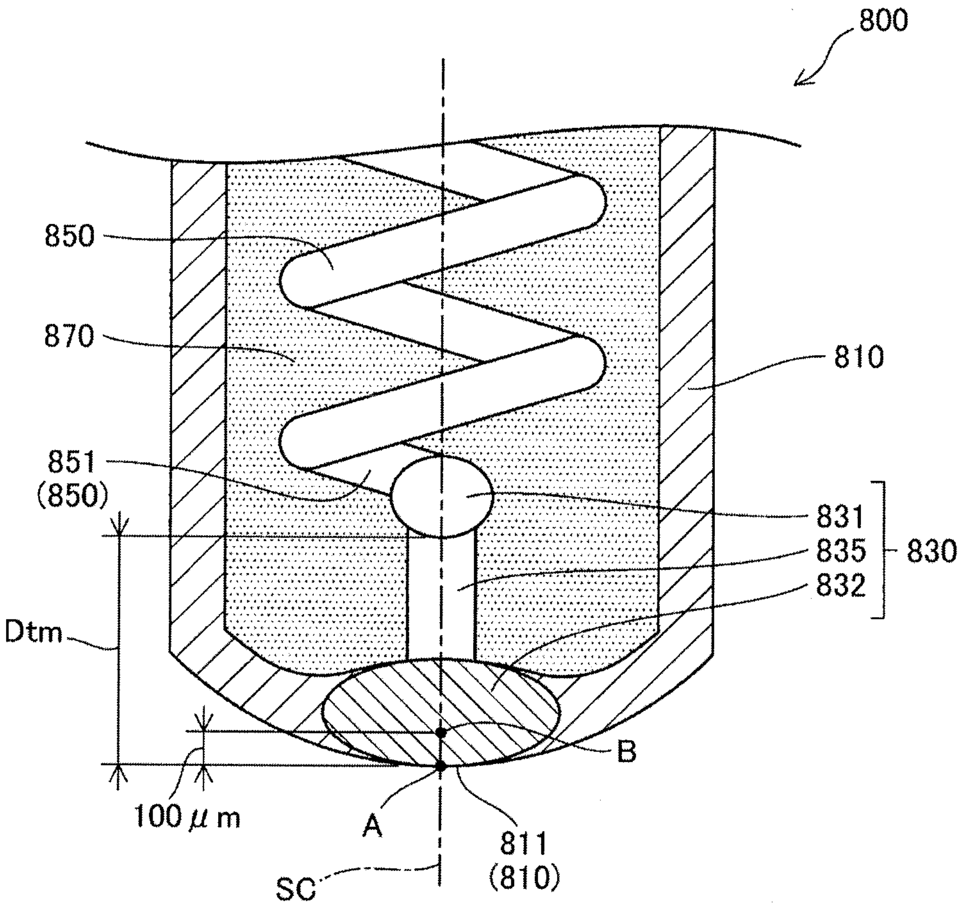


FIG. 4

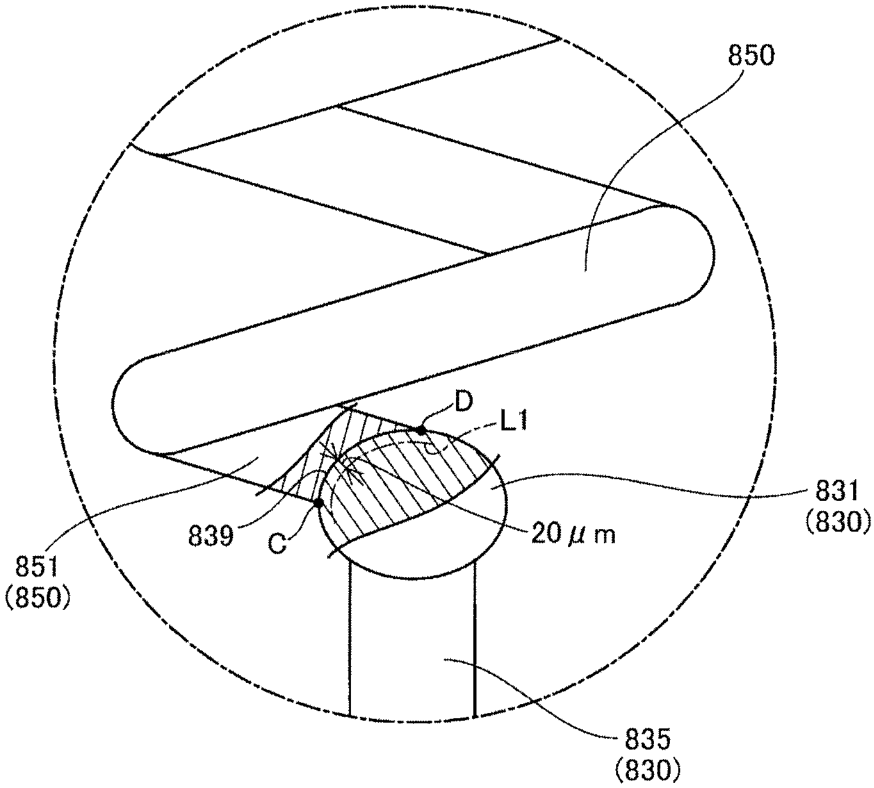


FIG. 5

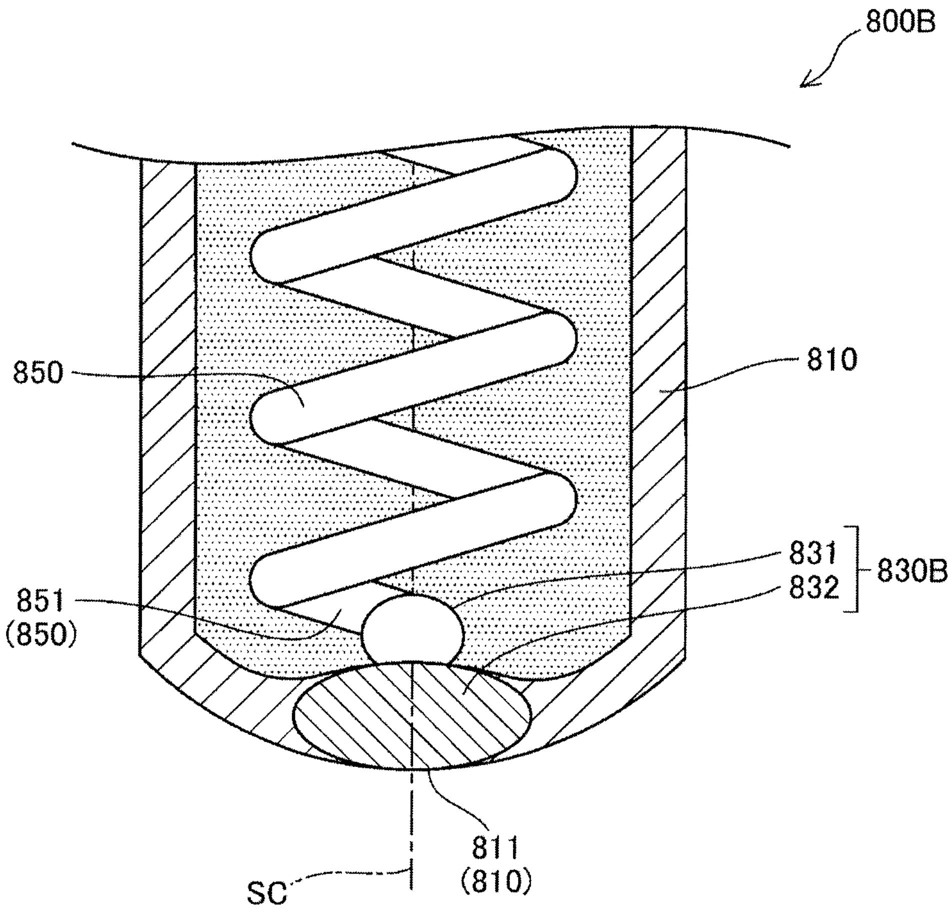


FIG. 6

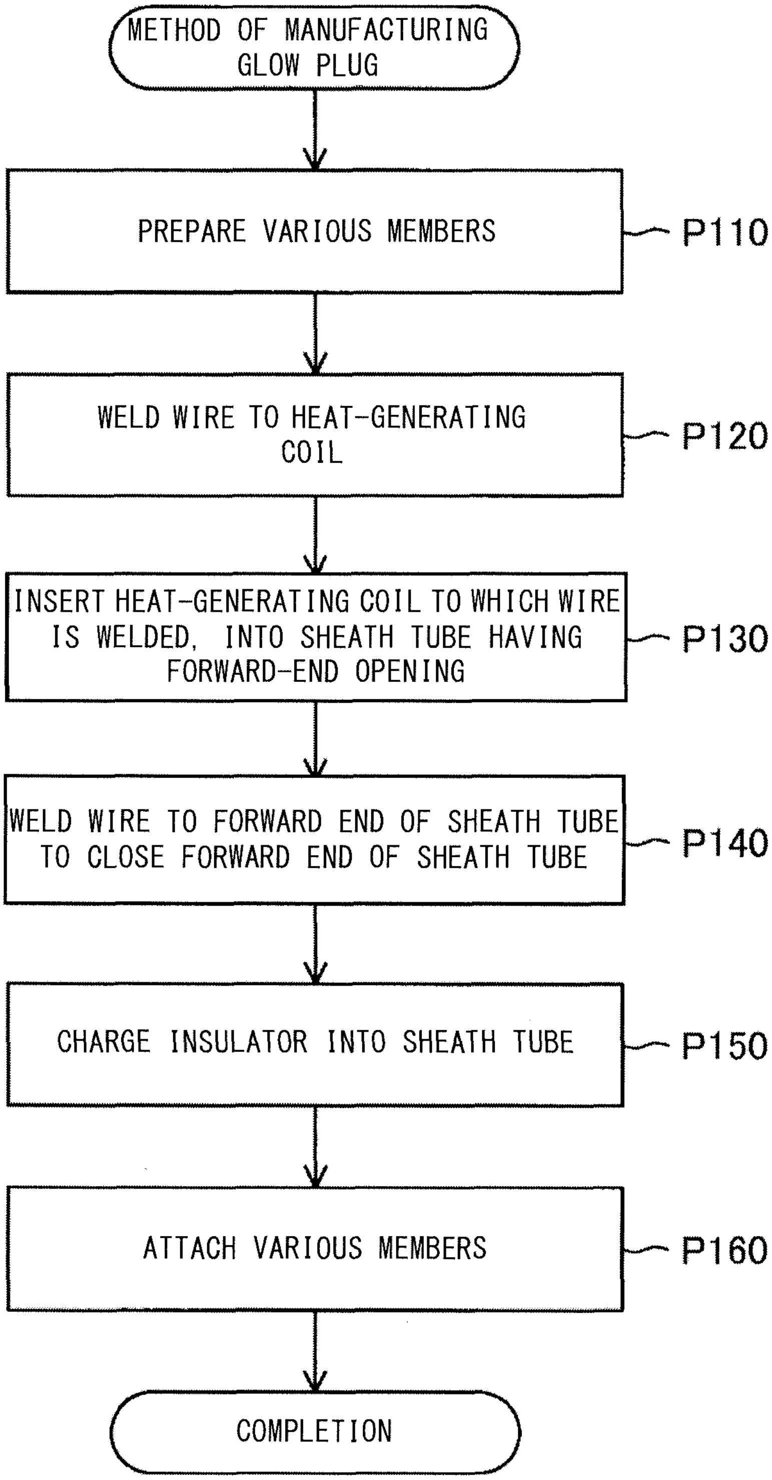

METHOD OF MANUFACTURING GLOW PLUG
PREPARE VARIOUS MEMBERS
P110
WELD WIRE TO HEAT-GENERATING COIL
P120
INSERT HEAT-GENERATING COIL TO WHICH WIRE IS WELDED, INTO SHEATH TUBE HAVING FORWARD-END OPENING
P130
WELD WIRE TO FORWARD END OF SHEATH TUBE TO CLOSE FORWARD END OF SHEATH TUBE
P140
CHARGE INSULATOR INTO SHEATH TUBE
P150
ATTACH VARIOUS MEMBERS
P160
COMPLETION

FIG. 7

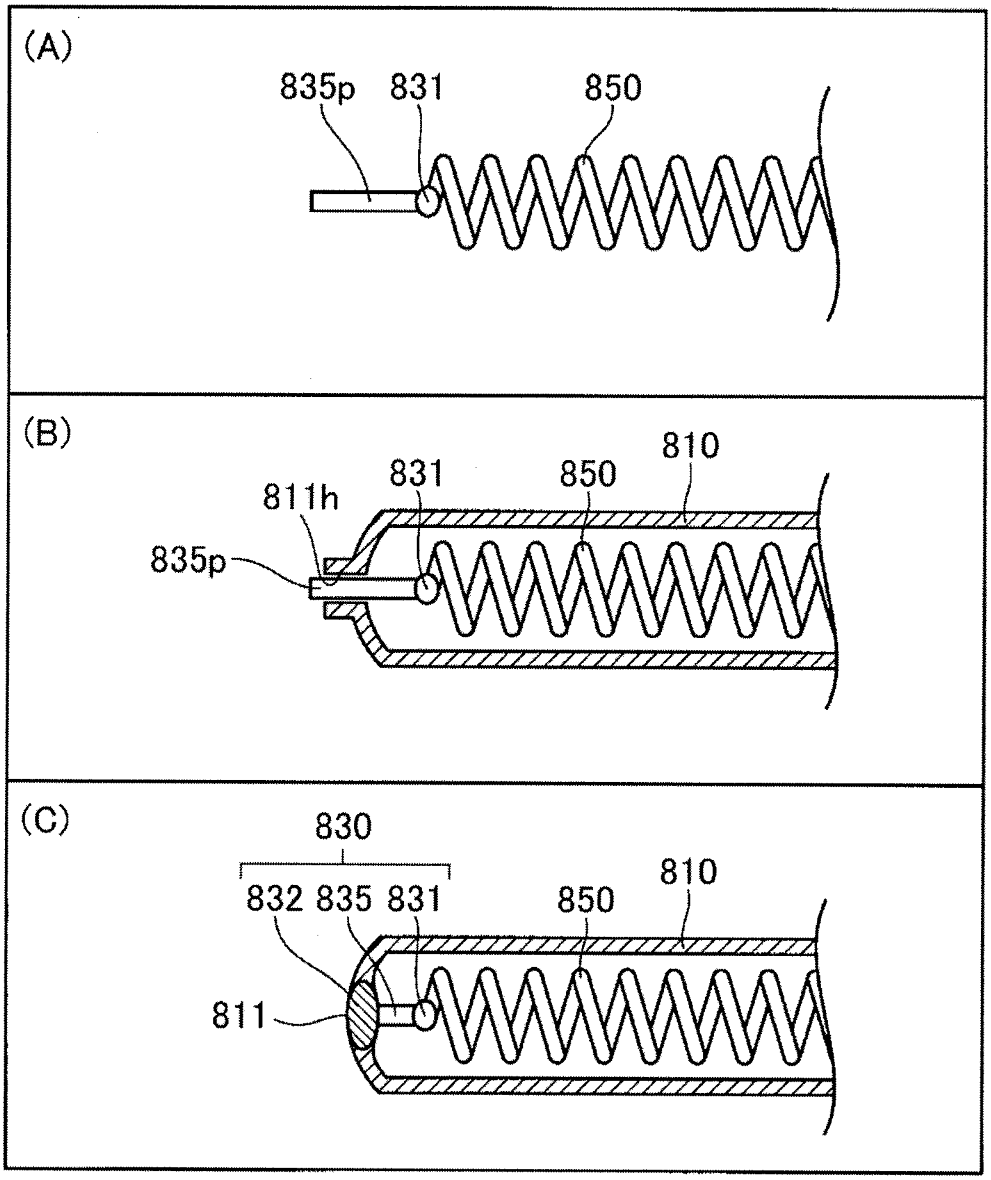

(A)
835p
831
850
(B)
810
831
850
811h
835p
(C)
830
832
835
831
810
850
811

FIG. 8

Material of sheath tube: Ni-23% Cr-14% Fe-1.4% Al (INCONEL 601) Material of heat-generating coil: W						
Sample	Material of wire	Ni content in a portion of rear-end fusion zone extending up to 20 μm from interface	Ni content in a portion of rear-end fusion zone extending up to 10 μm from interface	Cr content in a forward end portion of sheath tube	Number of wire-breaking cycles	Judgment
A1	Fe-18% Cr (SUS430)	Not detected	Not detected	18% by mass	13,427	A
A2	Fe-18% Cr-3% Al (SUH21)	Not detected	Not detected	20% by mass	15,230	A
A3	Fe-12% Cr (SUS403)	Not detected	Not detected	13% by mass	8,931	B
A4	Fe-10% Cr	Not detected	Not detected	10% by mass	6,459	C
A5	Ni-23% Cr-14% Fe-1.4% Al (INCONEL 601)	42% by mass	Not detected	23% by mass	5,324	F
A6	Fe-26% Cr-22% Ni (SUS310s)	12% by mass	Not detected	24% by mass	4,390	F

FIG. 9

Material of sheath tube: Ni-23% Cr-14% Fe-1.4% Al (INCONEL 601) Material of heat-generating coil: Mo						
Sample	Material of wire	Ni content in a portion of rear-end fusion zone extending up to 20 μm from interface	Ni content in a portion of rear-end fusion zone extending up to 10 μm from interface	Cr content in a forward end portion of sheath tube	Number of wire-breaking cycles	Judgment
B1	Fe-18% Cr (SUS430)	Not detected	Not detected	18% by mass	13,209	A
B2	Fe-18% Cr-3% Al (SUH21)	Not detected	Not detected	20% by mass	12,483	A
B3	Fe-12% Cr (SUS403)	Not detected	Not detected	13% by mass	8,472	B
B4	Fe-10% Cr	Not detected	Not detected	10% by mass	6,823	C
B5	Ni-23% Cr-14% Fe-1.4% Al (INCONEL 601)	37% by mass	Not detected	23% by mass	4,220	F
B6	Fe-26% Cr-22% Ni (SUS310s)	15% by mass	Not detected	24% by mass	4,824	F

FIG. 10

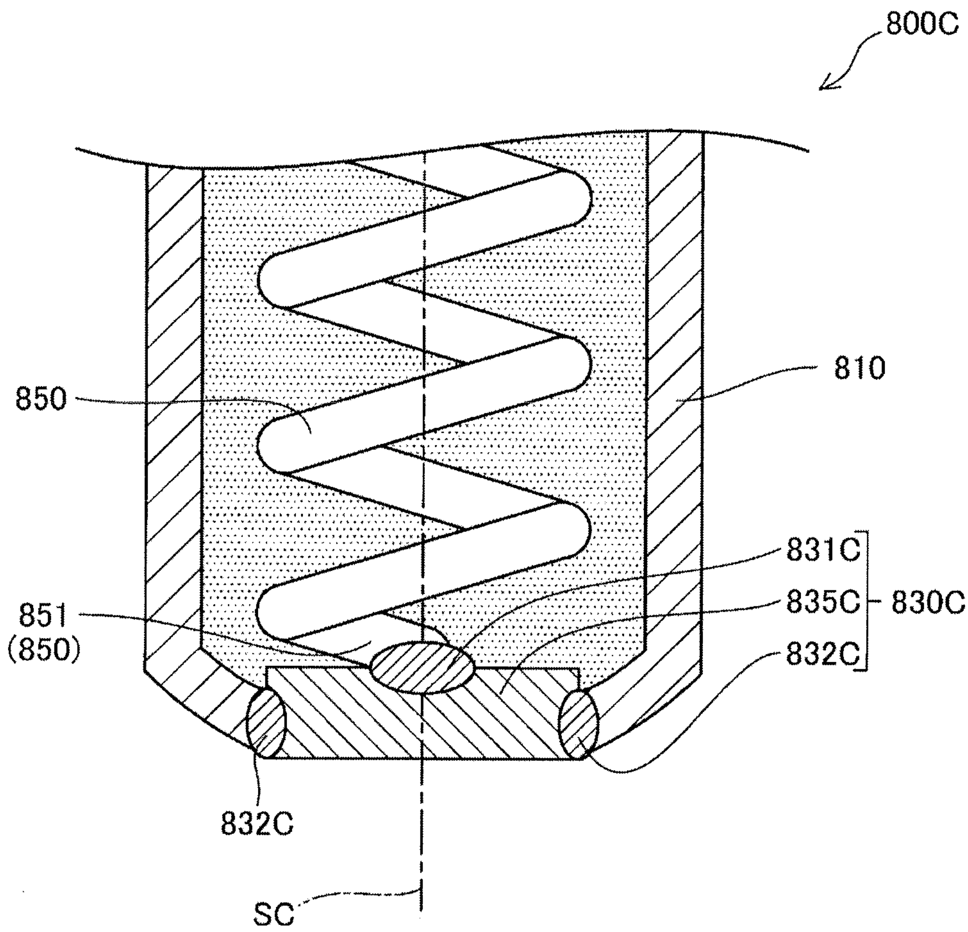


FIG. 11

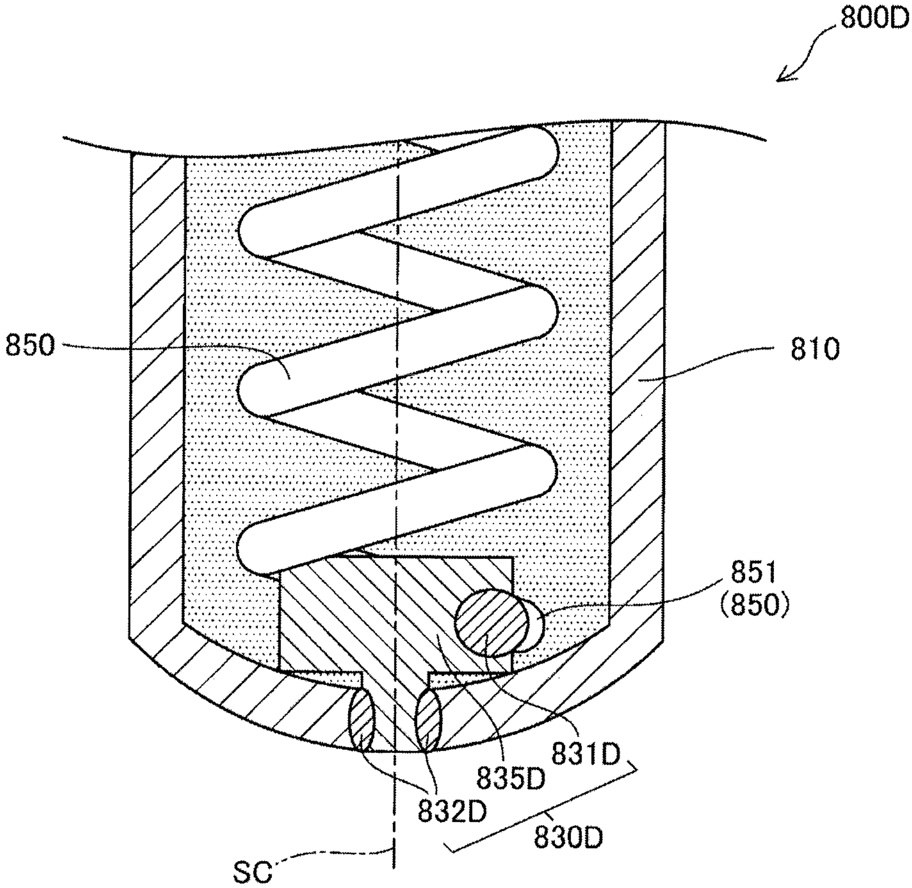


FIG. 12

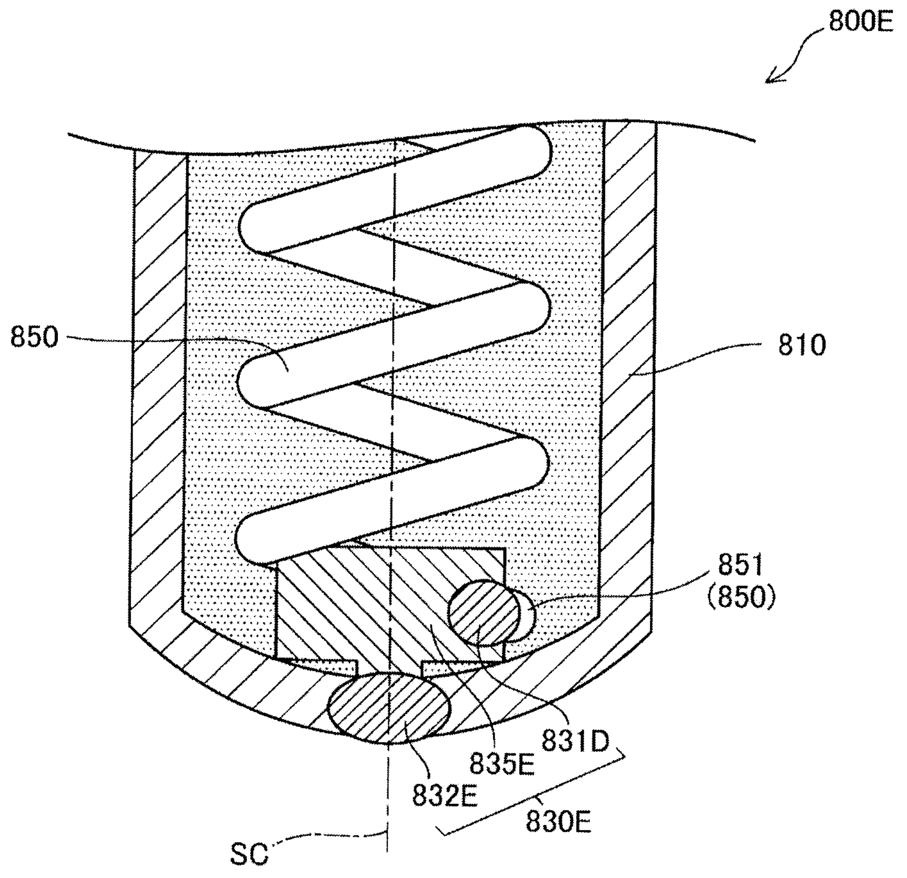
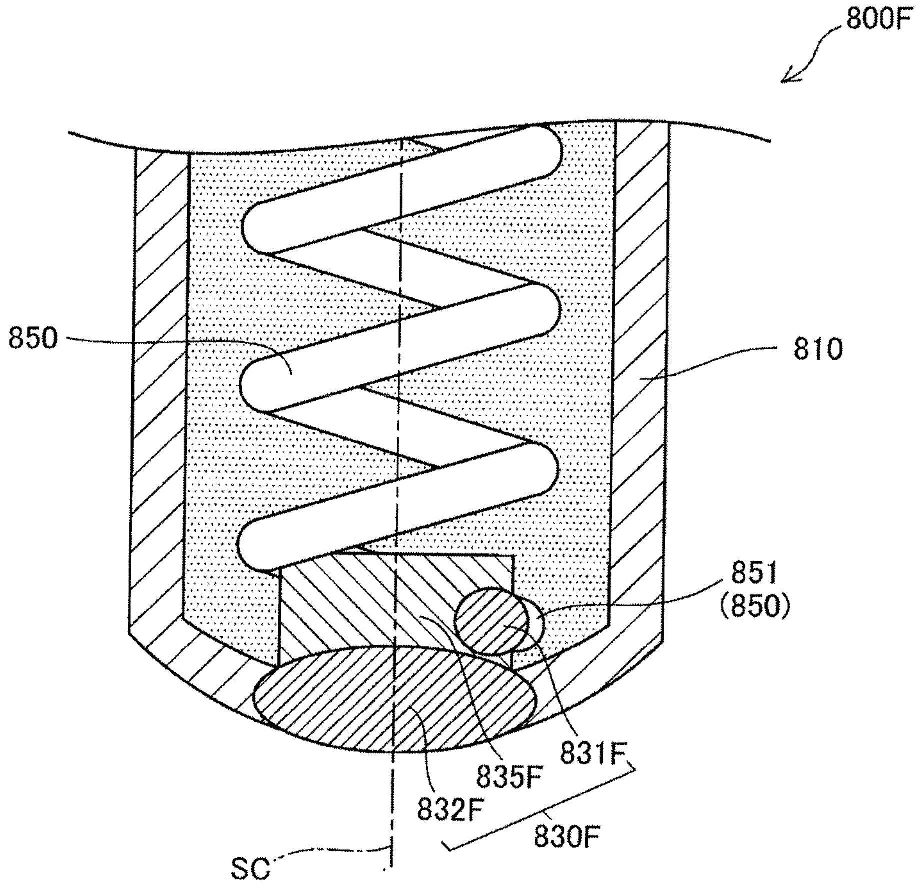


FIG. 13



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2011162074 A **[0004]**
- JP 2012057820 A **[0004]**