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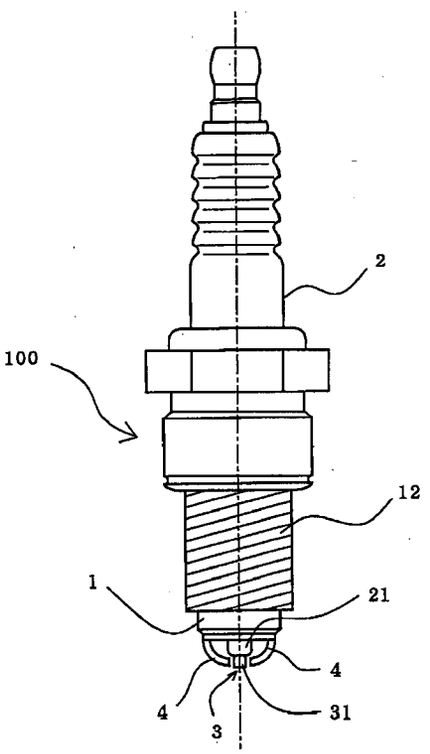
(54) A spark plug

(57) The spark plug 100 comprises a center electrode 3 , an insulator 2 arranged outside of the center electrode 3, a metal shell 1 which is arranged outside of the insulator 2 and from one end of which the center electrode 3 protrudes, a protruding portion 11 which is formed on the inner surface of the metal shell 1 at the end portion thereof and protrudes toward the insulator 2, and a ground electrode 4 one end of which is joined to the metal shell 1 and another end of which is arranged facing to the side surface of the center electrode 4. A first spark gap g1 is formed between the tip 41 of the ground electrode 4 and the side surface of the center electrode 3. A second spark gap g2 is formed between the end surface 22 of the insulator 2 and the inner surface 42 of the ground electrode 4. An auxiliary gap g3 is formed between the protruding portion 11 and the corresponding outer surface 23 of the insulator 2. The amount of the second gap g2 is less than that of the first gap g1. In such spark plug 1, a spark is generated at the second spark gap g2 when the spark discharge voltage becomes lower at the second gap g2 than at the first gap g1 due to a deposition of electrically conductive substance onto the surface of the insulator 2, thereby removing said deposition by combustion. Furthermore, a spark is generated also at the auxiliary gap g3 when the spark discharge voltage becomes lower at the auxiliary gap g3 than at the first gap g1.

Fig. 1



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Description

Field of Invention

This invention relates to a spark plug used for an internal combustion engine.

Back Ground of Invention

In a conventional spark plug used for an internal combustion engine, as shown in Fig.8, a center electrode 104 held in an insulator 102 is arranged inside a metal shell 106 which has a threaded portion on its circumference for securing the plug 200 on the engine. A ground electrode 105 is joined to one end of the metal shell 106 so as to face the center electrode 104 with forming a spark gap g1 therebetween.

As in the case of e.g. automobiles loading on a ship, the engine may be driven in such a way that a short time cycle of no-load or rather light-load running is intermittently repeated, or otherwise such light-load state is continued for a long period of time. Such a driving pattern may cause a fuel excessive state in a engine cylinder and prevent the insulator 102 of the plug 200 from being heated sufficiently, so that electrically conducive substance such as carbons and engine-oil components may deposit on the surface of the insulator 102 without being perfectly burned and cause so-called "fouling" state. Then, the surface electrical resistance of the insulator 102 decreases, and unexpected spark discharge may occur at a site remote from the spark gap g1, for instance at a portion 107 where the insulator 102 engages with the metal shell 106.

For solving the above problem, a spark plug 101 as referred in Fig.7 has been proposed in U.S Patent No.4,289,990. In this spark plug 101, the tip end of a ground electrode 105 is located opposing to a side surface of a center electrode 104 thereby forming a spark gap g1. On the other hand, a convex portion or rather flange 108 is formed annularly on an inner surface of the metal shell 106, and an auxiliary gap g3 is formed between the protruding portion 108 and the outer surface of the insulator 102. The carbons or engine oil components are to be prevented from entering further inside the metal shell 106 by the protruding portion 108, and even when the surface electrical resistance of the insulator 102 is decreased by the deposition of the carbons thereon, sparks can be generated at the auxiliary gap g3 thereby dissolving the deposit and eliminating the unexpected spark discharge at the remote site other than spark gap g1. In this case, the spark generated at the auxiliary gap g3 functions also as the ignition source for the fuel injected into the engine cylinder.

However, although this concept of the spark plug 101 having the annular flange 108 for the auxiliary gap g3 is very effective in preventing fouling, in other words, stopping the intrusion of the carbons, etc. into the undesired ares 107 remote from the spark gap g1 and thereby limiting most of the deposition around the insulator nose 102 which is more or less projected from the end of the metal shell 106, the spark plug 101 of this configuration has drawbacks in that the ignitability for the fuel by the spark discharge at the auxiliary gap g3 is not sufficient. That is to say, when the spark generation becomes impossible at the first spark gap g1 due to fouling, sparks are to be generated mainly at the auxiliary gap g3. The annular flange 108 is, however, a thick metallic portion having a large heat capacity, so that it quickly dissipates the heat of fuel combustion and thereby lowers said ignitability attributed to the gap g3.

On the other hand, in an environment where soot-fouling proceeds more significantly, spark generation at the auxiliary gap g3 is not necessarily satisfactory for sufficient cleaning of the surface of the insulator 102, and the effect of preventing the malfunction in the spark generation is not achieved enough. Furthermore, when the amount of the auxiliary gap g3 is set in a too small value, the annular flange 108 may obstruct the heat radiation from the inner side of the metal shell 106 to outside, so that the cooling of the insulator 102 does not sufficiently proceed, particularly in a condition of high speed engine running.

The first object of this invention is to offer a spark plug having a plurality of additional gaps besides said first spark gap, whereby the malfunction of the spark generation can be prevented by a removal of the deposit on the insulator with a combinational help of the spark generation at one of the additional gaps, and wherein the ignitability for the fuel is excellent also at the additional gaps. The second object of this invention is to offer a spark plug wherein the heat radiation from the plug proceed sufficiently in spite of a formation of the auxiliary gap.

Summary of the Invention

For accomplishing said first object, the spark plug of this invention comprises a center electrode, an insulator which is arranged outside of the center electrode and from one end of which the center electrode protrudes, a metal shell which is arranged outside of the insulator, a protruding portion which is formed on the inner surface of the metal shell at the end portion thereof and protrudes toward the insulator, and a ground electrode one end of which is joined to the metal shell and another end of which is arranged facing to a side surface of said center electrode, wherein a first spark gap is formed between a firing tip end of said ground electrode and the side surface of said center electrode, wherein a second spark gap is formed between an end surface of the insulator and an inner side of the ground electrode, wherein an auxiliary gap is formed between the protruding portion and the corresponding outer surface of the insulator, wherein a spark is generated at the second spark gap when the spark discharge voltage becomes lower at the second spark gap than at the first spark gap due to a deposition of electrically conductive substance onto the surface of the

insulator, thereby removing said deposition by combustion, and wherein a spark is generated also at the auxiliary gap when the spark discharge voltage becomes lower at the auxiliary gap than at the first spark gap due to the deposition of electrically conductive substance onto the surface of the insulator, thereby removing the deposition by combustion.

As shown in Figs.2A, 2B and shown in Figs.3A, 3B, the spark plug (100) of this invention is different from the spark plug disclosed in the aforementioned U.S. Patent No.4,289,990 with respect to the additional feature that the end portion of the insulator (2) is intentionally located close to the ground electrode (4) so as to form the second gap (g2) therebetween and to remove the substance deposition on the insulator (2). When the surface resistivity of the insulator (2) in the spark plugs of the invention is decreased due to the deposition, the spark discharge voltage may become lower at the second spark gap (g2) than at the first one (g1), resulting in that a spark is generated at the second spark gap (g2), and thereby said deposition is removed by combustion due to the spark discharge. In addition, the second spark gap (g2) is formed by a ground electrode (4) of a wire shape having relatively small heat capacity and low ability of heat transfer, so that the heat of fuel combustion is hardly lost, and thereby the ignitability for the fuel becomes excellent.

On the other hand, in the spark plug disclosed in said U.S. patent, although sparks can discharge only at the auxiliary gap (g3) in such a state of "heavy fouling" as the fouling develops over a wide region of the insulator surface ranging from the firing tip to the auxiliary gap (g3), in such another state of "light or rather not heavy fouling" as that the fouling region is limited only around the tip of the insulator (2) without reaching to the auxiliary gap (g3), spark discharge hardly occurs at the auxiliary gap (g3), so that such the light fouling can not be eliminated or rather prevented according to said configuration of the prior art spark plug.

However, the spark plug according to this invention has an advantage that the light fouling shall be limited or rather removed by sparks discharged at the second spark gap (g2) which is contemplated in the vicinity of the first gap (g1).

According to the spark plug of the present invention, in the case that the surface electric resistivity of the insulator (2) is decreased further at the portion near the end of the metal shell (1) due to acceleration of the deposition, sparks are generated at the auxiliary gap (g3) if the amount of the gap or rather the gap distance is optimized. That is to say, the auxiliary gap (g3) provides another additional site of spark discharge for removing the deposit other than the first and second gaps (g1, g2). Therefore, the spark generation occurs more frequently to diminish the deposition on the insulator (2), and the surface condition of the insulator (2) is to be maintained in a clean condition. In addition, sparks are generated mainly at the first or the second spark gaps (g1, g2) unless the fouling proceeds very significantly, i.e. a heavy fouling, so that the ignitability of the spark plug is always maintained in a good condition, reducing a possible acceleration of fouling.

Furthermore, even if the, depositing substance enters into the metal shell (1) thorough the auxiliary gap (g3), the sparks to be generated at the auxiliary gap (g3) shall cut off an electrical current path from the center electrode, so that spark generation may hardly occur at the site deep inside beyond the auxiliary gap (g3) in the metal shell (1). The spark plug thus constructed according to this invention is superior in the fouling resistance in comparison with a conventional one, and has a stable and excellent performance of spark generation even under such a severe environment where the fouling proceeds rapidly as in an intermittent or otherwise continuous light-load engine running at a low temperature.

The inventors have further discovered that, when the fouling of the insulator is proceeded by the electrical substance deposition in the spark plug of the invention having said three gaps (g1, g2, g3), the probability of spark discharge at the second spark gap (g2) is increased by making the amount or rather distance of said first spark gap (g1) equal to or larger than that of the second spark gap (g2), that is to say, by making a ratio (b/a) of the amount (b) of the second spark gap (g2) to that (a) of the first spark gap (g1) less than 1. When the ratio of b/a exceeds 1, the spark discharge at the second spark gap (g2) becomes difficult at a fouling state. On the other hand, if the ratio of b/a is less than 0.25, it may cause the short circuit at the second gap (g2) due to the deposition by the electrical substance such as carbons and oil components. The value of b/a is adjusted more preferably in 0.3 - 0.9 according to the invention.

The amount (a) of the first spark gap (g1) is preferably adjusted in a range of 0.7 - 1.2 mm. The value (a) of less than 0.7 mm may cause the short circuit at the first spark gap (g1) due to the deposition by the electrical substance, and that value exceeding 1.2 mm makes the first gap (g1) difficult to cause spark discharge because of too high discharge voltage to be required. The amount (b) of the second spark gap (g2) is preferably adjusted in a range of 0.3 - 1.2 mm according to the invention. The value (b) of less than 0.3 mm may cause the short circuit at the second spark gap (g2) due to the deposition by the electrical substance, and that value exceeding 1.2 mm may lead to a difficulty in spark discharge at the second gap (g2) under the fouling state, thereby causing an insufficiency of the cleaning effect by the spark generation at the second gap (g2). The amount (b) of the second spark gap (g2) is more preferably adjusted in a range of 0.4 - 0.9 mm according to the invention.

Next, in the spark plug for accomplishing the first and second objects of this invention, the amount (c) of the auxiliary gap (g3) is adjusted to be more than 0.4 mm. With this construction, the heat radiation from the inner side of the metal shell (1) to outside is not

obstructed, and thereby the cooling of the insulator (2) sufficiently proceeds even in a condition of high speed or rather high load engine running. The inventors have discovered that, by adjusting the amount (c) of the auxiliary gap (g3) in a range of 0.4 - 1.3 mm, the reliability of the spark generation at the auxiliary gap (g3), resulting in the effective cleaning of the surface of the insulator (2) is improved. The value (c) of less than 0.4 mm may cause not only an obstruction for the heat radiation from the plug, but also the short circuit by the deposition at the auxiliary gap (g3), and whereby the effect of preventing the plug from fouling is lost or the spark is hardly generated. On the other hand, the value (c) if exceeding 1.3 mm, the effect for preventing the depositing substance from penetrating or entering deeply inside the metal shell (1) becomes insufficient. The value (c) is adjusted more preferably in 0.5 - 1.1 mm.

The ratio (c/a) of the amount (a) of said auxiliary gap (g3) to that (a) of the first spark gap (g1) is preferably adjusted in the range of 0.4 - 1.3. When the ratio of c/a exceeds 1.3, the spark discharge at the auxiliary gap (g3) becomes difficult. On the other hand, c/a of less than 0.4 may cause the short circuit at the auxiliary gap due to the deposition by the electrical substance. The value of c/a is adjusted more preferably in 0.4 - 1.0.

By setting the amount (c) of the auxiliary gap (g3) to exceed 0.4 mm but to be less than the amount (a) of the first spark gap (g1), the reliability of the spark generation at the auxiliary gap (g3), resulting in the effective removing of the deposition is improved. Therefore, it is more preferable to adjust the amount (c) of the auxiliary gap (g3) so as to be in a range of 0.4 - 1.3 mm but to be less than the amount (a) of the first spark gap (g1) since an effect of preventing the deposited substance from intruding inside the metal shell (1) and that of spark discharge at the auxiliary gap (g3) are simultaneously achieved.

In the plug construction described above, the protruding portion (11) may be annularly formed on the end portion of the inner surface of the metal shell (1). In this case, the cross section of the protruding portion (11) according to a sectional plane parallel to the axis of said center electrode (3) may be formed in a shape that the width is narrower in the end portion thereof facing to said insulator than in the basal portion thereof. According to this preferable construction, a high voltage is apt to concentrate on the tapered tip of the protruding portion (11), and the reliability of the spark generation at the auxiliary gap (g3) is enhanced.

Brief Description of Drawings

In the accompanying drawings:

Fig.1 is a side view presenting a spark plug relating to this invention;

Fig.2A presents an enlarged bottom view of the spark plug in Fig.1;

Fig.2B shows an enlarged partial sectional side view of the main part of the spark plug in Fig.1 corresponding to Fig.2A;

Fig.3A presents an enlarged bottom view of another spark plug according to the invention;

Fig.3B presents an enlarged partial sectional side view of the main part of the spark plug corresponding to Fig.3A;

Fig.4 presents an engine running pattern used for soot fouling test on spark plugs;

Fig.5 presents results of a spark plug performance in an experimental test example 1;

Fig.6 presents results of a spark plug performance in an experimental test example 2;

Fig.7 is a partial sectional side view of the main part of a spark plug in the prior art;

Fig.8 is a partial sectional side view of the main part of a conventional spark plug.

Detailed Description of the Preferable Embodiments

Several embodiments of this invention will now be described with reference to drawings.

A spark plug 100 presented in Fig.1, as one of the embodiments of this invention, comprises a tubular metal shell 1, an insulator 2 which is engaged inside with the metal shell 1 so that the end portion 21 protrudes from one end opening of the shell 1, a center electrode 3 which is held in the insulator 2 and protrudes its ignition tip 31, and ground electrodes 4 each one end of which is joined to the metal shell 1 and each another end of which is facing to the side surface of the ignition tip 31, i.e., the center electrode 3.

As is shown in Fig.2A and Fig.2B, two ground electrodes 4 are arranged facing or rather opposing each other with the ignition tip 31 inbetween, and each of them is formed in a crooked shape so that the end surface 41 thereof is almost parallel to the side surface of the ignition tip 31 while the other end thereof is joined to the metal shell 1 by means of, for example, welding. The metal shell 1 consists of a carbon steel, and as shown in Fig.1, a threaded portion 12 is formed on its circumference for mounting the plug 100 on an engine. On the other hand, the insulator 2 is formed as a ceramic sintered body such as of aluminum oxide.

In this embodiment, the center electrode 3 has a rod-like shape with a diameter of ca. 2.5 mm. The width w and thickness t of the ground electrode 4 are ca. 2.5 mm and 1.5 mm, respectively. The height h of the ground electrode 4 from the end of the metal shell 1 to the center of the first spark gap g1 is ca. 4.5 mm. The outer diameter of the end portion 21 of the insulator 2 is ca. 5 mm, and the protruding length of the insulator 2 from the end of the metal shell 1 is ca. 3.5 mm.

As is shown in Fig.2B, the first spark gap g1 is formed between the end surface 41 of each ground electrode 4 and the outer side surface of the ignition tip 31. Said end surface 41 of the ground electrode 4 is located inside the circumference of the an insulator top

22 which is elevated to form the second gap g2 with the inner surface of the ground electrode 4 bent inwardly. As is shown in Fig.2A, the end surface 41 of the ground electrode 4 is formed in a shape following the side surface of the center electrode 3.

Furthermore, a flange or rather protruding portion 11 protruding toward said insulator 2 is formed on the inner surface of the metal shell 1 at the end portion thereof, so as to form an auxiliary gap g3 between the end 11a of the protruding portion 11 and the corresponding outer surface 23 of the insulator 21. The preferred protruding portion 11 is annularly formed on the end portion of the inner surface of the metal shell 1, and the cross section thereof according to a sectional plane parallel to the axis of the center electrode 3 is formed in a shape that the width of the end portion thereof facing to the insulator 2 is narrower than that in the base portion thereof connecting the shell 1. The outer surface 23 of the insulator 2 and the counter tip surface 11a of the protruding portion 11 are formed to be almost uniaxial and parallel to each other.

The ratio of the amount of the second spark gap g2 (a) to that of the first spark gap g1 (b), i.e. b/a, is adjusted in the range of 0.25 - 1, preferably in 0.3 - 0.9 according to the invention. The value of a is adjusted in the range of 0.7 - 1.2 mm. The value of b is adjusted in the range of 0.3 - 1.2 mm, preferably in the range of 0.4 - 0.9 mm. On the other hand, the amount or rather clearance c of the auxiliary gap g3 is adjusted in the range of 0.4 - 1.3 mm, preferably in 0.4 - 1.0 mm according to the invention. The ratio of c/a is adjusted in the range of 0.4 - 1.3, preferably in 0.4 - 1.0. More specifically, the amount c of the auxiliary gap g3 is adjusted to be more than 0.4 mm but to be less than that of the first spark gap g1, i.e., a.

Now, the action of the spark plug 100 is going to be explained. The spark plug 100 is secured to an internal combustion engine, such as gasoline engine, by screwing the threaded portion 12 (Fig.1) so that the ignition tip 31 is located inside the combustion chamber of the engine. The plug 100 is used as an ignition source to ignite fuel-air mixture introduced to the chamber. When the engine is continuously driven for a long time under a condition of light-load, carbon or engine oil is apt to deposit on the surface of the spark-plug 100 causing soot-fouling thereon. In this case, the electrical resistance of the insulator 2 decreases because the electrically conductive substance, such as carbon, may be deposited thereon to the extent that sparks are generated at the second spark gap g2 formed between the insulator 2 and the center electrode 3 thereby removing the deposit by combustion, due to the invented configuration that the spark discharge voltage becomes lower at the second spark gap g2 than at the first spark gap g1. The ground electrode 4 has a relatively small heat capacity since it has a wire shape, so that the ignitability at the second spark gap g2 is excellent.

On the other aspect of the invention, if the high conductivity area or low electrical resistivity area due to the deposition develops on the surface of the insulator to the neighborhood of the metal shell 1, the auxiliary gap g3 is then brought in a condition of being apt to generate sparks, and the frequent spark generation can remove the heavy deposit more effectively. Thus, the spark plug 100 of the present invention becomes more resistive against possible fouling by spark-combination of the gaps g1, g2, g3. Furthermore, the protruding portion 11 on the inner surface of the metal shell 1 is so adequately made that the clearance c formed with the side surface 23 of the insulator 2 can suppress the deposition of the fouling substance entering deeply inside toward the interior of the metal shell 1 through the gap g3.

The number of the ground electrodes 4 may be more than three as shown in Figs.3A, 3B. Three ground electrodes 4 are equiangularly arranged around the center electrode 3, and each of them is formed in a crooked shape so that the end surface 41 thereof is almost parallel to the side surface of the ignition tip 31.

(Experimental example 1)

A performance test was carried out on the spark plug 100 as presented in Figs.2A,2B according to the following procedure. In spark plugs according to Fig.2B, the amount (a) of the first spark gap g1 and that (b) of the second spark gap g2 was set to be 1.0 mm and 0.5 mm, respectively. The amount (c) of the auxiliary gap g3 was adjusted in a range of 0.3 - 1.6 mm. In samples No.1 - 8, No.1 and No.7 are comparable samples. Furthermore, a spark plug having no protruding portion 11 on the inner surface of the metal shell 1 was also prepared as a comparable example (No.8).

These plug samples were mounted on the engine of a test car, respectively, and subjected to a running pattern for the soot fouling test as shown in Fig.4 (based on JIS:D1606, test temperature: -20°C). The test was cycled or rather repeated up to 20 times on all samples. The plug performance was evaluated by the test cycle number until the engine start became impossible. The test results were gathered in Fig.5. The test cycle number until when the engine became impossible to start was larger for the spark plugs of this invention as shown in sample No.2 - 6 than those of comparable examples. When the amount of auxiliary gap g3 was 0.4 - 1.3 mm, improvement was observed and the best improvement was in the range of 0.4 - 0.8 mm. This result indicates that the spark plug of this invention is superior in the resistance against fouling.

(Experimental example 2)

Several spark plugs 100 relating to Figs.2A,2B were prepared so that the amount (c) of the auxiliary gap g3 was fixed to 0.6 mm, and those of the first and second spark gaps g1 (a) and g2 (b) were adjusted in 0.5 - 1.4 mm and 0.1 - 1.4 mm, respectively. In samples No.11 - 22, No.11, 13, 18, 19 and 22 are comparable samples. The spark plug performance test on these

spark plugs was carried out according to the same soot-fouling test as in the experimental example 1 except that the running cycle was repeated up to 10 times. The results were gathered in Fig.6. The cycle number until impossible to start the engine was larger for the spark plugs regarding this invention than for those of comparable examples. This result indicates that the spark plugs of this invention were superior in the resistance against fouling.

Claims

1. A spark plug comprising:

a center electrode;
an insulator which is arranged outside of said center electrode and from one end of which said center electrode protrudes;
a metal shell which is arranged outside of said insulator and;
a protruding portion which is formed on the inner surface of said metal shell at the end portion thereof and protrudes toward said insulator;
a ground electrode one end of which is joined to said metal shell and another end of which is arranged facing to the side surface of said center electrode;

wherein a first spark gap is formed between a firing tip end of said ground electrode and the side surface of said center electrode;

wherein a second spark gap is formed between an end surface of said insulator and an inner side of said ground electrode;

and wherein an auxiliary gap is formed between said protruding portion and the corresponding outer surface of said insulator.

2. A spark plug comprising:

a center electrode;
an insulator which is arranged outside of said center electrode and from one end of which said center electrode protrudes;
a metal shell which is arranged outside of said insulator and;
a protruding portion which is formed on the inner surface of said metal shell at the end portion thereof and protrudes toward said insulator;
a ground electrode one end of which is joined to said metal shell and another end of which is arranged facing to the side surface of said center electrode;

wherein a first spark gap is formed between a firing tip end of said ground electrode and the side surface of said center electrode;

wherein a second spark gap is formed between an end surface of said insulator and an inner side of said ground electrode;

wherein an auxiliary gap is formed between said protruding portion and the corresponding outer surface of said insulator;

wherein a spark is generated at said second spark gap when the spark discharge voltage becomes lower at said second spark gap than at said first spark gap due to a deposition of electrically conductive substance onto the surface of said insulator, thereby removing said deposition by combustion;

and wherein a spark is generated also at said auxiliary gap when the spark discharge voltage becomes lower at said auxiliary spark gap than at said first spark gap due to a deposition of electrically conductive substance onto the surface of said insulator, thereby removing said deposition by combustion.

3. A spark plug comprising:

a center electrode;
an insulator which is arranged outside of said center electrode and from one end of which said center electrode protrudes;
a metal shell which is arranged outside of said insulator and;
a protruding portion which is formed on the inner surface of said metal shell at the end portion thereof and protrudes toward said insulator;
a ground electrode one end of which is joined to said metal shell and another end of which is arranged facing to the side surface of said center electrode;

wherein a first spark gap is formed between a firing tip end of said ground electrode and the side surface of said center electrode;

wherein a second spark gap is formed between an end surface of said insulator and an inner side of said ground electrode;

wherein an auxiliary gap is formed between said protruding portion and the corresponding outer surface of said insulator;

and wherein the amount of said first spark gap is equal to or larger than that of said second spark gap.

4. A spark plug comprising:

a center electrode;
an insulator which is arranged outside of said center electrode and from one end of which said center electrode protrudes;
a metal shell which is arranged outside of said insulator and;

a protruding portion which is formed on the inner surface of said metal shell at the end portion thereof and protrudes toward said insulator;

a ground electrode one end of which is joined to said metal shell and another end of which is arranged facing to the side surface of said center electrode;

wherein a first spark gap is formed between a firing tip end of said ground electrode and the side surface of said center electrode;

wherein a second spark gap is formed between an end surface of said insulator and an inner side of said ground electrode;

wherein an auxiliary gap is formed between said protruding portion and the corresponding outer surface of said insulator;

and wherein the amount of said auxiliary gap is adjusted in a range of 0.4 - 1.3 mm.

5. A spark plug according to one of claims 1, 2 and 4 wherein the amount of said first spark gap is equal to or larger than that of said second spark gap.

6. A spark plug according to claim 3 or 5 wherein the ratio of the amount of said second spark gap b to that of said first spark gap a, b/a, is in the range of 0.25 - 1.

7. A spark plug according to one of claims 1, 2, 5 and 6 wherein the amount of said first gap is in the range of 0.7 - 1.2, and wherein the amount of said second gap is in the range of 0.3 - 1.2.

8. A spark plug according to one of claims 1 - 7 wherein the ratio of the amount of said auxiliary gap c to that of said first spark gap a, c/a, is in the range of 0.4 - 1.3.

9. A spark plug according to one of claims 1 - 8 wherein the amount of the auxiliary gap is equal to or larger than 0.4 mm and is less larger than the amount of said first spark gap.

10. A spark plug according to one of claims 1 - 9 wherein the end surface of said ground electrode is formed in a shape following said side surface of said center electrode.

11. A spark plug according to one of claims 1 - 10 wherein said protruding portion is annularly formed on the end portion of the inner surface of said metal shell.

12. A spark plug according to one of claims 1 - 11 wherein the cross section of said protruding portion according to a sectional plane parallel to the axis of said center electrode is formed in a shape that the width is narrower in the end portion thereof facing to said insulator than in the basic portion thereof.

13. A spark plug according to one of claims 1 - 12 wherein the outer surface of said insulator for forming said auxiliary gap and the counter tip surface of said protruding portion are formed to be almost parallel to each other.

Fig. 1

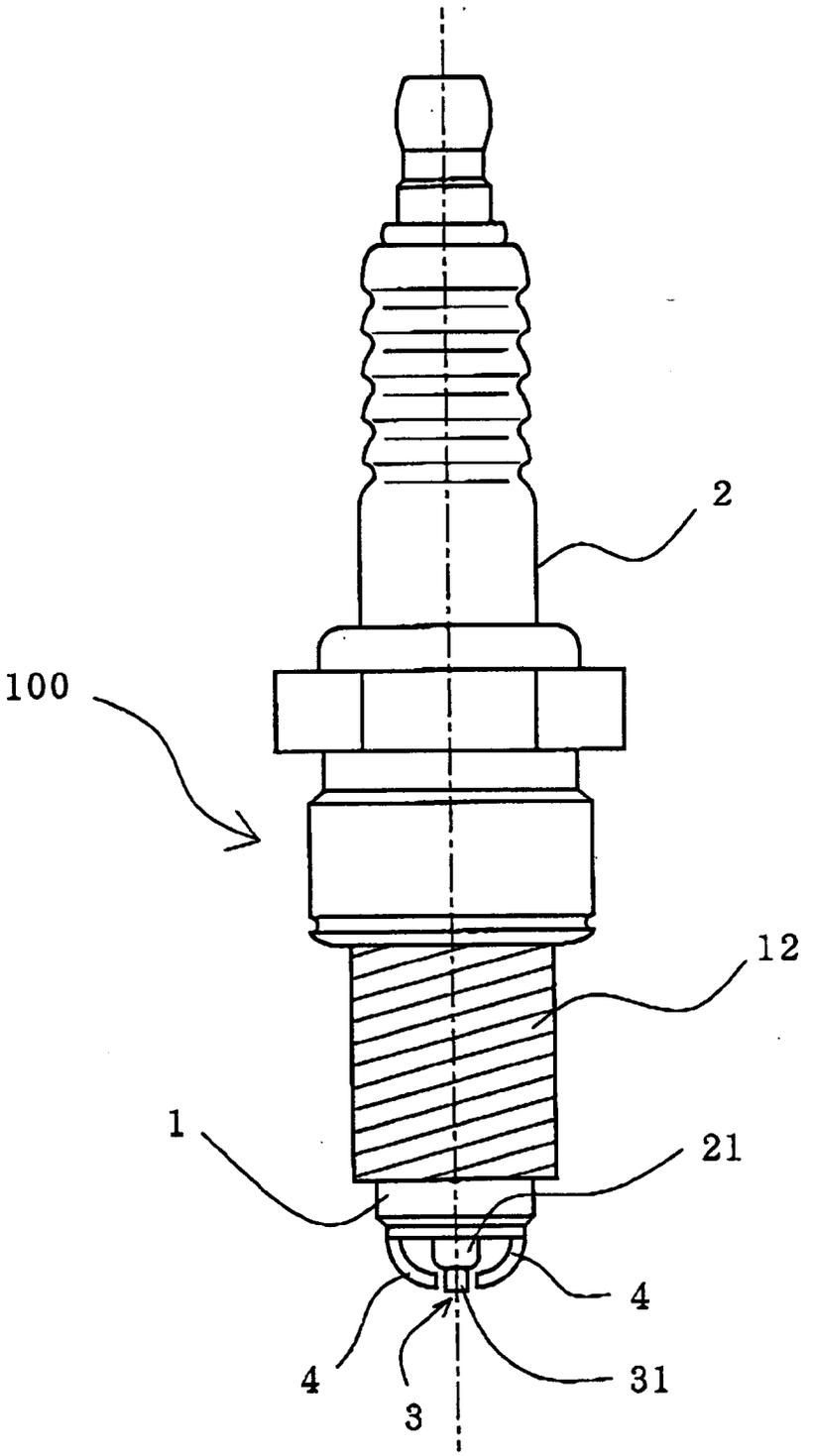


Fig. 2A

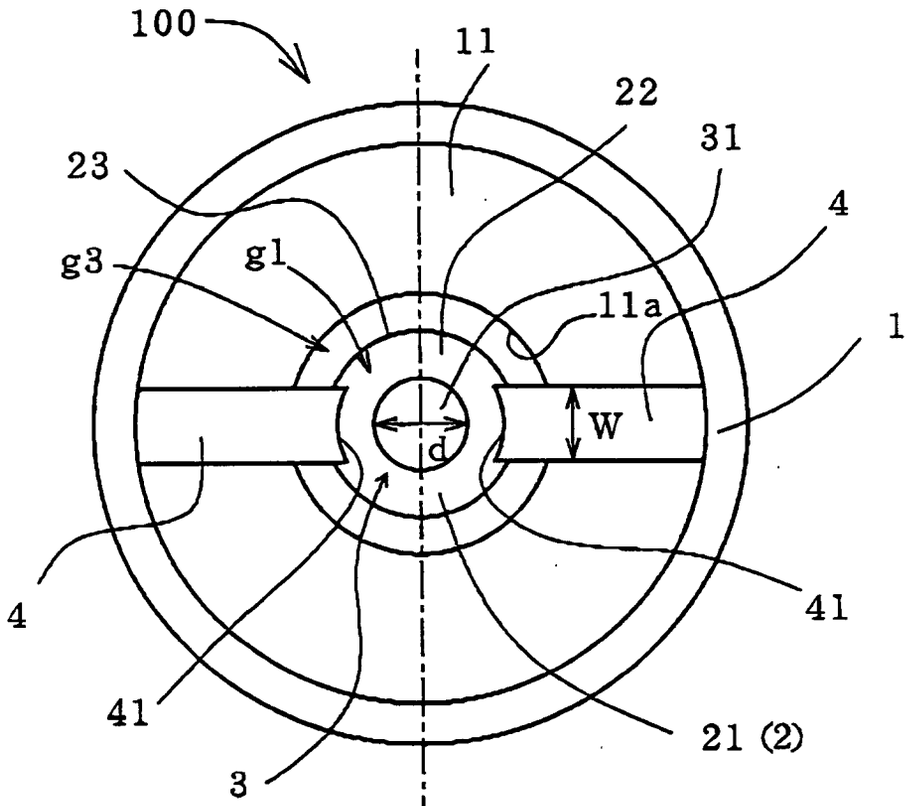
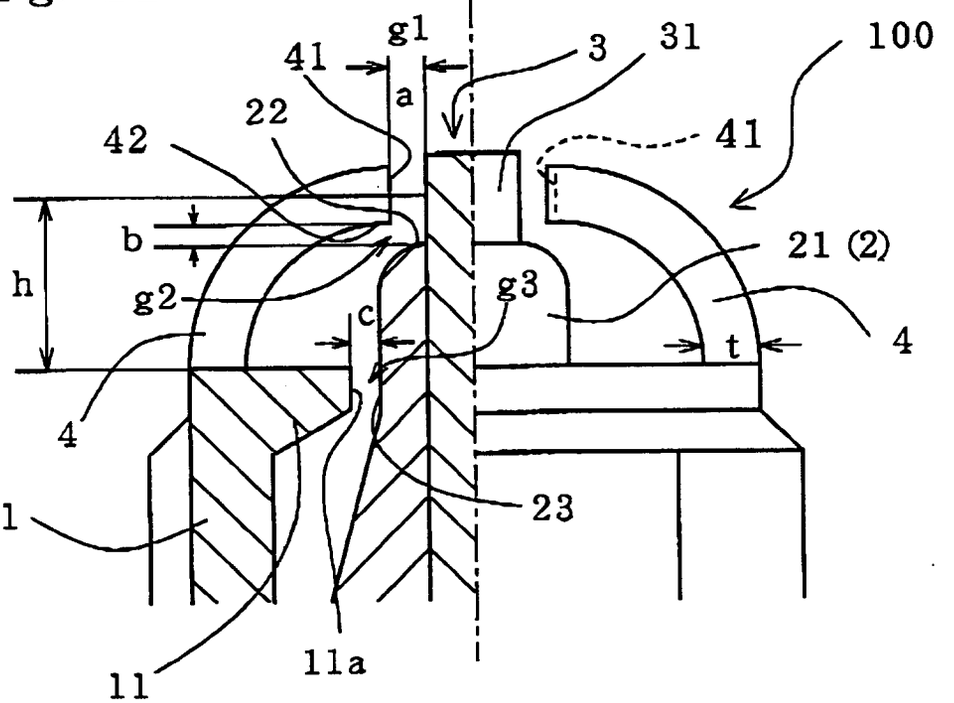

100
11
22
31
23
4
g3
g1
11a
1
W
d
4
41
41
21 (2)
3

Fig. 2B


g1
41
a
3
31
100
22
42
41
b
21 (2)
h
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23
11
11a

Fig. 3A

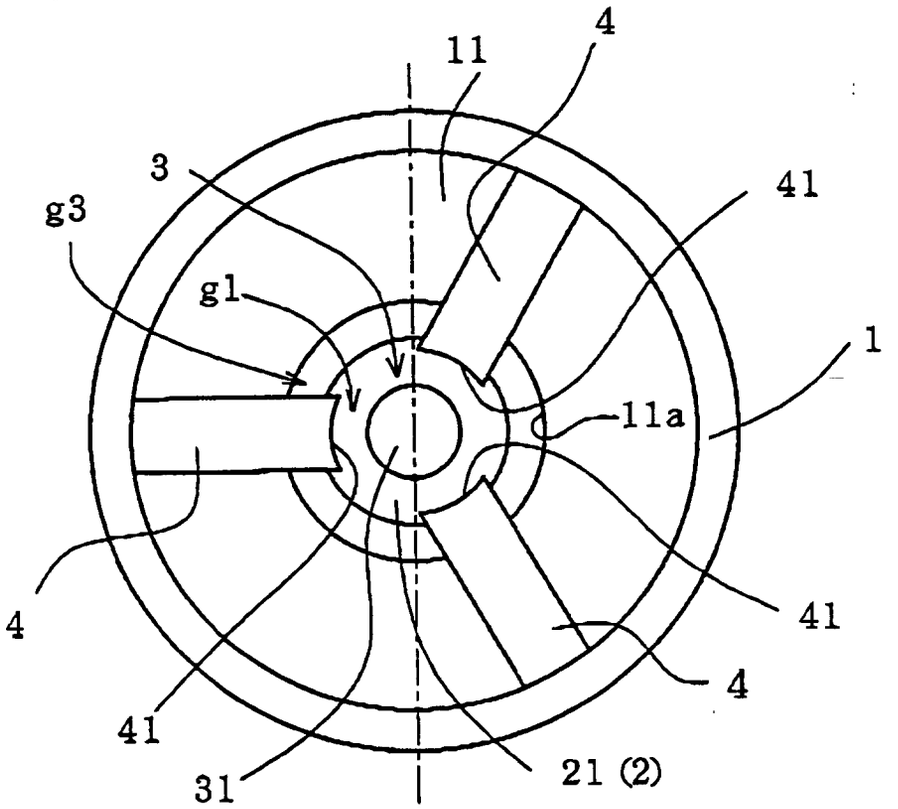
4
11
3
41
g3
g1
1
11a
4
41
4
41
31
21 (2)

Fig. 3B

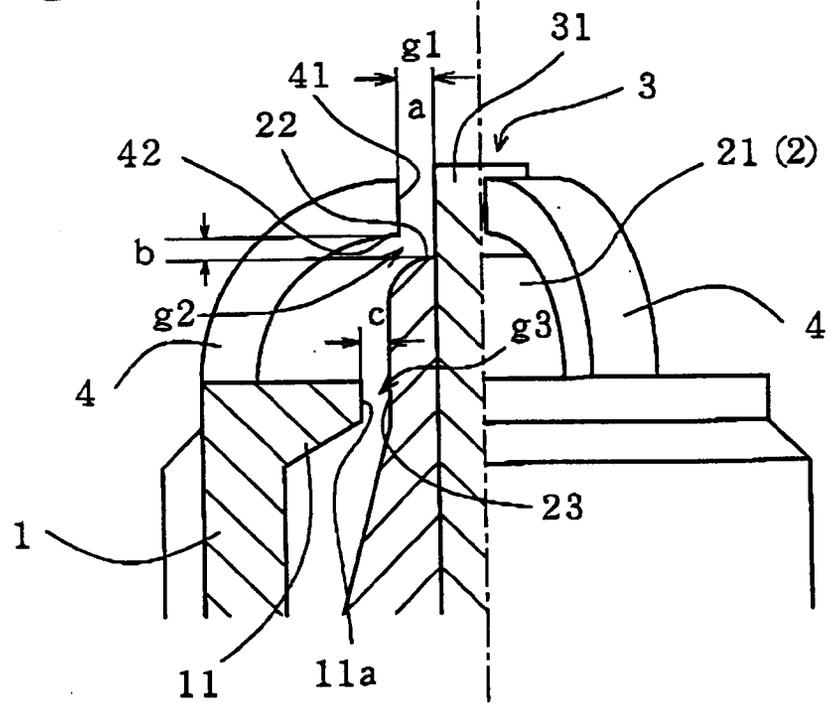
31
g1
41
a
3
22
42
21 (2)
b
g2
c
g3
4
4
23
1
11
11a

Fig. 4

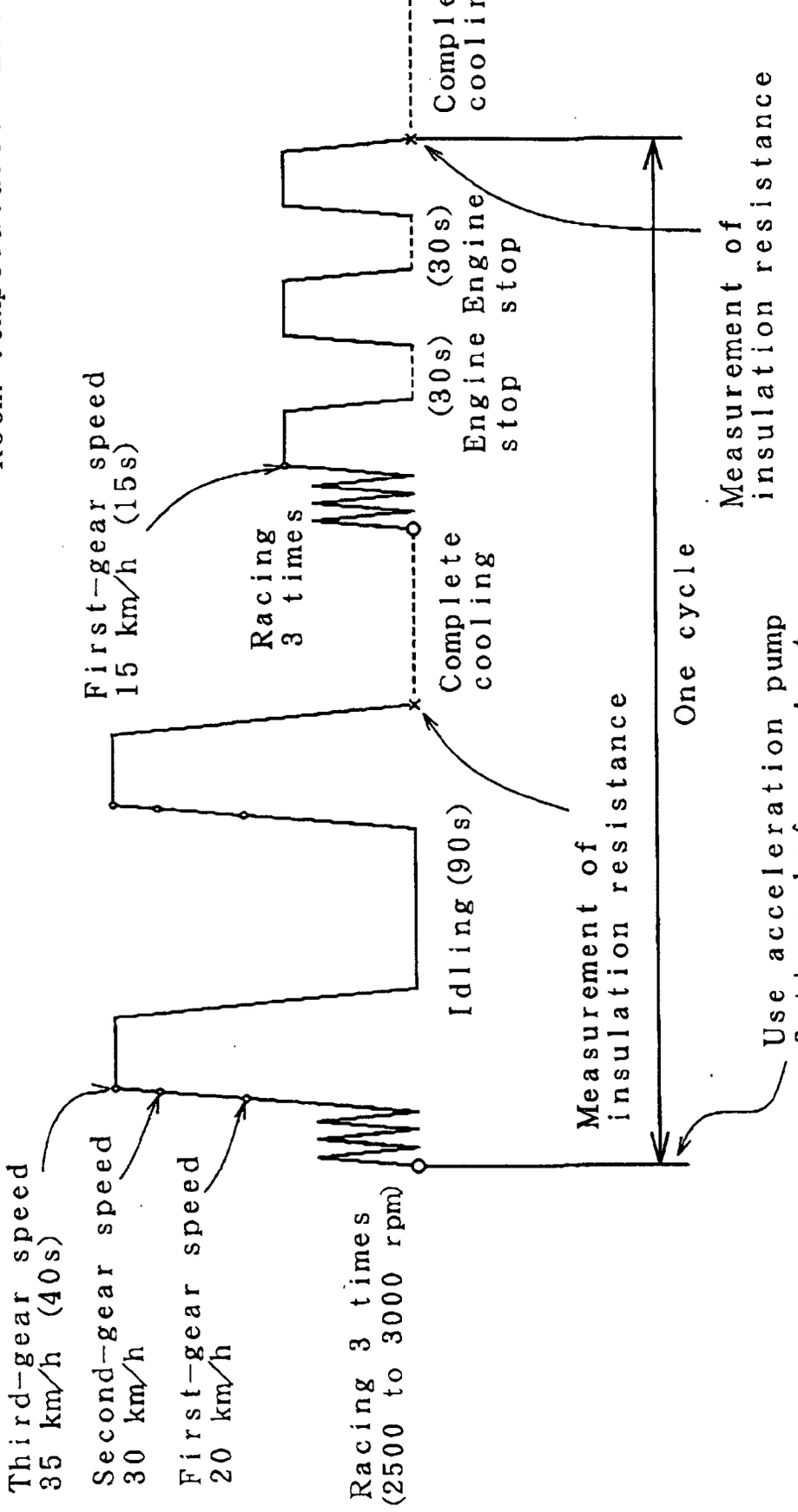
Room temperature: −20℃
Third-gear speed
35 km/h (40s)
Second-gear speed
30 km/h
First-gear speed
20 km/h
Racing 3 times
(2500 to 3000 rpm)
Idling (90s)
First-gear speed
15 km/h (15s)
Racing
3 times
Complete
cooling
Measurement of
insulation resistance
One cycle
(30s)
Engine
stop
(30s)
Engine
stop
Complete
cooling
Measurement of
insulation resistance
Use acceleration pump
3 times before start

Fig. 5

Sample No.	amount of the auxiliary gap g_3 (c : mm)	c / a	Testcycle number possible to start the engine (1 5 10 15 20)
* 1	0. 3	0. 3	
2	0. 4	0. 4	
3	0. 8	0. 8	
4	1. 0	1. 0	
5	1. 2	1. 2	
6	1. 3	1. 3	
* 7	1. 4	1. 4	
* 8	1. 6	1. 6	

(No. 1, 7 and 8 are comparable samples.)

the amount (a) of first gap g_1 =1. 0mm

the amount (b) of second gap g_2 =0. 5mm

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Fig. 6

Sample No.	amount of the second gap g_2 (b : mm)	amount of the first gap g_1 (a : mm)	b / a	Testcycle number possible to start the engine 0 5 10
* 1 1	0. 4	0. 5	0. 80	
1 2	0. 4	0. 7	0. 57	
* 1 3	0. 2	1. 0	0. 2	
1 4	0. 4	1. 0	0. 40	
1 5	0. 6	1. 0	0. 60	
1 6	0. 8	1. 0	0. 80	
1 7	1. 0	1. 0	1. 00	
* 1 8	1. 4	1. 0	1. 40	
* 1 9	0. 1	1. 2	0. 08	
2 0	0. 3	1. 2	0. 25	
2 1	0. 6	1. 2	0. 50	
* 2 2	0. 6	1. 4	0. 43	

(No. 11, 13, 18, 19 and 22 are cmparable samples.)

the amount (c) of auxiliary gap g_3 =0.6mm

Fig. 7

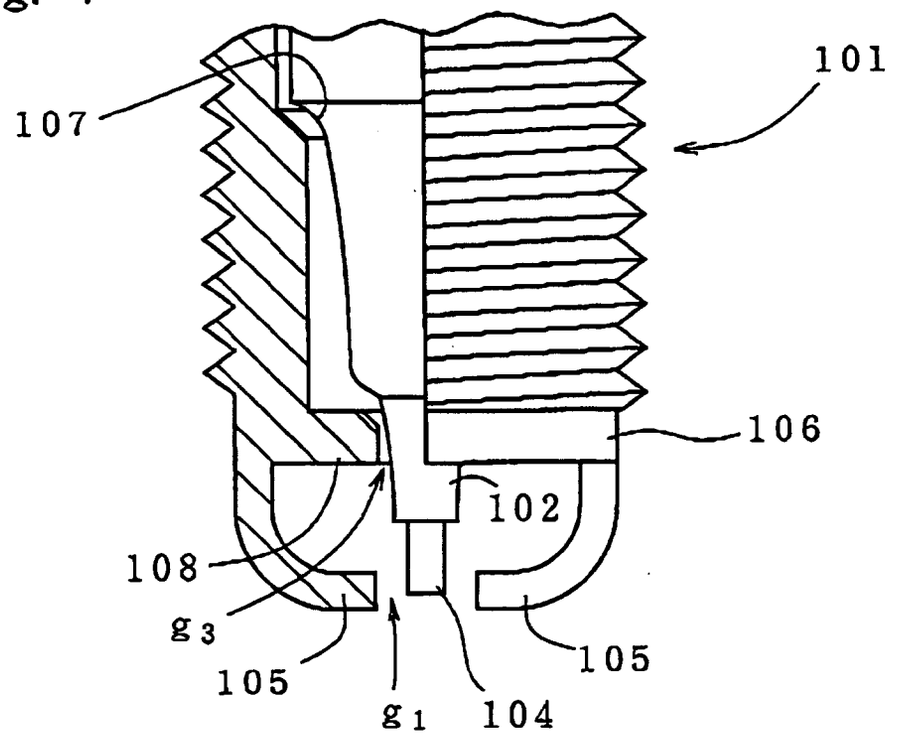
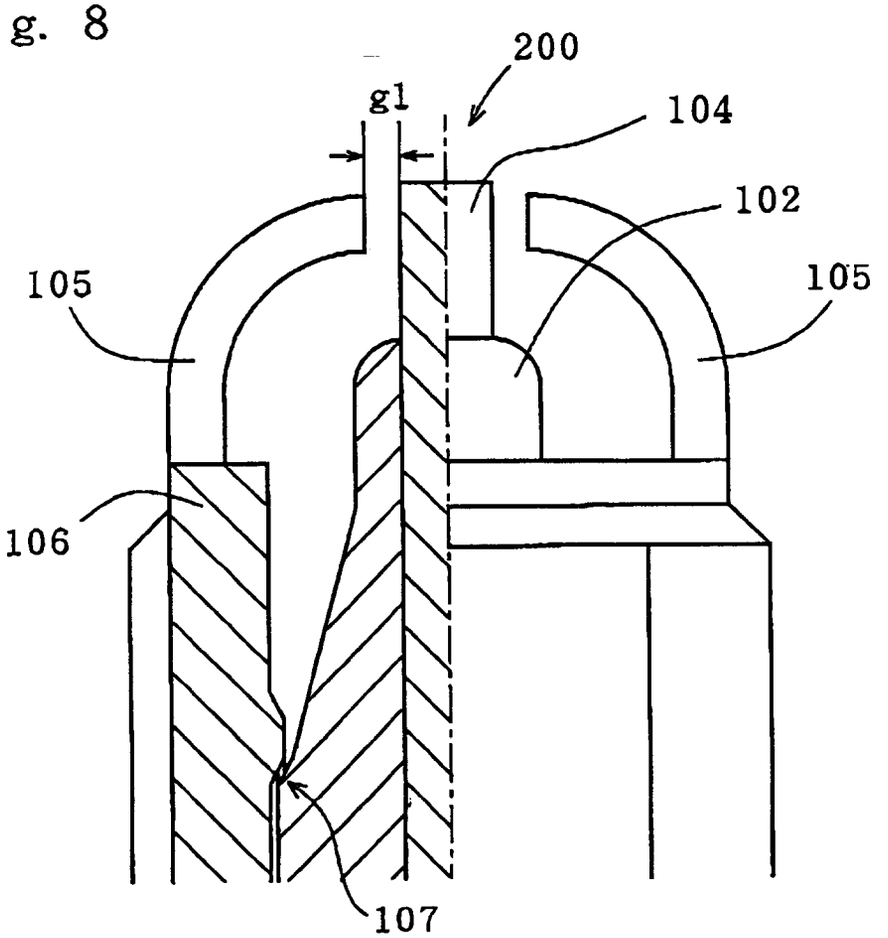

101
107
106
102
108
g_3
105
105
g_1
104

Fig. 8


200
g1
104
102
105
105
106
107

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 2882

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.6)
X	EP-A-0 554 852 (BERU WERK RUPRECHT GMBH CO A) 11 August 1993 * column 4, line 53 - column 5, line 49; figures 2,4 *	1-5	H01T13/46
D,A	US-A-4 289 990 (MAYUMI KAZUHISA ET AL) 15 September 1981		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

H01T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 September 1996	Bijn, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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