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(54) **Spark Plug and ignition system for use with internal combustion engine**

Zündkerze und Zündanordnung zur Anwendung in einem Verbrennungsmotor

Bougie d'allumage et système d'allumage pour utilisation dans un moteur à combustion interne

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- **PATENT ABSTRACTS OF JAPAN vol. 012, no. 281 (E-641), 2 August 1988 (1988-08-02) & JP 63 058910 A (NIPPON DENSO CO LTD), 14 March 1988 (1988-03-14)**

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Description

[0001] The present invention relates to a spark plug for use with an internal combustion engine and to an ignition system for use with an internal combustion engine having the spark plugs.

[0002] As shown in FIG. 11 of the accompanying drawings, an ignition system for use with an automotive internal combustion engine having spark plugs has conventionally employed a distributor. In an ignition system 249 of FIG. 11, an ignition coil 251 includes a primary coil 252, which receives electricity from a battery 256 via an ignition switch 257 and is connected to an igniter 254, and a secondary coil 253, which is connected to a distributor 250. When an electronic control unit 255 issues a break instruction signal to the igniter 254 at a predetermined firing timing, the igniter 254 causes a contactless switch unit to operate so as to interrupt current flowing to the primary coil 252. As a result, a high-voltage current is induced in the secondary coil 253. The distributor 250 distributes the induced current to spark plugs 100 through high-tension cables C.

[0003] However, recently, the above-described distributor ignition system has been replaced by a full-transistor type coil-on-plug ignition system (hereinafter referred to as a "DLI" (Distributor-Less Ignition) system). The DLI system features easy control of ignition timing and does not require maintenance of contacts. In the DLI system, an ignition coil is mounted directly on each spark plug. A control unit interrupts current flowing to the primary coil of the ignition coil of each spark plug at a predetermined timing to thereby fire the spark plug. Since ignition coils are mounted directly on the respective spark plugs, high-tension cables are not required.

[0004] Conventionally, in order to improve resistance to spark consumption of a spark plug, a chip of Pt (platinum) serving as a spark portion is formed at one end of an electrode of the spark plug. However, since Pt is expensive and the melting point thereof is approximately 1769°C indicating that resistance to spark consumption of Pt is insufficient, use of Ir (iridium), which has a melting point of approximately 2454°C, as material for the chip has been proposed. However, a spark portion of Ir produces a volatile oxide at a temperature of 900°C to 1000°C, indicating a tendency to be consumed within this temperature range.

[0005] In a spark plug having a chip of an Ir-based material as a spark portion, employment of the above-mentioned DLI system may have a significantly adverse effect on durability of the spark portion. Specifically, spark discharge of a spark plug is generally classified, according to form, into glow discharge and arc discharge. A glow discharge occurs, for example, when the impedance of a power source (hereinafter referred to as a "power-source impedance") is relatively high. Since a discharge current is relatively weak, the glow discharge causes a less severe temperature increase and less consumption of the spark portion. By contrast, an arc discharge often occurs when a power-source impedance is relatively low. Accordingly, a strong discharge current tends to flow, causing a considerable temperature increase in the spark portion with a resultant advancement of consumption of the spark portion. Therefore, from the viewpoint of suppression of consumption of the spark portion, glow discharge is desirably dominant in a spark discharge.

[0006] In the distributor ignition system, the power-source impedance is high because of the electric resistances of a contact gap and a high-tension cable. Accordingly, glow discharge is dominant in a spark discharge. However, in the DLI system, the power-source impedance is low, since the electric resistances of a contact gap and a high-tension cable are not present. Accordingly, depending on the material used for an electrode, the rate of transition from glow discharge to arc discharge increases in a spark discharge, potentially causing consumption of the electrode. According to a study conducted by the inventors of the present invention, a spark portion of an Ir-based material exhibits a particularly high rate of transition from glow discharge to arc discharge, potentially shortening spark plug life. This tendency is further accelerated by consumption of the spark portion caused by volatilization through oxidation.

[0007] Further, Japanese Patent Application Laid-Open No. 7-50192 (USP 5,514,929) which is considered to represent the closest prior art describes that when a spark plug with a tip mainly formed of Ir is used in a gas engine, the energy of induced discharge can be decreased by use of a resistor having a resistance not less than 50 kΩ but not greater than 200 kΩ. However, although such a gas engine would not have a problem in relation to ignitability even when the discharge energy decreases, a gasoline engine would have a problem in relation to ignitability when the discharge energy decreases.

[0008] A first object of the present invention is to provide a spark plug in which an arc discharge becomes unlikely to occur in spite of a spark portion being formed from an Ir-based metal, to thereby suppress consumption of an electrode and deterioration of ignitability.

[0009] A second object of the present invention is to provide an ignition system for use with an internal combustion engine having the spark plugs.

[0010] To achieve the first object, the present invention provides a spark plug comprising: a center electrode; an insulator which surrounds said center electrode; a metallic shell which surrounds said insulator; a ground electrode which faces said center electrode; a spark portion formed from a metal which contains not less than 60% by weight Ir fixedly attached to at least either one of said center electrode and said ground electrode to thereby define a spark discharge gap, a metallic terminal fixedly attached into one end portion of a through-hole formed axially in the insulator, the center electrode being fixedly attached into the other end portion of the through-hole; and a resistor disposed within the through-hole and between the metallic terminal and the center electrode characterised in that said resistor has an electric resistance of not less than 10 kΩ but not greater than 25 kΩ.

[0011] To achieve the second object, the present invention provides an ignition system for use with an internal combustion engine comprising a spark plug and a coil unit, according to the features of claim 7.

[0012] The spark plug comprises a center electrode; an insulator which surrounds the center electrode; a metallic shell which surrounds the insulator; a ground electrode which faces the center electrode; and a spark portion which is fixedly attached to at least either one of the center electrode and the ground electrode to thereby define a spark discharge gap. The spark portion is formed from a metal which contains not less than 60% by weight Ir. The spark plug further comprises a metallic terminal fixedly attached into one end portion of a through-hole formed axially in the insulator, the center electrode being fixedly attached into the other end portion of the through-hole.

[0013] The coil unit comprises a casing attached to the spark plug; and an ignition coil accommodated within the casing and connected to the metallic terminal of the spark plug in order to apply a high voltage to the spark plug for effecting an electrical discharge.

[0014] The ignition system further comprises a resistance portion disposed between the ignition coil and the center electrode so as to establish an electric resistance of not less than 10 kΩ but not greater than 25 kΩ between the ignition coil and the center electrode.

[0015] When the spark portion is formed from an Ir-based metal, the metal must contain Ir in an amount of not less than 60% by weight; otherwise, the high melting point of Ir fails to lead to sufficient improvement in resistance to spark consumption of the spark portion. However, as described previously, in the DLI system, a high Ir content of the spark portion tends to cause transition to a strong-current discharge, such as an arc discharge. As a result, the temperature of the spark portion increases to such a level that an Ir component volatilizes through oxidation, so that the spark portion is consumed accordingly.

[0016] The present inventors conducted extensive studies and, as a result, found that even in the DLI system a spark plug whose spark portion is of the above-described Ir-based metal (hereinafter may be referred to as an "Ir-type plug") stably maintains an electrical discharge with a relatively weak current, such as a glow discharge, through establishment of an electric resistance of not less than 10 kΩ (corresponding to a power-source impedance) between the ignition coil and the center electrode. On the basis of this finding, the present invention has been achieved. Through establishment of such an electric resistance, even when the Ir-type plugs are employed in the DLI system, transition to a strong-current discharge, such as an arc discharge, becomes unlikely to occur. Thus, even at high-speed or heavy-load operation, consumption of the spark portion caused by volatilization of Ir through oxidation can be suppressed, thereby extending spark plug life. Notably, electric resistance as measured between the ignition coil and the center electrode is preferably not less than 15 kΩ. However, if the electric resistance is in excess of 25 kΩ, ignitability may be impaired.

[0017] In order to establish an electric resistance of not less than 10 kΩ but not greater than 25 kΩ between the ignition coil and the center electrode, there may be utilized a resistor incorporated in a spark plug and adapted to reduce radio noise. In this case, the electric resistance of the resistor may be increased such that an electric resistance of not less than 10 kΩ (preferably not less than 15 kΩ) but not greater than 25 kΩ is established between the metallic terminal and the center electrode. When the resistor is not incorporated as in the case of an inexpensive, popular spark plug, a resistance portion, such as a resistor, may be provided in the coil unit such that an electric resistance of the above-mentioned range is established between the ignition coil and the center electrode.

[0018] In a spark plug, as the diameter of an end portion of the center electrode decreases, the volume of the end portion decreases. As a result, the end portion of the center electrode absorbs less heat from ignited flame, thereby improving ignitability. In the spark plug or ignition system of the present invention, in which the spark portion of the above-described Ir-based metal is formed at an end portion of the center electrode, the diameter of the end portion is preferably adjusted to not greater than 1.1 mm. By rendering the diameter of the end portion not greater than 1.1 mm, ignitability is improved significantly. More preferably, the diameter of the end portion is adjusted to 0.3 mm to 0.8 mm. By rendering the diameter of the end portion not greater than 0.8 mm, ignitability is further improved. When the diameter of the end portion becomes less than 0.3 mm, the temperature of the spark portion tends to increase due to spark concentration. As a result, the spark portion tends to be consumed due to volatilization of Ir through oxidation.

[0019] Generally, in a spark plug, the metallic shell surrounds the insulator. When the surface of the insulator becomes contaminated due to, for example, soot or fuel adhesion, a spark occurs between the inner surface of the metallic shell and the outer surface of the insulator, potentially hindering a normal generation of electrical discharge across a spark discharge gap. Decreasing the spark discharge gap is an effective way to maintain normal electrical discharge across the gap when the surface of the insulator becomes contaminated. In order to maintain resistance to contamination of the spark plug, the spark discharge gap is preferably set to not greater than 1.2 mm, more preferably not greater than 0.8 mm. In order to prevent the occurrence of a short circuit across the gap, the spark discharge gap is preferably set to not less than 0.3 mm.

[0020] Embodiments of the invention will be further described by way of example only with reference to the accompanying drawings, in which:

FIG. 1 is a longitudinal, partially sectional view of a spark plug according to an embodiment of the present invention;
FIG. 2 is an enlarged sectional view of portions of the spark plug of FIG. 1 located in the vicinity of a spark discharge gap;
FIG. 3 is a circuit diagram showing an ignition system example employing the spark plugs of FIG. 1;
FIG. 4 is a schematic front view showing the ignition system of FIG. 3 mounted on an engine;
FIG. 5 is a graph showing the results of a test for a gap-increasing behavior conducted on the spark plugs of FIG. 1;
FIG. 6A is a graph showing the waveform of one electrical discharge;
FIG. 6B is a graph showing the waveform of another electrical discharge;
FIG. 7 is a graph showing the effects of spark gap and electric resistance on the frequency of transition from glow discharge to arc discharge;
FIG. 8 is a graph showing the frequency of transition from glow discharge to arc discharge as measured with respect to the ignition system of FIG. 3 and an ignition system of FIG. 11;
FIG. 9 is a graph showing the relationship between a consumed volume of an electrodc and an electrode diameter;
FIG. 10 is a graph showing the behavior of gap increase with operating hours;
FIG. 11 is a circuit diagram showing a distributor ignition system;
FIG. 12 is a graph showing the relationship between the number of durability cycles and a spark gap; and
FIG. 13 is a graph showing the relationship between resistance and ignitable limit.

[0021] Embodiments of the present invention will next be described in detail with reference to the drawings.

[0022] FIG. 1 shows a spark plug 100, into which a resistor is incorporated, according to an embodiment of the present invention. The spark plug 100 includes a cylindrical metallic shell 1; an insulator 2, which is fitted into the metallic shell 1 such that a tip end portion is projected from the metallic shell 1; a center electrode 3, which is provided within the insulator 2 such that a tip end is projected from the insulator 2; and a ground electrode 4, which is disposed such that one end is connected to the metallic shell 1, and the other end faces the tip end of the center electrode 3. As shown in FIG. 2, a spark portion 32 is formed on the ground electrode 4 in such a manner as to face a spark portion 31 of the center electrode 3. The facing spark portions 31 and 32 define a spark discharge gap g therebetween.

[0023] The insulator 2 is formed from a ceramic sintered body, such as alumina or aluminum nitride. The metallic shell 1 is formed from, for example, low-carbon steel and serves as the housing of the spark plug 100. A screw portion 7 is formed on the outer surface of the metallic shell 1 and is adapted to attach the spark plug 100 to an unillustrated engine block. The designation of the screw portion 7 is, for example, M14S. Length L_1 between an open end from which the center electrode 3 is projected and the rear end of the insulator 2 (the term "rear" refers to the upper side of FIG. 1) is, for example, 58.5 mm.

[0024] Body portions 3a and 4a (FIG. 2) of the center electrode 3 and the ground electrode 4, respectively, are formed from an Ni alloy (e.g., Inconel, Trademark). The spark portions 31 and 32 are formed from a metal that contains Ir in an amount of not less than 60% by weight.

[0025] As shown in FIG. 2, the body portion 3a of the center electrode 3 is tapered such that the diameter is decreased toward the tip end, and the face of the tip end is finished to a flat surface. A disk chip of an alloy, serving as the spark portion 31, is fixedly attached onto the end face of the body portion 3a through circumferential welding along the boundary between the disk chip and the body portion 3a. As a result of this welding, a weld zone W is formed along the boundary. Specific examples of this welding include laser welding, electron beam welding, and resistance welding. The spark portion 32 is formed in the following manner. A disk chip is positioned on the ground electrode 4 so as to be aligned with the facing spark portion 31. A weld zone W is formed along the boundary between the disk chip and the ground electrode 4 through welding as in the case of the spark portion 31, thereby fixedly attaching the disk chip onto the ground electrode 4. These chips may be formed from, for example, a fused material obtained by mixing components of an alloy in predetermined proportions and melting the resultant mixture, or a sintered material obtained by compacting and sintering an alloy powder or a mixture of powders of metal components of predetermined proportions.

[0026] Examples of alloy to be used as material for the above-mentioned chips are as follows:

[0027] (1) An alloy which contains Ir as a main component and Rh in an amount of 3% by weight to 40% by weight. Through use of the alloy, consumption of the spark portion, which would otherwise result from volatilization of Ir through oxidation at high temperature, is effectively suppressed, thereby realizing a spark plug having excellent durability.

[0028] When the Rh content of the alloy becomes less than 3% by weight, the effect of suppressing volatilization-through-oxidation of Ir becomes insufficient. As a result, the spark portion tends to be consumed, causing impairment in spark plug durability. When the Rh content of the alloy becomes 40% by weight or higher, the melting point of the alloy starts to decrease, with the result that in some cases, the durability of the spark plug starts to decrease. Thus, the Rh content of the alloy is 3% by weight to 50% by weight (excluded), preferably 7% by weight to 30% by weight, more preferably 15% by weight to 25% by weight, most preferably 18% by weight to 22% by weight.

[0029] (2) An alloy which contains Ir as a main component and Pt in an amount of 1% by weight to 20% by weight.

Through use of the alloy, consumption of the spark portion, which would otherwise result from volatilization of Ir through oxidation at high temperature, is effectively suppressed, thereby realizing a spark plug having excellent durability. Notably, when the Pt content of the alloy becomes less than 1% by weight, the effect of suppressing volatilization-through-oxidation of Ir becomes insufficient. As a result, the spark portion tends to be consumed, causing impairment in spark plug durability. When the Pt content of the alloy becomes 20% by weight or higher, the melting point of the alloy lowers, causing impairment in spark plug durability.

[0030] A material for the chip (spark portion) may contain an oxide or composite oxide of a metallic element belonging to group 3A (so-called rare-earth metals) or group 4A (Ti, Zr, and Hf) of the periodic table in an amount of 0.1 % by weight to 15% by weight. Through addition of such an oxide, consumption of the spark portion, which would otherwise result from volatilization of Ir through oxidation, is more effectively suppressed. Accordingly, when such an oxide is added to the material for the chip, a metallic component of the material may be elemental Ir, as well as the Ir alloy described above in (1) or (2). When the oxide content of the material is less than 0.1% by weight, the addition of such an oxide fails to sufficiently yield the effect of suppressing volatilization-through-oxidation of Ir. When the oxide content of the material is in excess of 15% by weight, resistance to thermal shock of the chip is impaired. As a result, when, for example, the chip is welded to the electrode, the chip may crack. Notably, Y_2O_3 is preferred as the above-mentioned oxide. Further, La_2O_3, ThO_2, or ZrO_2, for example, may also be preferred.

[0031] The diameter δ of the spark portion 31, i.e., the diameter δ of the end portion of the center electrode 3, is not greater than 1.1 mm, preferably 0.3 mm to 0.8 mm. A dimension γ of the spark discharge gap g is not greater than 1.2 mm, preferably 0.3 mm to 1.1 mm, more preferably 0.6 mm to 0.9 mm. Either the spark portion 31 or the spark portion 32 may be omitted. In this case, the spark discharge gap g is defined by the spark portion 31 and the ground electrode 4 or by the spark portion 32 and the center electrode 3.

[0032] Referring back to FIG. 1, in the spark plug 100, a through-hole 6 is formed axially in the insulator 2. A metallic terminal 13 is fixedly inserted into one end portion of the through-hole 6, while the center electrode 3 is fixedly inserted into the other end portion of the through-hole 6. A resistor 15 is disposed within the through-hole 6 and between the metallic terminal 13 and the center electrode 3. The opposite ends of the resistor 15 are connected to the center electrode 3 and the metallic terminal 13 via conductive glass seal layers 16 and 17, respectively.

[0033] The metallic terminal 13 is formed from, for example, low-carbon steel. An Ni plating layer (for example, 5 µm thick) is formed on the surface of the metallic terminal 13 against corrosion. The metallic terminal 13 includes a seal portion 13c (a tip end portion), a terminal portion 13a projected from the rear end of the insulator 2, and a bar portion 13b extending between the terminal portion 13a and the seal portion 13c. The seal portion 13c assumes an axially extending cylindrical form and is inserted into the conductive glass seal layer 17, so that the space between the seal portion 13c and the wall of the through-hole 6 is sealed by the seal layer 17.

[0034] The resistor 15 is fabricated by the steps of: mixing glass powder, ceramic powder, metal powder (which contains, as a main component, a metal selected singly or in combination from the group consisting of Zn, Sb, Sn, Ag, and Ni), nonmetallic conductive substance powder (for example, amorphous carbon (carbon black) or graphite), and an organic binder in predetermined proportions; and sintering the resulting mixture by a known method, for example, by use of a hot press. The composition and dimensions of the resistor 15 are adjusted so as to establish an electric resistance of not less than 10 kΩ (preferably not less than 15 kΩ) but not greater than 25 kΩ as measured between the metallic terminal 13 and the center electrode 3.

[0035] The conductive glass seal layers 16 and 17 are formed from glass mixed with metal powder, which contains, as a main component, metal selected singly or in combination from among metals including Cu and Fe. The metal content of the resulting mixture is 35% by weight to 70% by weight. Notably, the conductive glass seal layers 16 and 17 may contain semiconducting inorganic compound powder, such as TiO_2, in an appropriate amount.

[0036] FIG. 3 shows an ignition system employing the spark plugs 100. As shown in FIG. 3, an ignition system 150 does not employ a distributor, but includes ignition coils 51 adapted to directly apply voltage to the corresponding spark plugs 100. Each of the ignition coils 51 includes a primary coil 52 adapted to receive electricity from a battery 156 and connected to an igniter 154. The ignition coil 51 further includes a secondary coil 53 connected to the corresponding spark plug 100. The igniter 154 includes contactless switches, such as transistors, corresponding to the ignition coils 51. Upon reception of a break instruction signal issued from the corresponding output port of an electronic control unit 155, each of the contactless switches comes into a broken or open state. A diode 5 la is provided between each ignition coil 51 and each spark plug 100 in order to prevent re-electrification of the spark plug 100, which would otherwise occur when the corresponding contactless switch returns to a conducting state from the open state.

[0037] As shown in FIG. 4, when an internal combustion engine 180 assumes the form of a multiple-cylinder gasoline engine, the spark plug 100 is mounted, by means of the mounting screw portion 7, on each of cylinders 181 such that the spark discharge gap g is located within a combustion chamber. Coil units 50 are attached to the spark plugs 100 in one-to-one correspondence and are connected to the electronic control unit 155. The coil unit 50 includes a casing 60 fitted to the rear end portion of the spark plug 100. The casing accommodates the ignition coil 51 and the igniter 154. The ignition coil 51 is electrically connected to the metallic terminal 13 of the spark plug 100 by means of an unillustrated terminal portion of the coil unit 50.

[0038] In the spark plug 100, the resistor 15 may be omitted, and the metallic terminal 13 and the center electrode 3 may be connected by means of, for example, a single conductive glass seal layer. In the spark plug 100 provided with the resistor 15 and the conductive glass seal layer 16 disposed between the resistor 15 and the center electrode 3, the conductive glass seal layer 16 may be omitted. In this case, a resistor may be disposed, for example, between the ignition coil 51 and the terminal portion of the coil unit 50 so as to establish an electric resistance of not less than 10 kΩ (preferably not less than 15 kΩ) but not greater than 25 kΩ between the ignition coil 51 and the center electrode 3 of the spark plug 100.

EXAMPLE

[0039] In order to confirm the effect of the above-described spark plug 100 and ignition system 150, the following experiments were conducted. Fine glass powder (average grain size 80 µm; 30 parts by weight), ZrO_2 powder (average grain size 3 µm; 60 parts by weight) serving as ceramic powder, Al powder (average grain size 20-50 µm; 1 part by weight) serving as metal powder, carbon black (2-9 parts by weight) serving as nonmetallic conductive substance powder, and dextrin (3 parts by weight) serving as an organic binder were mixed. The resulting mixture was wetmilled in a ball mill while water was used as solvent. The resulting mixture was dried, obtaining a preliminary material. Coarse glass powder (average grain size 250 µm) was mixed with the preliminary material in an amount of 400 parts by weight per 100 parts by weight of the preliminary material, obtaining a resistor composition in the form of powder. A material for the glass powder was borosilicate lithium glass, which was obtained by the steps of mixing 50 parts by weight SiO_2, 29 parts by weight B_2O_5, 4 parts by weight Li_2O, and 17 parts by weight BaO and melting the resulting mixture and whose softening temperature was 585°C.

[0040] Next, the resistors 15 were formed from the resistor composition powder by use of a hot press. Through use of the resistor 15, there were manufactured various samples of the spark plug 100 of FIG. 1 into which the resistor 15 is incorporated. In the samples, the center electrode 3 was formed from an Ni alloy (INCONEL 600) and had an axial length of 20.7 mm and a cross-sectional diameter of 2.6 mm. The diameter of the through-hole 6 formed in the insulator 2 (substantially identical to the cross-sectional diameter of the resistor 15) was 4.0 mm. Hot pressing was performed at a heating temperature of 900°C and an applied pressure of 100 kg/cm^2. Conductive glass powder employed was a mixture of conductive powders of, for example, Cu, Fe, Sn, and TiO_2, and borosilicate calcium glass powder (the conductive powders are contained in an amount of approximately 50% by weight). In the obtained spark plug samples, the length L2 of the resistor 15 was 7.0 mm to 15.0 mm. The electric resistance R_k as measured between the center electrode 3 and the metallic terminal 13 was adjusted to 5 kΩ to 30 kΩ through adjustment of the length L2 and composition of the resistor 15.

[0041] The spark portions 31 and 32 were fabricated in the following manner. Ir and Pt of predetermined amounts were mixed and melted, thereby obtaining an alloy which contains Pt in an amount of 5% by weight and Ir as the balance. The alloy was formed into disk chips having a diameter of 0.2 mm to 1.6 mm and a thickness of 0.6 mm. By use of the chips, the spark portions 31 and 32 of the spark plug 100 shown in FIGS. 1 and 2 were formed (in other words, spark plug samples having spark portions of various sizes ranging from 0.2 mm to 1.6 mm were fabricated). The spark discharge gap g was initially set to various values of γ ranging from 0.4 mm to 1.4 mm.

[0042] The thus-obtained spark plug samples were mounted on a 6-cylinder gasoline engine (engine capacity 1998 cc). The engine was continuously operated for up to 800 hours at an engine speed of 5600 rpm (at a center electrode temperature of approximately 780°C) while throttles were completely opened. After engine operation was halted, an increase in the spark discharge gap g was measured. The test employed the ignition system shown in FIG. 3. The ignition system effected an electrical discharge under the following conditions: the polarity of the center electrode was negative; the peak value of the secondary current was 70 mA; and the discharge energy was 65 mJ. During discharge, current and voltage waveforms were recorded by use of an oscilloscope. For comparison, a similar test was conducted by use of the distributor ignition system (DIS) shown in FIG. 11. In this case, the electric resistance as measured between the ignition coil 251 and the far end of each high-tension cable C was set to 5 kΩ to 10 kΩ.

[0043] FIG. 5 shows the results of a test for a gap-increasing behavior (i.e., electrode consumption). The test was conducted under the following conditions: the electric resistance Rk was 5 kΩ; the end diameter 6 of the center electrode was 1.0 mm; and the initial spark discharge gap y was 0.5, 0.8, and 1.1 mm. As seen from FIG. 5, spark plugs having an initial spark gap γ of 0.8 or 1.1 mm cause a large amount of electrode consumption, so that the gap increases considerably. Since it was considered that the form of an electrical discharge was responsible for a difference in gap increase, waveforms of discharge were observed. FIG. 6A shows the waveform of an electrical discharge at a γ value of 0.5 mm, and FIG. 6B shows the waveform of an electrical discharge at a γ value of 0.8 mm. In FIG. 6A, current shows a relatively stable behavior, implying that glow discharge is dominant. By contrast, in FIG. 6B, current frequently shows an abruptly increasing behavior, implying the occurrence of arc discharge. Particularly, it is conceivable that a strong current flows at the moment of transition from glow discharge to arc discharge. Conceivably, in the case of FIG.

6B, the frequency of transition from glow discharge to arc discharge within a single discharge cycle increases; hence, an instantaneous flow of a strong current occurs frequently, resulting in a significant consumption of the electrode.

[0044] In FIG. 6A, in a region where glow discharge conceivably occurs, while the variation in the current falls within a range of 5 mA, the absolute value of current gradually decreases toward the end of a discharge cycle; i.e., a background current level is formed. In the present example, one discharge cycle is divided in 0.5 ms units, and an average value in each division is calculated to thereby obtain the above-mentioned background current level. When current which is at least 20 mA greater than the obtained background current level flows, it is interpreted as transition from glow discharge to arc discharge. The number (frequency) of transitions within a single discharge cycle was counted to thereby evaluate transition susceptibility.

[0045] FIG. 7 shows result of a test in which the frequency of transition from glow discharge to arc discharge was measured while the electronic resistance R_k and the initial spark discharge gap γ were changed. Specifically, a first group of spark plugs in which the end diameter δ of the center electrode was set to 1.0 mm and the electronic resistance R_k was set to 5 kΩ were manufactured, while the initial spark discharge gap y was changed in the range of 0.4 - 1.4 mm. A second group of spark plugs in which the end diameter δ of the center electrode was set to 1.0 mm and the electronic resistance R_k was set to 10 kΩ were manufactured, while the initial spark discharge gap γ was changed in the range of 0.4 - 1.4 mm. Similarly, a third group of spark plugs in which the end diameter δ of the center electrode was set to 1.0 mm and the electronic resistance R_k was set to 15 kΩ were manufactured, while the initial spark discharge gap y was changed in the range of 0.4 - 1.4 mm. Subsequently, the frequency of transition from glow discharge to arc discharge was measured for each of the thus-manufactured spark plugs. In FIG. 7, the frequency of transition is represented in the form of index when the frequency of transition as measured at a γ value of 0.8 mm and an R_k value of 5 kΩ is taken as 100. Table 1 shows measurements.

Table 1

Spark discharge gap (mm)	Frequency of transition (index)		
	R_k = 5 kΩ	R_k = 10 kΩ	R_k = 15 kΩ
0.4	8	4	3
0.5	33	17	12
0.6	67	33	23
0.7	83	42	29
0.8	100	50	35
0.9	83	42	29
1	67	33	23
1.1	33	17	12
1.2	8	4	3
1.3	0	0	0
1.4	0	0	0

[0046] As seen from FIG. 7, as the electric resistance R_k increases, the frequency of transition decreases. Meanwhile, in order to examine resistance to contamination of spark plugs, a predelivery durability test as specified in JIS D1606 was conducted on three groups of spark plugs, in which the first group of spark plugs were manufactured such that their electric resistances were set to 10 kΩ and their initial spark discharge gaps γ were set to 0.8 mm, the second group of spark plugs were manufactured such that their electric resistances were set to 10 kΩ and their initial spark discharge gaps γ were set to 1.2 mm, and the third group of spark plugs were manufactured such that their electric resistances were set to 10 kΩ and their initial spark discharge gaps γ were set to 1.3 mm. The spark plugs were mounted on the engine of a test car, and the test car underwent a test run. While a travelling pattern specified in JIS D1606 is taken as one cycle, there was counted the number of cycles until a rough idle occurred or until the insulation resistance of the spark plug sample decreased to 1 MΩ or less (the number of durability cycles). Resistance to contamination was evaluated in terms of the number of durability cycles. The test results are shown in FIG. 12. As seen from FIG. 12, when the value of γ exceeds 1.2 mm, the number of durability cycles begins to decrease, indicating impairment in resistance to contamination.

[0047] FIG. 8 shows results of a test performed for each of the DLI system of FIG. 3 and the DIS system of FIG. 11, in which the frequency of transition from glow discharge to arc discharge was measured while the electric resistance

R_k was changed. That is, for each of the DLI system of FIG. 3 and the DIS system of FIG. 11, spark plugs having initial spark discharge gap γ of 0.8 mm were manufactured such that the spark plugs had respective R_k values with in the range of 5 kΩ - 30 kΩ. The frequency of transition was measured for each of the thus-manufactured spark plugs. Table 2 shows measurements.

Table 2

Electric resistance (kΩ)	Frequency of transition (index)	
	DIS	DLI
5.00	63.5	100
7.50	45.8	70
10.00	30.6	50
12.50		40
15.00		35
20.00		32
22.50		30
25		28
27.5		26
30		24

[0048] As seen from FIG. 8, even when the DLI system is employed, the frequency of transition from glow discharge to arc discharge decreases with the electric resistance R_k. At an electric resistance R_k of not less than 10 kΩ, the frequency of transition is suppressed as low as that in the case of the DIS system. Notably, at an electric resistance R_k of not less than 20 kΩ, a decrease in the frequency of transition becomes gradual.

[0049] FIG. 9 shows a consumed volume of a center electrode per spark as measured with respect to spark plugs having various values of end diameter δ of the center electrode after a continuous test operation of 800 hours was completed. This test employed an initial spark discharge gap γ of 1.1 mm and an electric resistance R_k of 5 kΩ. As seen from FIG. 9, an electrode of a smaller diameter is consumed more per spark. Conceivably, this is because an electrode of a smaller diameter increases in temperature more readily and is thus more susceptible to temperature increase effected by glow-to-arc transition. FIG. 10 shows the behavior of gap increase with operating hours (up to 800 hours) as measured with respect to an electric resistance R_k of 5 kΩ, 10 kΩ, and 15 kΩ. This test employed an initial spark discharge gap γ of 0.5 mm and an end diameter δ of 1.0 mm of the center electrode. As seen from FIG. 10, electrode consumption can be suppressed more effectively by increasing the electric resistance R_k to 10 kΩ, and this effect is enhanced by increasing the electric resistance R_k to 15 kΩ.

[0050] FIG. 13 is a graph showing the results of a test performed in order to evaluate the ignitabilty of spark plug samples each manufactured such a manner that the spark discharge gap γ was set to 0.8 mm, the end diameter δ of the center electrode was set to 0.8 mm, and the electric resistance R_k was set to a value in the range of 10 kΩ to 30 kΩ (the values are shown in Table 3). The spark plug samples were mounted on a 6-cylinder gasoline engine of a DOHC lean-burn type (engine capacity 1998 cc). The engine was operated at a boost pressure of 350 mmHg and an engine speed of 2000 rpm (corresponding to a driving speed of 60 km/h), while the air-fuel ratio was changed. An air-fuel ratio at the time when misfire reached 1% was measured as an ignitable limit.

Table 3

Resistance (kΩ)	Air-fuel ratio (A/F)
10	22.2
15	22.2
20	22.1
21	22.07
22	22.03
23	21.98

Table 3 (continued)

Resistance (kΩ)	Air-fuel ratio (A/F)
24	21.92
25	21.85
26	21.77
27	21.69
28	21.6
29	21.5
30	21.4

[0051] From the test results, it is understood that when the resistance becomes equal to or greater than 20 kΩ, the ignitable limit gradually decreases (it becomes impossible to ignite fuel unless the air-fuel ratio is increased) and that the ignitable limit starts to sharply decrease when the resistance exceeds 25 kΩ.

[0052] Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the present invention may be practiced otherwise than as specifically described herein.

Claims

1. A spark plug comprising a center electrode (3), an insulator (2) which surrounds said center electrode (3), a metallic shell (1) which surrounds said insulator (2), a ground electrode (4) which faces said center electrode (3), a spark portion (31, 32) formed from a metal which contains not less than 60% by weight Ir fixedly attached to at least either one of said center electrode (3) and said ground electrode (4) to thereby define a spark discharge gap (g), a metallic terminal (13) fixedly attached into one end portion of a through-hole (6) formed axially in said insulator (2), said center electrode (3) being fixedly attached into the other end portion of the through-hole (6), and a resistor (15) disposed within the through-hole (6) and between said metallic terminal (13) and said center electrode (3), characterized in that
said resistor (15) has an electric resistance of not less than 10 kΩ but not greater than 25 kΩ.

2. A spark plug according to Claim 1, characterized in that the electric resistance betiween said metallic terminal (13) and said center electrode (3) is not less than 15 kΩ.

3. A spark plug according to Claim 1 or 2, characterized in that said spark portion (31, 32) is formed at an end portion of said center electrode (3), and the diameter of the end portion of said center electrode (3) is not greater than 1.1 mm.

4. A spark plug according to Claim 3, characterized in that the diameter of the end portion of said center electrode (3) is adjusted to 0.3 mm to 0.8 mm.

5. A spark plug according to Claim 1, 2, 3 or 4 characterized in that the spark discharge gap (g) is not greater than 1.2 mm.

6. A spark plug according to Claim 5, characterized in that the spark discharge gap (g) is not greater than 0.8 mm.

7. An ignition system for use with an internal combustion engine comprising:

a spark plug (100) having a center electrode (3), an insulator (2) which surrounds the center electrode (3), a metallic shell (1) which surrounds the insulator (2), a ground electrode (4) which faces the center electrode (3), a spark portion formed from a metal which contains not less than 60% by weight Ir (31, 32) fixedly attached to at least either one of the center electrode (3) and the ground electrode (4) to thereby define a spark discharge, and a metallic terminal (13) fixedly attached into one end portion of a through-hole (6) formed axially in.the insulator (2), the center electrode (3) being fixedly attached into the other end portion of the through-hole (6); characterized by further comprising a coil unit (50) having a casing (60) attached to said spark plug (100), an ignition coil (51) accommodated within said casing (60) and connected to the metallic terminal (13) of said spark plug (100) in order to apply a high voltage to said spark plug (100) for effecting an electrical discharge,

wherein a resistance portion is disposed between the ignition coil (51) and the center electrode (3) so as to establish an electric resistance of not less than 10 kΩ but not greater than 25 kΩ between the ignition coil (51) and the center electrode (3).

8. An ignition system for use with an internal combustion engine according to Claim 7, characterized in that said resistance portion establishes an electrical resistance of not less than 15 kΩ between the ignition coil (51) and the center electrode (3).

9. A spark plug according to any one of claims 1 to 6 or an ignition system according to Claim 7 or 8, characterized in that said spark portion (31, 32) is formed from a metal which contains Ir as a main component and Rh in an amount of 3% by weight to 50% by weight (excluded).

10. A spark plug according to any one of claims 1 to 6 or an ignition system according to Claim 7 or 8, characterized in that said spark portion (31, 32) is formed from a metal which contains Ir as a main component and Pt in an amount of 1 % by weight to 20% by weight.

11. A spark plug according to any one of claims 1 to 6 or an ignition system according to any one of Claims 7 - 10, characterized in that the material of said spark portion (31, 32) contains an oxide or composite oxide of a metallic element belonging to group 3A or group 4A of the periodic table in an amount of 0.1% by weight to 15% by weight.

Patentansprüche

1. Zündkerze, umfassend eine Mittelelektrode (3), einen die Mittelelektrode (3) umgebenden Isolator (2), eine den Isolator (2) umgebende Metallhülse (1), eine der Mittelelektrode (3) gegenüberliegende Masseelektrode (4), einen Zündabschnitt (31, 32), der aus einem Metall gebildet ist, welches nicht weniger als 60 Gew.-% Ir enthält, fest an zumindest einer Elektrode von der Mittelelektrode (3) und der Masseelektrode (4) angebracht ist, um eine Funkenentladungsstrecke (g) zu definieren, einen metallischen Anschluß (13), der fest in dem einen Endabschnitt eines axial in dem Isolator (2) ausgebildeten Durchgangslochs (6) angebracht ist, wobei die Mittelelektrode (3) fest in dem anderen Endabschnitt des Durchgangslochs (6) angebracht ist, und ein Widerstand in dem Durchgangsloch (6) zwischen dem metallischen Anschluß (13) und der Mittelelektrode (3) angeordnet ist, **dadurch gekennzeichnet,** daß der Widerstand (15) einen elektrischen Widerstandswert von nicht weniger als 10 kΩ, jedoch nicht mehr als 25 kΩ besitzt.

2. Zündkerze nach Anspruch 1, **dadurch gekennzeichnet,** daß der elektrische Widerstandswert zwischen dem metallischen Anschluß (13) und der Mittelelektrode (3) nicht weniger als 15 kΩ beträgt.

3. Zündkerze nach Anspruch 1 oder 2, **dadurch gekennzeichnet,** daß der Zündabschnitt (31, 32) an einem Endabschnitt der Mittelelektrode (3) ausgebildet ist, und der Durchmesser des Endabschnitts der Mittelelektrode (3) nicht größer als 1,1 mm ist.

4. Zündkerze nach Anspruch 3, **dadurch gekennzeichnet,** daß der Durchmesser des Endabschnitts der Mittelelektrode (3) auf 0,3 mm bis 0,8 mm eingestellt ist.

5. Zündkerze nach Anspruch 1, 2, 3 oder 4, **dadurch gekennzeichnet,** daß die Funkenentladungsstrecke (g) nicht größer als 1,2 mm ist.

6. Zündkerze nach Anspruch 5, **dadurch gekennzeichnet,** daß die Funkenentladungsstrecke (g) nicht größer als 0,8 mm ist.

7. Zündanlage zur Verwendung bei einem Verbrennungsmotor, umfassend:
eine Zündkerze (100), welche aufweist:

eine Mittelelektrode (3), einen die Mittelelektrode (3) umgebenden Isolator (2), eine den Isolator (2) umgebende Metallhülse (1), eine der Mittelelektrode (3) gegenüberliegende Masseelektrode (4), einen Zündabschnitt (31, 32), der aus einem Metall gebildet ist, welcher nicht weniger als 60 Gew.-% Ir enthält, fest an zumindest einer Elektrode von der Mittelelektrode (3) und der Masseelektrode (4) angebracht ist, um eine Funkenentladungsstrecke zu definieren, einen metallischen Anschluß (13), der fest in dem einen Endabschnitt eines axial in dem Isolator (2) ausgebildeten Durchgangslochs (6) angebracht ist, wobei die Mittelelektrode (3) fest in dem anderen Endabschnitt des Durchgangslochs (6) angebracht ist, und ein Widerstand in dem Durchgangsloch (6) zwischen dem metallischen Anschluß (13) und der Mittelelektrode (3) angeordnet ist, **dadurch gekennzeichnet,** daß sie weiterhin aufweist:

eine Spuleneinheit (50), mit einem an der Zündkerze (100) befestigten Gehäuse (60), wobei in dem Gehäuse eine Zündspule (51) aufgenommen ist, welche an dem metallischen Anschluß (13) der Zündkerze (100) angeschlossen ist, um eine Hochspannung an die Zündkerze (100) zum Bewirken einer elektrischen Entladung anzulegen,

wobei ein Widerstandsabschnitt zwischen der Zündspule (51) und der Mittelelektrode (3) angeordnet ist, um einen elektrischen Widerstandswert von nicht weniger als 10 kΩ und nicht mehr als 25 kΩ zwischen der Zündspule (51) und der Mittelelektrode (3) zu schaffen.

8. Zündanlage nach Anspruch 7, **dadurch gekennzeichnet,** daß der Widerstandsabschnitt einen elektrischen Widerstand von nicht weniger als 15 kΩ zwischen der Zündspule und der Mittelelektrode (3) schafft.

9. Zündkerze nach einem der Ansprüche 1 bis 6 oder Zündanlage nach Anspruch 7 oder 8, **dadurch gekennzeichnet,** daß der Zündabschnitt (31, 32) aus einem Metall gebildet ist, welches Ir als Hauptkomponente und außerdem Rh in einer Menge von 3 Gew.-% bis (ausschließlich) 50 Gew.-. % enthält.

10. Zündkerze nach einem der Ansprüche 1 bis 6 oder Zündanlage nach Anspruch 7 oder 8, **dadurch gekennzeichnet,** daß der Zündabschnitt (31, 32) aus einem Metall gebildet ist, welches Ir als Hauptkomponente und Pt in einer Menge von 1 Gew.-% bis 20 Gew.-% enthält.

11. Zündkerze nach einem der Ansprüche 1 bis 6 oder Zündanlage nach Anspruch 7 oder 8, **dadurch gekennzeichnet,** daß das Material des Zündabschnitts (31, 32) ein Oxid oder Komposit-Oxid eines metallischen Elements der Gruppe 3A oder der Gruppe 4A des Periodensystems in einer Menge von 0,1 Gew.-% bis 15 Gew.-% enthält.

Revendications

1. Bougie d'allumage comprenant une électrode centrale (3), un isolant (2) qui entoure ladite électrode centrale (3), une enveloppe métallique (1) qui entoure ledit isolant, une électrode de masse (4) disposée en regard de ladite électrode centrale (3), une partie de décharge d'étincelle (31, 32) en métal ne contenant pas moins de 60% en poids de Ir, assujettie d'une manière fixe à ladite électrode centrale (3) et/ou à ladite électrode de masse (4) pour définir de la sorte un intervalle de décharge (g), une borne métallique (13) assujettie d'une manière fixe dans une première extrémité d'un trou traversant (6) formé axialement dans ledit isolant (2), ladite électrode centrale (3) étant assujettie d'une manière fixe dans l'autre extrémité du trou traversant (6), et une résistance (15) disposée dans le trou traversant (6) et entre ladite borne métallique (13) et ladite électrode centrale (3), caractérisée en ce que

ladite résistance (15) a une valeur de résistance électrique non inférieure à 10 kΩ mais non supérieure à 25 kΩ.

2. Bougie d'allumage selon la revendication 1, caractérisée en ce que la valeur de résistance électrique entre ladite borne métallique (13) et ladite électrode centrale (3) n'est pas inférieure à 15 kΩ.

3. Bougie d'allumage selon la revendication 1 ou 2, caractérisée en ce que ladite partie de décharge d'étincelle (31, 32) est formée à une extrémité de ladite électrode centrale (3), et le diamètre de l'extrémité de ladite électrode centrale (3) n'est pas supérieur à 1,1 mm.

4. Bougie d'allumage selon la revendication 3, caractérisée en ce que le diamètre de l'extrémité de ladite électrode centrale (3) est ajusté entre 0,3 mm et 0,8 mm.

5. Bougie d'allumage selon la revendication 1, 2, 3 ou 4, caractérisée en ce que l'intervalle de décharge (g) n'est pas supérieur à 1,2 mm.

6. Bougie d'allumage selon la revendication 5, caractérisée en ce que l'intervalle de décharge (g) n'est pas supérieur à 0,8 mm.

7. Système d'allumage destiné à être utilisé avec un moteur à combustion interne, comprenant :
une bougie d'allumage (100) ayant une électrode centrale (3), un isolant (2) qui entoure l'électrode centrale (3), une enveloppe métallique (1) qui entoure l'isolant, une électrode de masse (4) disposée en regard de l'électrode centrale (3), une partie de décharge d'étincelle (31, 32) en métal ne contenant pas moins de 60% en poids d'Ir, assujettie d'une manière fixe à l'électrode centrale (3) et/ou à l'électrode de masse (4) pour définir de la sorte un intervalle de décharge, et une borne métallique (13) assujettie d'une manière fixe dans une première extrémité d'un trou traversant (6) formé axialement dans l'isolant (2), l'électrode centrale (3) étant assujettie d'une manière fixe dans l'autre extrémité du trou traversant (6) ; caractérisé en ce qu'il comprend en outre
un système de bobine (50) ayant un boîtier (60) fixé à ladite bougie d'allumage (100), une bobine d'allumage (51) logée dans ledit boîtier (60) et connectée à la borne métallique (13) de ladite bougie d'allumage (100) afin d'appliquer une forte tension à ladite bougie d'allumage (100) pour obtenir une décharge électrique, une partie formant résistance étant disposée entre la bobine d'allumage (51) et l'électrode centrale (3) afin d'établir entre la bobine d'allumage (51) et l'électrode centrale (3) une résistance électrique d'une valeur non inférieure à 10 kΩ mais non supérieure à 25 kΩ.

8. Système d'allumage selon la revendication 7 destiné à être utilisé avec un moteur à combustion interne, caractérisé en ce que ladite partie formant résistance établit entre la bobine d'allumage (51) et l'électrode centrale (3) une résistance électrique d'une valeur non inférieure à 15 kΩ.

9. Bougie d'allumage selon l'une quelconque des revendications 1 à 6 ou système d'allumage selon la revendication 7 ou 8, caractérisé en ce que ladite partie de décharge d'étincelle (31, 32) est en métal principalement composé de Ir et contenant 3% en poids à 50% en poids (exclusivement) de Rh.

10. Bougie d'allumage selon l'une quelconque des revendications 1 à 6 ou système d'allumage selon la revendication 7 ou 8, caractérisé en ce que ladite partie de décharge d'étincelle (31, 32) est en métal principalement composé de Ir et contenant 1% en poids à 20% en poids de Pt.

11. Bougie d'allumage selon l'une quelconque des revendications 1 à 6 ou système d'allumage selon l'une quelconque des revendications 7 à 10, caractérisé que ce que la matière de ladite partie de décharge d'étincelle (31, 32) contient un oxyde ou un oxyde composite d'un élément métallique appartenant au groupe 3A ou au groupe 4A du tableau périodique, à raison de 0,1% en poids à 15% en poids.

FIG. 1

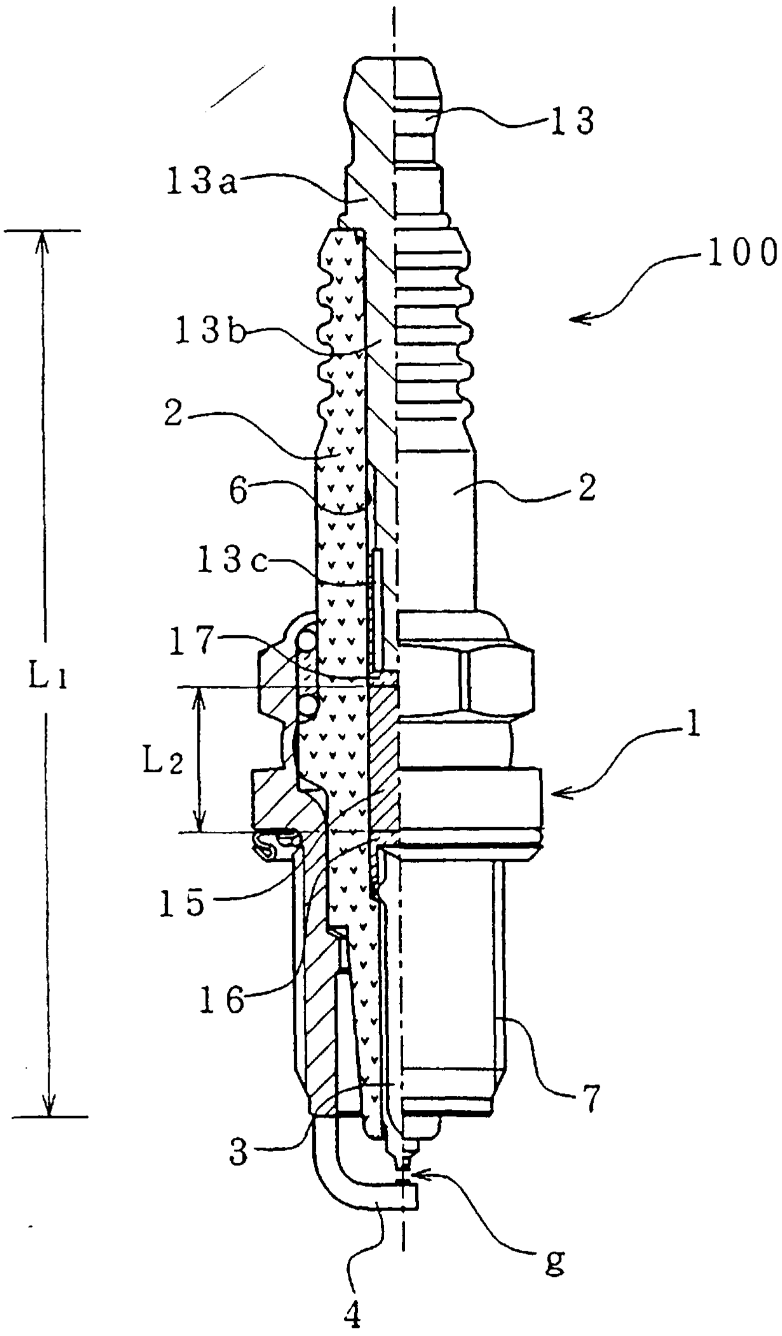
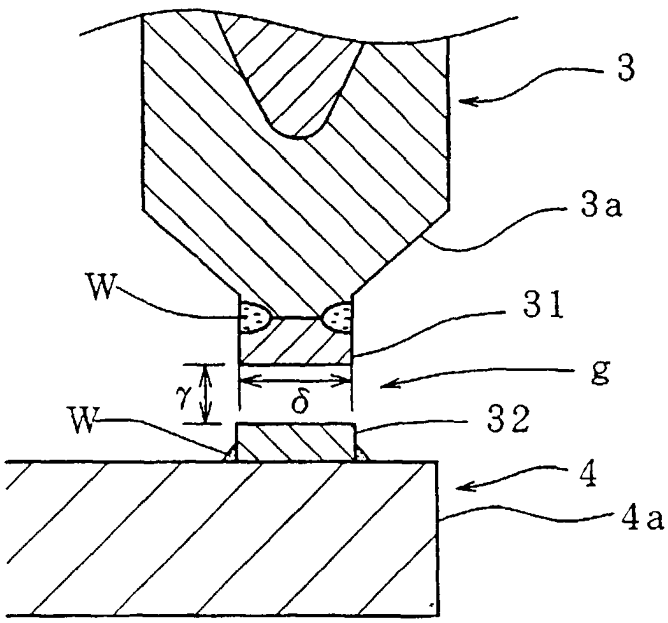


FIG. 2



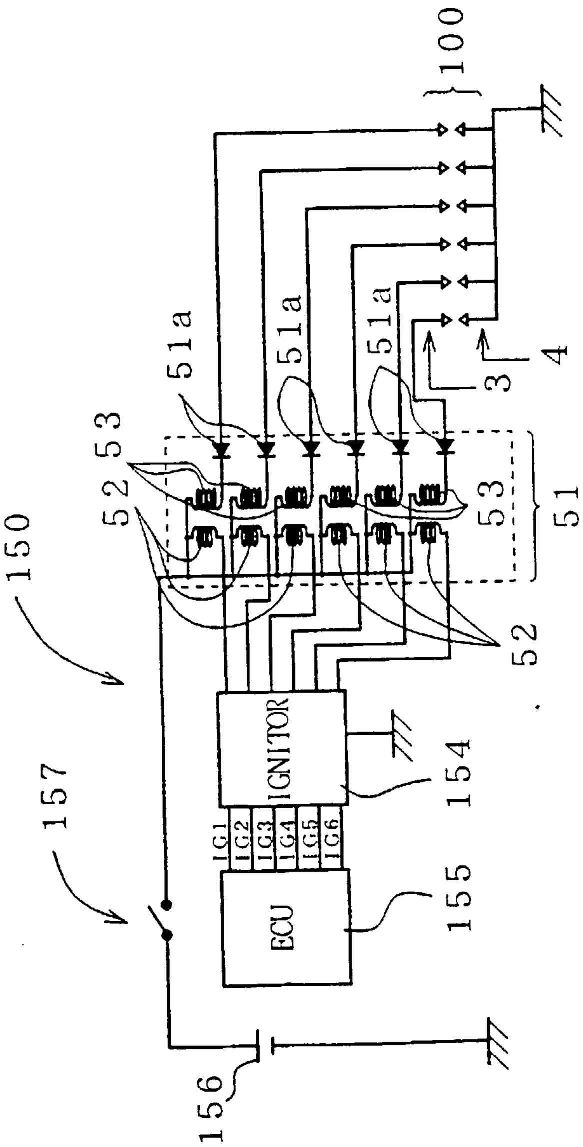

100
51a
51a
51a
53
52
53
51
52
150
3
4
IGNITOR
154
157
IG1
IG2
IG3
IG4
IG5
IG6
ECU
155
156

FIG. 3

FIG. 4

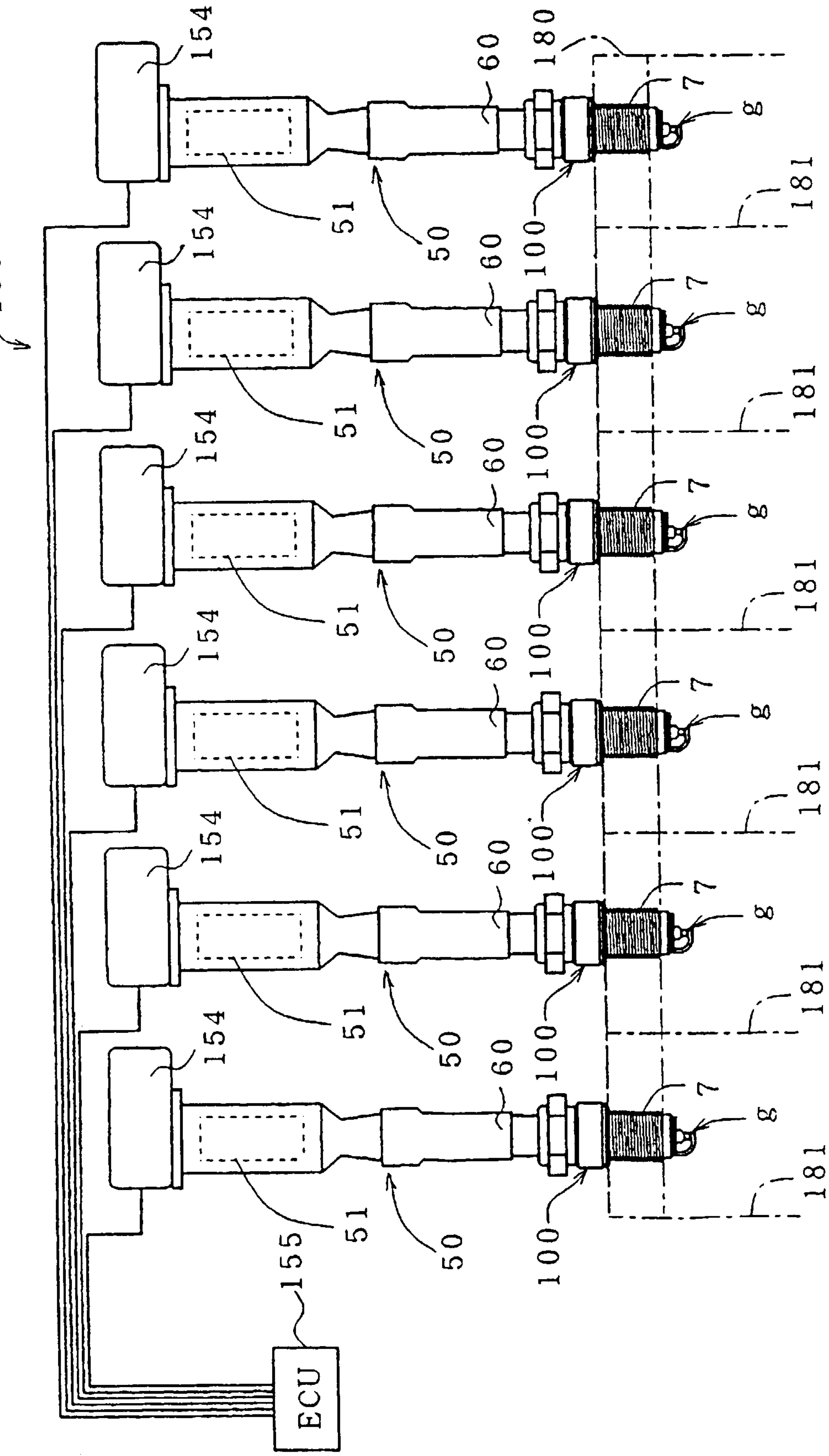


FIG. 5

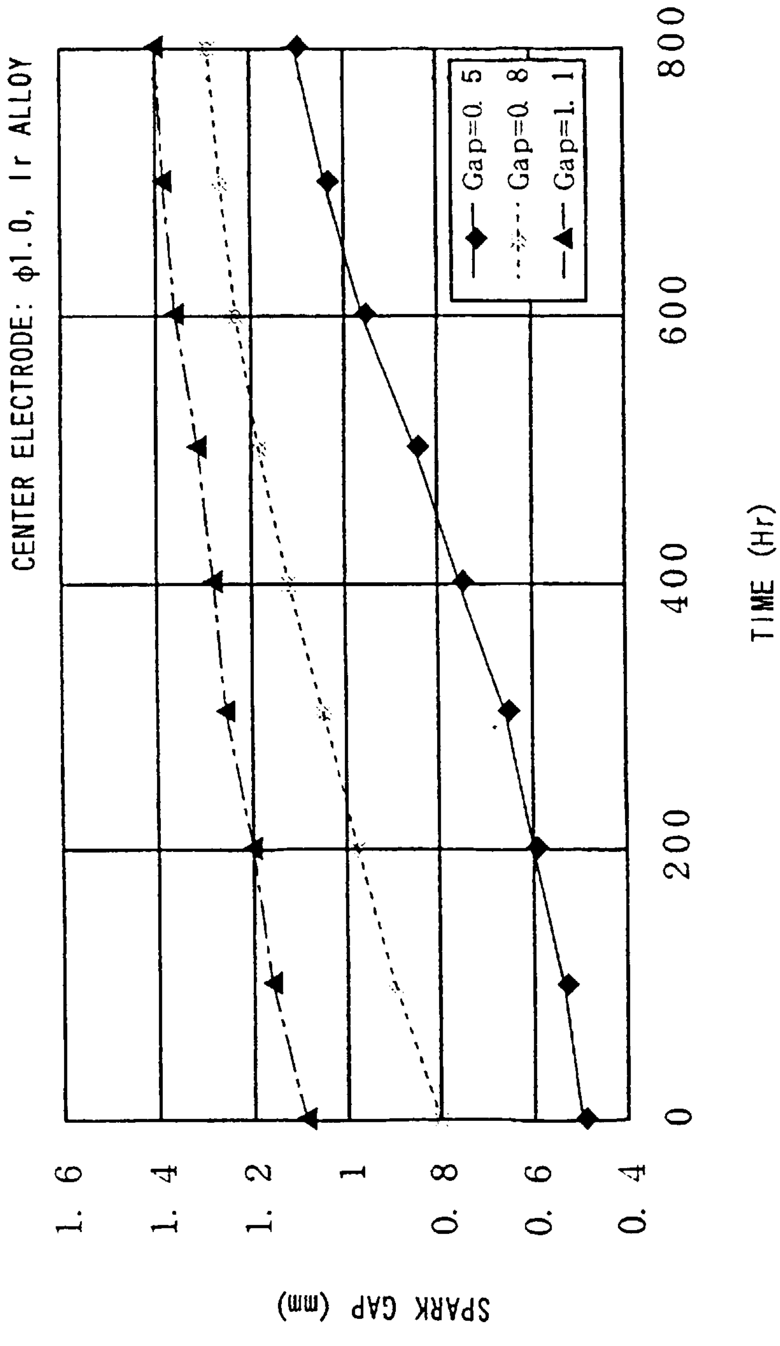

CENTER ELECTRODE: φ1.0, Ir ALLOY
Gap=0.5
Gap=0.8
Gap=1.1
SPARK GAP (mm)
TIME (Hr)
0
200
400
600
800
0.4
0.6
0.8
1
1.2
1.4
1.6

FIG. 6A

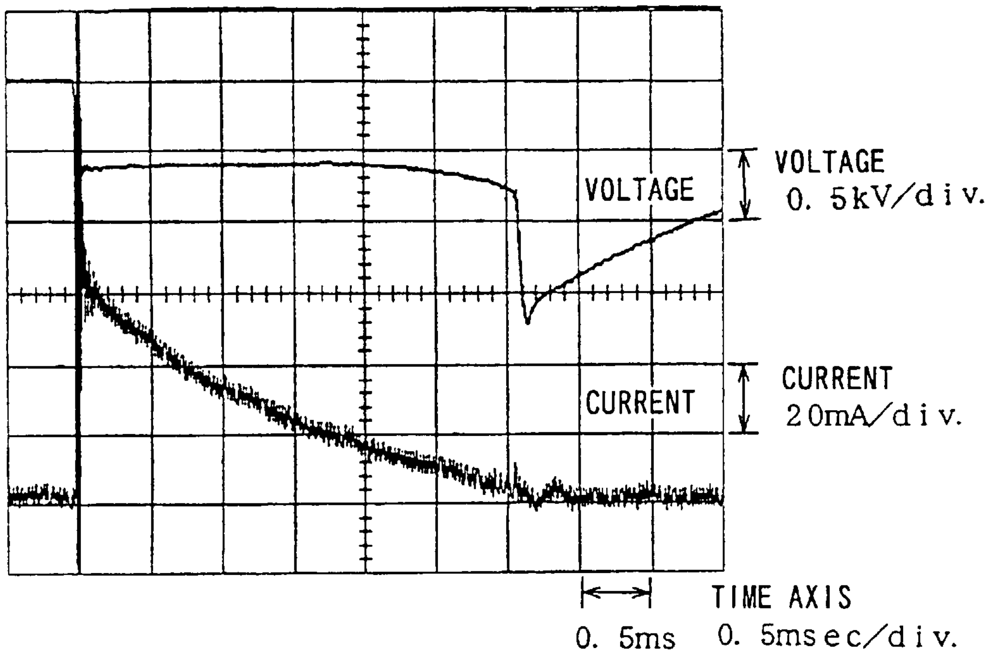

VOLTAGE
VOLTAGE
0. 5kV/div.
CURRENT
CURRENT
20mA/div.
TIME AXIS
0. 5ms
0. 5msec/div.

FIG. 6B

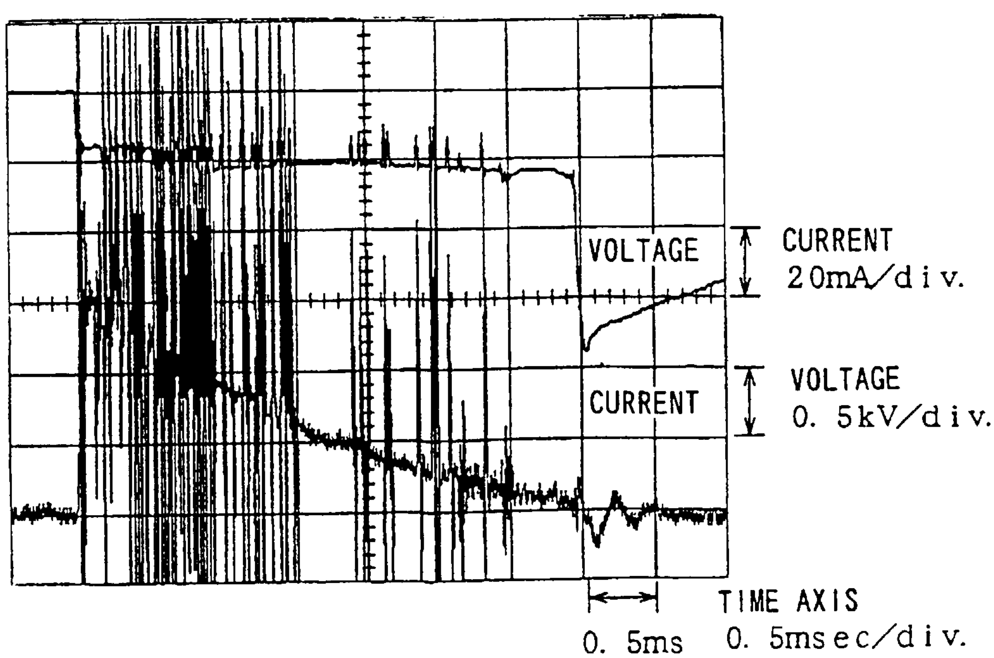

VOLTAGE
CURRENT
20mA/div.
CURRENT
VOLTAGE
0. 5kV/div.
TIME AXIS
0. 5ms
0. 5msec/div.

FIG. 7

CENTER ELECTRODE: φ1.0, Ir ALLOY

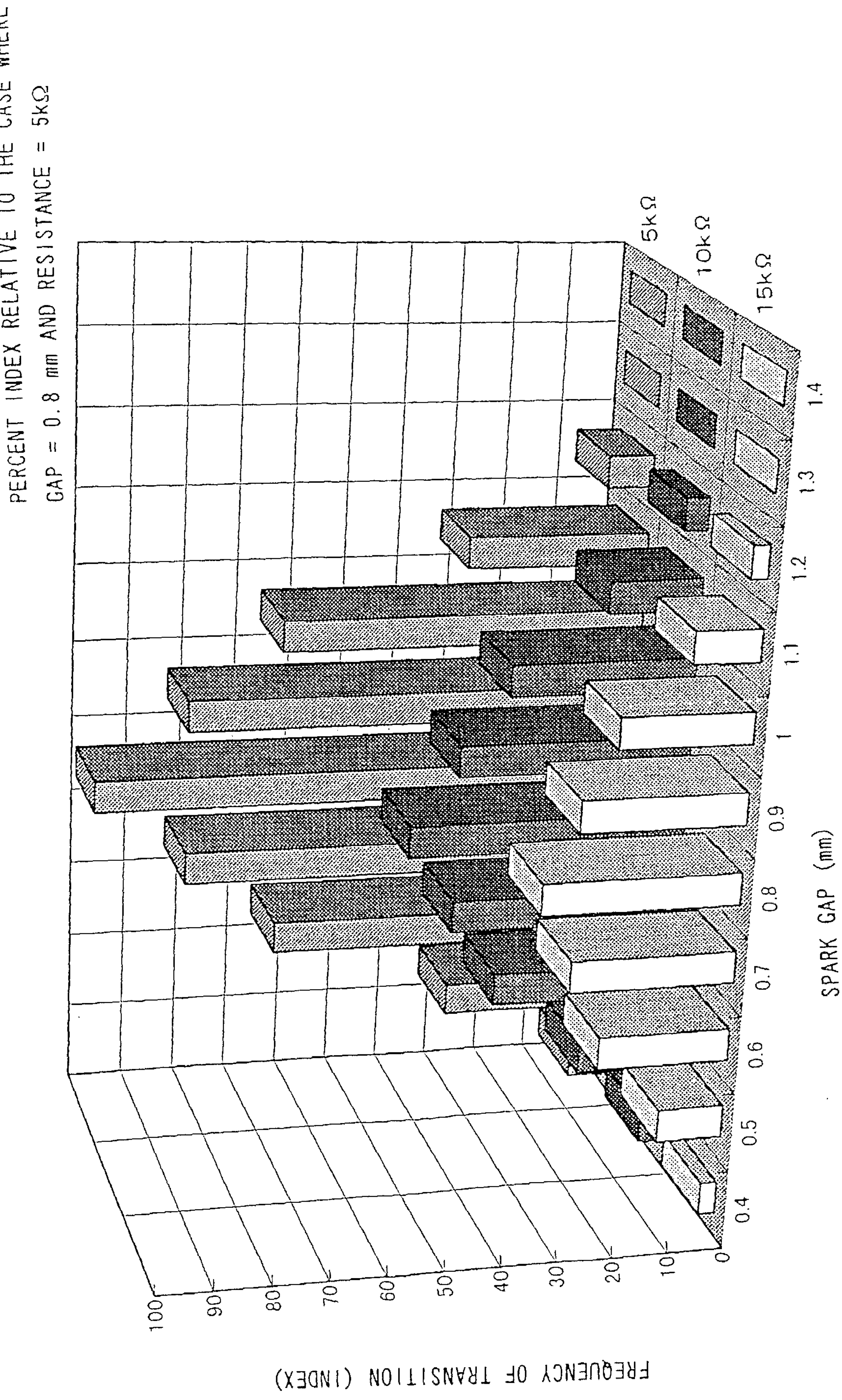


FIG. 8

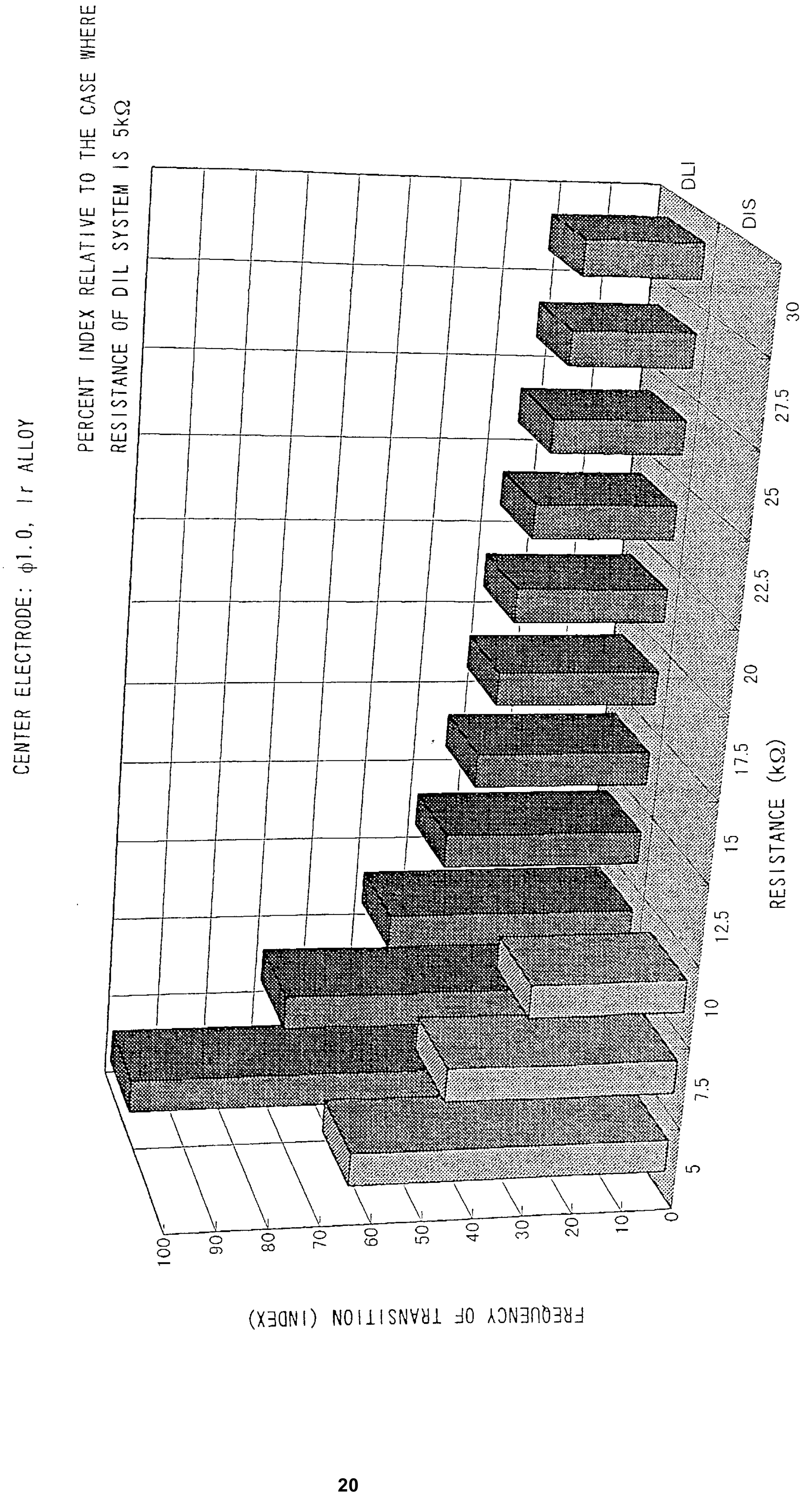

CENTER ELECTRODE: φ1.0, Ir ALLOY
PERCENT INDEX RELATIVE TO THE CASE WHERE
RESISTANCE OF DIL SYSTEM IS 5kΩ
DLI
DIS
FREQUENCY OF TRANSITION (INDEX)
100
90
80
70
60
50
40
30
20
10
0
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30
RESISTANCE (kΩ)

FIG. 9

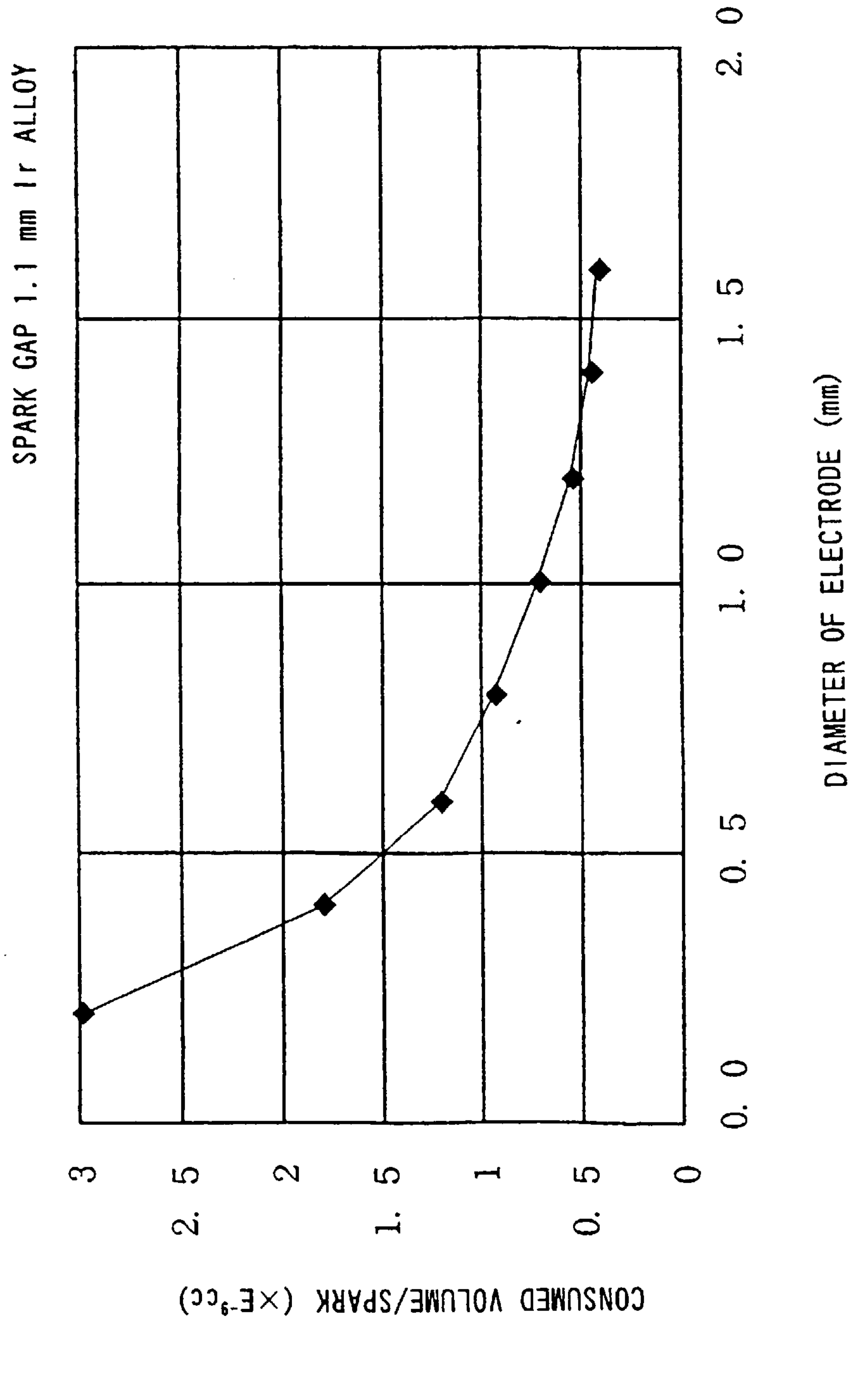

SPARK GAP 1.1 mm Ir ALLOY
CONSUMED VOLUME/SPARK ($\times E^{-9}$cc)
3
2.5
2
1.5
1
0.5
0
0.0
0.5
1.0
1.5
2.0
DIAMETER OF ELECTRODE (mm)

FIG. 10

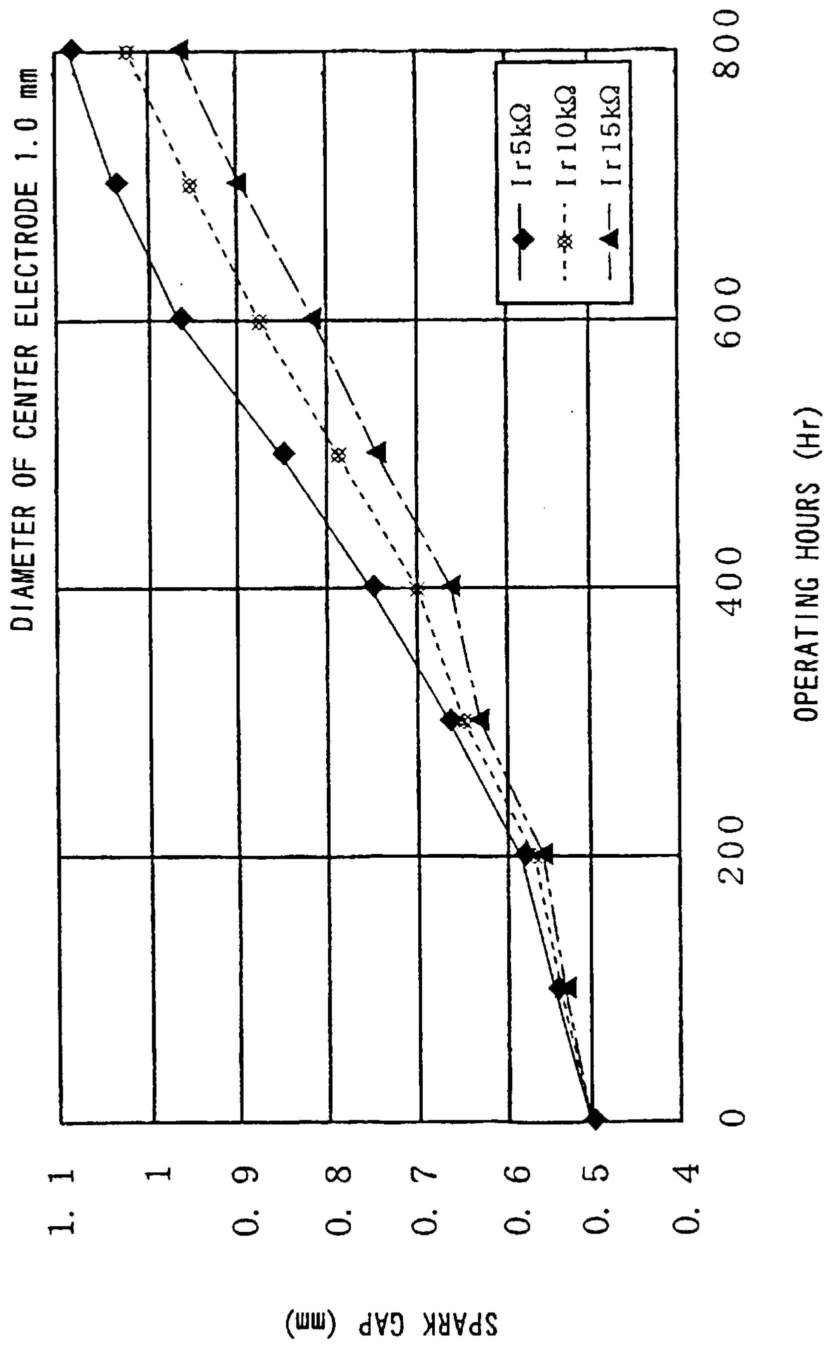

DIAMETER OF CENTER ELECTRODE 1.0 mm
SPARK GAP (mm)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
200
400
600
800
OPERATING HOURS (Hr)
Ir5kΩ
Ir10kΩ
Ir15kΩ

FIG. 11

(PRIOR ART)

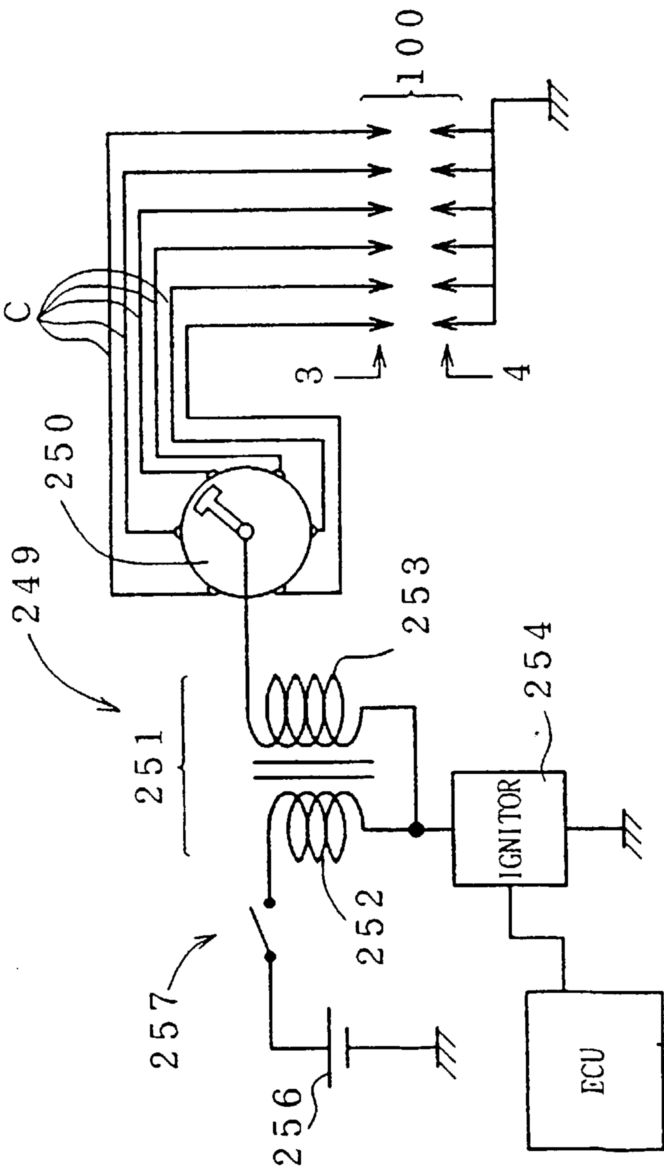


FIG. 12

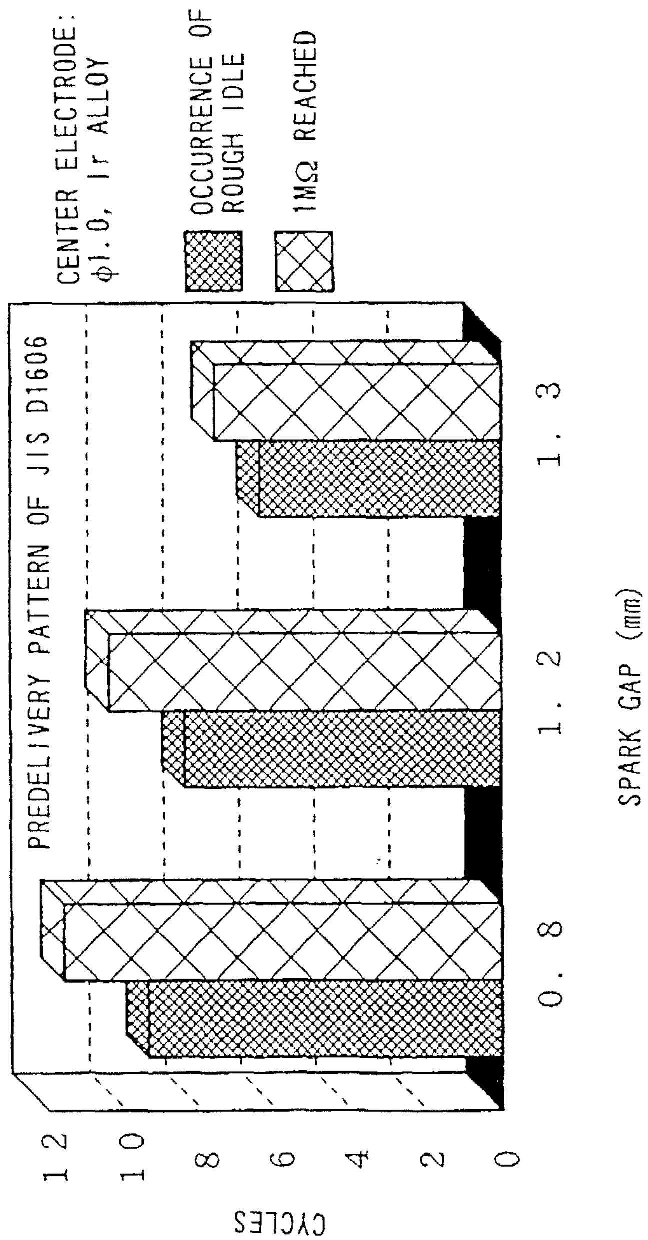
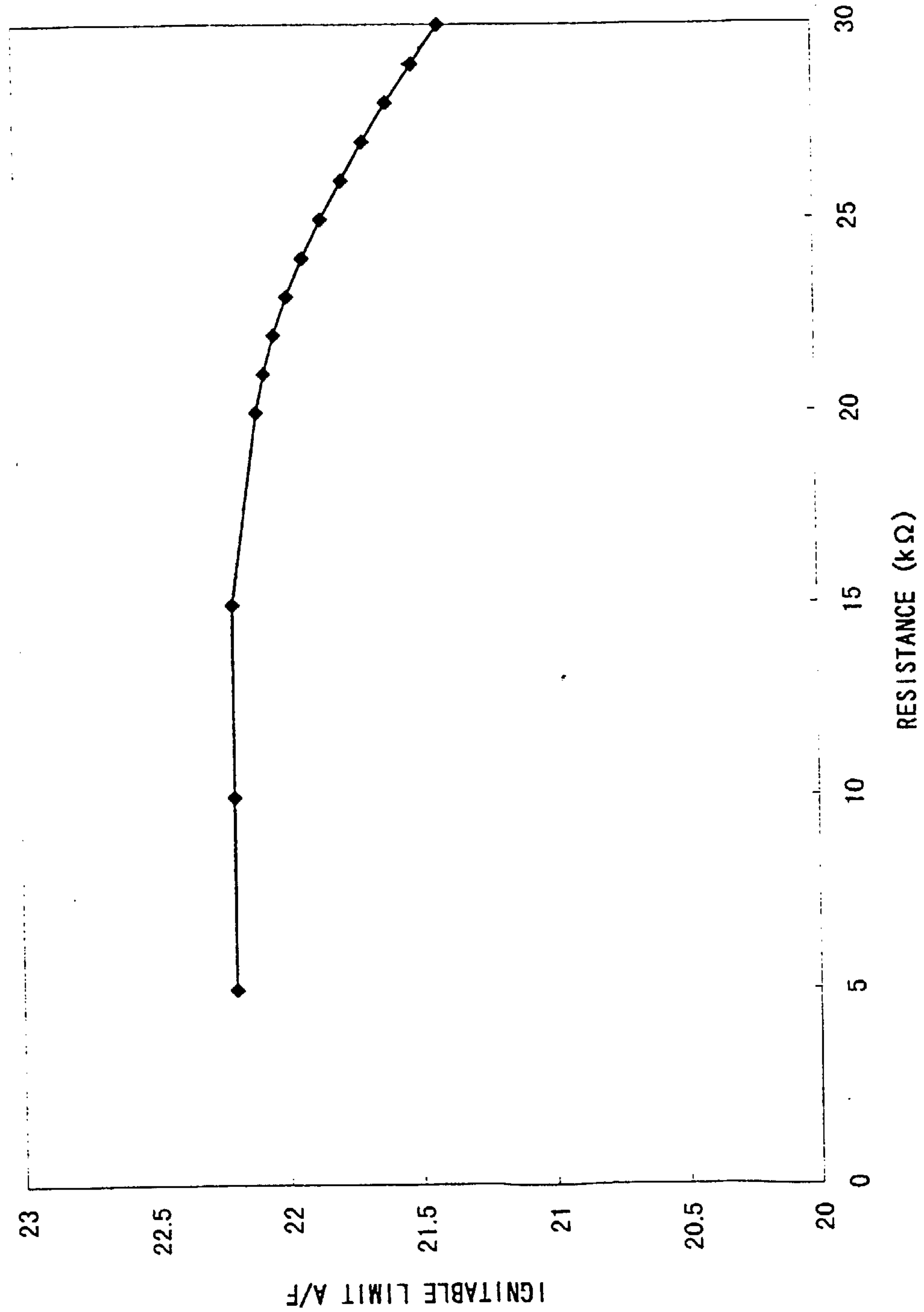

PREDELIVERY PATTERN OF JIS D1606
CENTER ELECTRODE:
φ1.0, Ir ALLOY
OCCURRENCE OF
ROUGH IDLE
1MΩ REACHED
CYCLES
12
10
8
6
4
2
0
0. 8
1. 2
1. 3
SPARK GAP (mm)

FIG. 13


IGNITABLE LIMIT A/F
23
22.5
22
21.5
21
20.5
20
RESISTANCE (kΩ)
0
5
10
15
20
25
30