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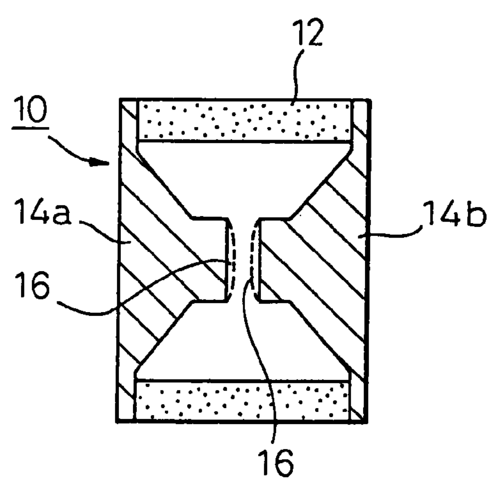
(54) **DISCHARGE TUBE WITH COATED DISCHARGE SURFACE**

(57) A discharge tube 10 including a pair of electrodes 14a, 14b arranged in opposed relation to each other with an insulating member 12 between them is disclosed. In order to provide a discharge tube capable of producing a stable break-down voltage even against a surge voltage with a short rise time, a coating material 16 containing at least one alkali metal salt including potassium bromide, potassium fluoride and sodium fluoride of 0.01 to 60 wgt % is applied on the discharge surfaces of the electrodes 14a, 14b.

Fig. 1



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Description

TECHNICAL FIELD

The present invention relates to a discharge tube suitably used as an arrester or a spark gap for supplying a constant voltage to an ignition plug, a high-voltage discharge lamp or the like, and more particularly relates to a discharge tube with a coating material applied on the discharge surfaces thereof.

BACKGROUND ART

Conventionally known discharge tube devices include an arrester mounted on a commercial power line to equipment for preventing intrusion of a spontaneous surge voltage caused by thunder or a spark gap used with a vehicle ignition plug or a high-voltage discharge lamp for continuously supplying a constant high-voltage. It is a common practice to apply various types of coating material on the discharge surfaces of the electrodes of the discharge tubes in order to minimize the initial break-down voltage against a surge voltage for the arrester or in order to produce a stable discharge voltage for the spark gap. A spark gap, which has a function of maintaining the discharge voltage below a predetermined level, can, of course, be used as an arrester.

The most generally known conventional coating material is composed of water as a solvent, sodium silicate, nitrocellulose or silicon rubber as a fixing agent to which barium titanate or aluminum oxide is added for improving the surge resistance.

However, it has been found that the discharge tube with the above-mentioned additives applied on the discharge surfaces thereof has a disadvantage in that, when the rise time of the input surge voltage is shortened, the breakdown voltage increases and the function of an arrester or a spark gap cannot be fully exhibited.

Especially for the spark gap, it has been found that the breakdown voltage is reduced or otherwise stable discharge characteristics are lost after continuous discharge. Specifically, in order to supply a stable constant voltage to a vehicle ignition plug or a high-voltage discharge lamp, a high-voltage pulse of several-msec duration must be applied or otherwise special means must be taken, in which case it is difficult to produce a stable discharge voltage.

DISCLOSURE OF THE INVENTION

The present invention has been developed to obviate the above-mentioned problems, and a first object of the invention is to provide a discharge tube capable of producing a stable discharge voltage even with a surge pulse having a short rise time. A second object of the invention is to provide a discharge tube capable of producing a stable discharge voltage even after continuous discharge.

In order to achieve the above-mentioned objects, according to the present invention, there is provided a discharge tube configured as described below.

Specifically, a discharge tube according to the invention comprises two electrodes arranged in opposed relation to each other with an insulating member between them for causing a discharge in the gap formed between the two opposed discharge surfaces of the electrodes, wherein a coating material containing 0.01 to 60 wgt % of at least one alkali metal salt selected from potassium bromide, potassium fluoride and sodium fluoride is applied on the discharge surfaces of the two electrodes.

This configuration can produce a stable discharge voltage even against a surge voltage having a short rise time.

The alkali metal salt contained in the coating material is preferably 5 to 30 wgt %, or especially 10 to 20 wgt %.

Further, a stable discharge voltage is produced even after continuous discharge by adding sodium silicate of 0.01 to 50 wgt % to the coating material.

Also, the sodium silicate contained in the coating material is preferably 0.5 to 10 wgt %, or more preferably 1 to 2.5 wgt %.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of a discharge tube according to the present invention.

Fig. 2 is a graph showing a voltage-time characteristic curve of a discharge tube (with a coating material containing potassium bromide) according to the first embodiment of the invention.

Fig. 3 is a graph showing a continuous discharge characteristic (indicating the upper and lower limits of the wave) with high-voltage pulses continuously applied to the discharge tube of Fig. 2.

Fig. 4 is a graph showing a voltage-time characteristic curve of a discharge tube (using a coating material containing sodium silicate and potassium bromide) according to a second embodiment of the invention.

Fig. 5 is a graph showing a continuous discharge characteristic (indicating the upper and lower limits of the wave) of the discharge tube of Fig. 4 continuously supplied with high-voltage pulses.

Fig. 6 is a graph showing a continuous discharge characteristic (indicating the upper and lower limits of the wave) of the discharge tube of Fig. 4 supplied with a continuous train of high-voltage pulses followed by another continuous train of high-voltage pulses.

Fig. 7 is a graph showing a continuous discharge characteristic (indicating the upper and lower limit of the wave) of a discharge tube supplied with high-voltage pulses according to a third embodiment of the invention.

Fig. 8 is a graph showing a continuous discharge characteristic (indicating the upper and lower limits of the wave) of a discharge tube supplied with high-voltage pulses according to a fourth embodiment of the invention.

Fig. 9 is a sectional view showing a configuration of the electrode section of a discharge tube according to another embodiment of the invention.

Fig. 10 is a graph showing a voltage-time characteristic curve of a conventional discharge tube supplied with high-voltage pulses.

Fig. 11 is a graph showing a continuous discharge characteristic (indicating the upper and lower limits of the wave) of an example of a conventional discharge tube using a coating material containing sodium silicate of 25 wgt % and barium titanate of 5 wgt %.

Fig. 12 is a graph showing a continuous discharge characteristic (indicating the upper and lower limits of the wave) of an example of a conventional discharge tube using a coating material containing sodium silicate of 6 wgt % and barium titanate of 3.5 wgt % applied thereto.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Prior to describing embodiments of the invention, conventional discharge tubes with a coating material applied to the discharge surfaces thereof will be explained with reference to Figs. 10 to 12.

Fig. 10 is a graph showing a voltage-time characteristic curve of a discharge tube with a coating material containing sodium silicate and barium titanate applied to the discharge surfaces thereof as an example. In this graph, the ordinate represents the break-down voltage with a surge pulse voltage applied, and the abscissa represents the duration of a surge pulse applied. The rise time (in voltage/time) of a surge pulse is also shown. This graph indicates the change of an actual break-down voltage with respect to the change of the surge pulse duration and the rise time of a discharge tube designed for a predetermined break-down time. The voltage-time characteristics of discharge tubes having break-down voltages of 600 volts, 350 volts and 200 volts are shown as an example of a specification.

As can be seen from this graph, a stable initial discharge characteristic is exhibited up to about 400 V/msec. in rise time. With a shorter rise time, however, the break-down voltage suddenly increases to such an extent that the discharge tube fails to function as an arrester.

Fig. 11 shows the initial discharge characteristic (continuous discharge characteristic) of a discharge tube using a coating material containing sodium silicate of 25 wgt % and barium titanate of 5 wgt % supplied with high-voltage pulses of 5 msec. duration. Fig. 12 shows an initial discharge characteristic (continuous discharge characteristic) of a discharge tube using a coating material containing sodium silicate of 6 wgt % and barium titanate of 3.5 wgt % supplied with high-voltage pulses of 5 msec. duration. Neither of the discharge tubes could produce a stable continuous break-down voltage.

Now, preferred embodiments of the present invention will be explained in detail with reference to Figs. 1 to 9.

Fig. 1 is a sectional view showing an embodiment of a discharge tube 10.

Numeral 12 designates a cylindrical insulating member composed of a ceramic such as alumina. Electrodes 14a, 14b are fixed in opposed relation to each other by silver solder to the end openings of the cylindrical insulating member 12, and a low-pressure inert gas, such as argon or the like, is sealed in the hermetic insulating member 12.

A carbon trigger line (not shown) is formed at appropriate points on the inner wall of the insulating member 12 for stabilizing the initial discharge.

The electrodes 14a, 14b composed of iron-nickel alloy, iron-nickel-cobalt alloy or copper include discharge surfaces 17a, 17b, respectively, to discharge in a gap 20 between the opposed discharge surfaces 17a, 17b. A coating material 16 is applied on the discharge surfaces 17a, 17b.

(First embodiment)

According to the first embodiment of the invention, the coating material 16 using water (pure water) as a solvent is produced by adding a solvent containing 0.01 to 60 wgt % of potassium bromide constituting an alkali metal salt to a well-known coating material using barium titanate. The coating material 16 is coated and dried on the discharge surface.

A specific example of the first embodiment will be explained. Fig. 2 is a graph showing a voltage-time characteristic curve of a specific example of the first embodiment (a discharge tube using a coating material containing barium titanate as a main component and 10 wgt % of potassium bromide).

Comparison of this characteristic curve with the voltage-time characteristic curve (Fig. 10) for a conventional coating material containing barium titanate not mixed with potassium bromide shows that the conventional discharge tube has the disadvantage that with a shorter rise time of the surge voltage, the break-down voltage of even a 200-V discharge tube increases and exceeds 2000 volts at 10 KV/μsec. This indicates that even in the case where a discharge tube having a specification of 200 volts is mounted as an arrester on the equipment to be protected, an abnormal voltage exceeding 2000 V will appear. The equipment, therefore, cannot be positively protected and may be broken. It can be seen from Fig. 10 that an abnormal voltage exceeding 200 volts can be removed only from the surge voltage of up to about 200 V/msec to 400 V/msec in rise time.

In the discharge tube 10 according to the first embodiment, by contrast, as shown in Fig. 2, the break-down voltage of a 200-V spark gap does not increase as rapidly as that of the conventional discharge tube. The discharge operation can thus be started at about 430 V with the rise time of 10 KV/msec, thus exhibiting a superior characteristic as an arrester. Consequently, the equipment can be positively protected and is liable to be broken at a lower rate.

Potassium bromide has a direct effect on the stability of the discharge voltage, and is usable in the range of 0.01 to 60 wgt %. The discharge characteristic, however, becomes stable in the range of 5 to 30 wgt %, or especially, the stability is improved in the range of 10 to 20 wgt % of potassium bromide. Other alkali metal salts, such as potassium fluoride or sodium fluoride, may be used in place of potassium bromide. At least one of these three alkali metal salts may be contained in the coating material with equal effect.

The discharge tube 10 according to the first embodiment, as shown in Fig. 3, cannot maintain a stable, constant discharge voltage in the case where high-voltage pulses of 5 msec. or less in duration are continuously applied as the initial discharge characteristic (continued discharge characteristic). The discharge tube 10 therefore cannot be used as a spark gap.

(Second embodiment)

The discharge tube 10 has a similar mechanical structure to the structure shown in Fig. 1.

According to the second embodiment, the coating material contains sodium silicate as a fixing agent.

Specifically, the coating material 16 uses water (pure water) as a solvent. The solvent contains 0.01 wgt % of sodium silicate and 0.01 to 60 wgt % of potassium bromide. The coating material 16 is applied and dried on the discharge surfaces.

The effect of the added sodium silicate begins to be exhibited from about 0.01 wgt %, and the discharge characteristic is most stable in the range of 1 to 2.5 wgt %. The stability of the discharge characteristic is gradually reduced for the content more than 2.5 wgt %. When the content exceeds 40 wgt %, a dynamic current discharge easily occurs. Therefore, the effect can be sustained up to 50 wgt % of sodium silicate which is an upper limit of the amount of sodium silicate that can be dissolved in the solvent water. The content of sodium silicate, however, should be maintained on the order of several percent as far as possible

The second embodiment will be explained with reference to a specific example. Fig. 4 is a graph showing the voltage-time characteristic curve of a specific example (sodium silicate of 2.5 wgt % and potassium bromide of 10 wgt %) according to the second embodiment.

As clearly understood from the graph of Fig. 4 showing the voltage-time characteristic curve of the discharge tube 10 according to the second embodiment, since the coating material contains potassium bromide, the breakdown voltage is prevented from increasing, as in the first embodiment, even with a short rise time, thereby making it possible to produce a superior breakdown time characteristic.

Fig. 5 shows the initial discharge characteristic of a spark gap supplied with a high-voltage pulse not more than 5 msec., having the discharge surfaces on which a coating material containing 2.5 wgt % of sodium silicate and 15 wgt % of potassium bromide is prescribed and applied. As can be seen from Fig. 5, since the coating material contains not only potassium bromide but also sodium silicate, the initial discharge characteristic (continuous discharge characteristic) as well as the voltage-time characteristic shown in Fig. 4 can be stabilized at 1000 V or thereabouts for the break-down voltage.

Further, in the case where the coating material contains sodium silicate, the initial discharge characteristic (continuous discharge characteristic) with high-voltage pulses of 5 msec. or less continuously applied is stabilized at about 1000 V as shown in Fig. 5. The discharge tube thus can be used not only as an arrester but also as a spark gap.

Fig. 6 shows the discharge characteristic after applying a high-voltage pulse of 5 msec. or less 20000 times each for one second to the same discharge tube as the one described above. As can be seen from Fig. 6, the break-down voltage is maintained at 1000 V and a stable discharge characteristic is exhibited even after continuous long-time operation.

(Third embodiment)

The configuration of a discharge tube according to the third embodiment is substantially the same as that of the discharge tube 10 described with reference to Fig. 1, the only difference being the composition of the coating material 16.

The coating material 16 uses water as a solvent which contains 0.01 to 50 wgt % of sodium silicate and 0.01 to 60 wgt % of potassium fluoride. The coating material 16 is applied and dried on the discharge surfaces.

The amount of sodium silicate added is the same as that explained with reference to the second embodiment and will not be described.

Potassium fluoride has a direct effect on the stability of the discharge voltage and can be used in the range of 0.01 to 60 wgt %. The discharge characteristic is stable with 5 to 30 wgt % of potassium fluoride, or preferably about 10 to 20 wgt % at which high stability is obtained.

Fig. 7 shows the initial discharge characteristic (continuous discharge characteristic) obtained when a high-voltage pulse of 5 msec. or less is impressed on a spark gap using a coating material containing 2.5 wgt % of sodium silicate and 15 wgt % of potassium fluoride prescribed and applied on the discharge surfaces thereof. As can be clearly seen from Fig. 7, the breakdown voltage is stable at about 1000 V.

The discharge characteristic of this discharge tube obtained after high-voltage pulses of 5 msec. or less are impressed 20000 times each time for one second is found to be stable, though not shown. The break-down voltage of 1000 V is maintained even after long-term continuous discharge in the same manner as the discharge tube of the second embodiment. The voltage-time characteristic curve, though not shown, is also substantially similar to that of the second embodiment.

(Fourth embodiment)

The configuration of a discharge tube according to the fourth embodiment is substantially the same as that of the discharge tube 10 described with reference to the first embodiment, the only difference being the composition of the coating material 16.

The coating material 16 uses water as a solvent and contains 0.01 to 50 wgt % of sodium silicate and 0.01 to 60 wgt % of sodium fluoride. The coating material 16 is applied and dried on the discharge surfaces.

The amount of the sodium silicate added is the same as that explained with reference to the second embodiment and will not be explained.

Sodium fluoride has a direct effect on the stability of the discharge voltage, and is usable in the range of 0.01 to 60 wgt %. The content of 5 to 30 wgt %, however, produces a stable discharge characteristic, and the content of 10 to 20 wgt % is more preferable as the stability is further improved.

Fig. 8 shows the initial discharge characteristic obtained when high-voltage pulses of 5 msec. or less are applied to a discharge tube using a coating material 16 containing 2.5 wgt % of sodium silicate and 15 wgt % of sodium fluoride prepared and applied on the discharge surfaces thereof. As can be seen from Fig. 8, the break-down voltage is stabilized at about 1000 V.

The discharge characteristic obtained after applying high-voltage pulses of 5 msec. or less in 20000 cycles each one second in length, though not shown, indicates that a break-down voltage of 1000 V and a stable discharge characteristic are maintained even after long-term continuous use in the same manner as the discharge tube of the first embodiment. Also, the voltage-time characteristic, though not shown, is substantially identical to that of the second embodiment.

In the first to fourth embodiments described above, potassium bromide, potassium fluoride or sodium fluoride is used as an alkali metal salt contained together with sodium silicate in the coating material 16. Alternatively, the coating material 16 may contain a mixture of a plurality of alkali metal salts with equal effect, including a combination of potassium bromide and potassium fluoride, a combination of potassium bromide and sodium fluoride, a combination of potassium fluoride and sodium fluoride or a combination of potassium bromide, potassium fluoride and sodium fluoride.

In such a case, the content of each alkali metal salt in the coating material 16 may be in the range of 0.01 to 60 wgt % as in the case where only one type of alkali metal salt is used with sodium silicate. Nevertheless, the discharge characteristic is stabilized in the range of 5 to 30 wgt % or preferably in the range of 10 to 20 wgt % where an especially high stability is obtained.

As an example, assume that two alkali metal salts (potassium bromide and potassium fluoride) are used. The coating material 16 is prepared to contain 2.5 wgt % of sodium silicate, 15 wgt % of potassium bromide and 15 wgt % of potassium fluoride. In the case of using all the above-mentioned three alkali metal salts (potassium bromide, potassium fluoride and sodium fluoride), on the other hand, the coating material 16 preferably has the contents of 2.5 wgt % of sodium silicate, 15 wgt % of potassium bromide, 15 wgt % of potassium fluoride and 15 wgt % of sodium fluoride. Also, the coating material according to this invention can be applicable to a triode discharge tube and the like.

Further, instead of a flat discharge surface of the electrodes of the discharge tube 19 as shown in Fig. 1, a recess 18 may be formed in the discharge surface of each electrode as shown in Fig. 9. This configuration can assure a large surface area contributing to a longer service life.

Various preferred embodiments of the present invention have been explained above. The invention, however, is not limited to these embodiments and can of course be modified in various ways without departing from the scope and spirit of the invention.

INDUSTRIAL APPLICABILITY

It will thus be understood from the foregoing description that according to the present invention, there is provided a discharge tube in which a stable break-down voltage can be obtained even with a short rise time of the surge voltage. The discharge tube according to the invention can be used as an arrester, thereby preventing the equipment involved from being damaged.

Further, in the case where the coating material contains sodium silicate at the same time, a stable break-down voltage is obtained even when high-voltage, high-frequency pulses are applied continuously. The present invention, therefore, can exhibit a superior characteristic even when used for a vehicle ignition plug or a high-voltage discharge lamp.

Claims

1. A discharge tube comprising two electrodes in opposed relation to each other with an insulating member interposed therebetween, and a gap formed between said opposed surfaces of said electrodes for causing a discharge, wherein a coating material containing at least a selected one of alkali metal salts including potassium bromide, potassium fluoride and sodium fluoride of 0.01 to 60 wgt % is applied to the discharge surfaces of said electrodes.

2. A discharge tube according to claim 1, wherein said coating material contains at least a selected one of

said alkali metal salts at 5 to 30 wgt %.

3. A discharge tube according to claim 1, wherein said coating material contains at least a selected one of said alkali metal halts at 10 to 20 wgt %.

4. A discharge tube according to claim 1, wherein said coating material further contains sodium silicate of 0.1 to 50 wgt %, preferably 0.5 to 10 wgt %, or more preferably 1 to 2.5 wgt %.

5. A discharge tube according to claim 2, wherein said coating material further contains sodium silicate of 0.1 to 50 wgt %, preferably 0.5 to 10 wgt %, or more preferably 1 to 2.5 wgt %.

6. A discharge tube according to claim 3, wherein said coating material contains sodium silicate of 0.1 to 50 wgt %, preferably 0.5 to 10 wgt %, or more preferably 1 to 2.5 wgt %.

Fig.1

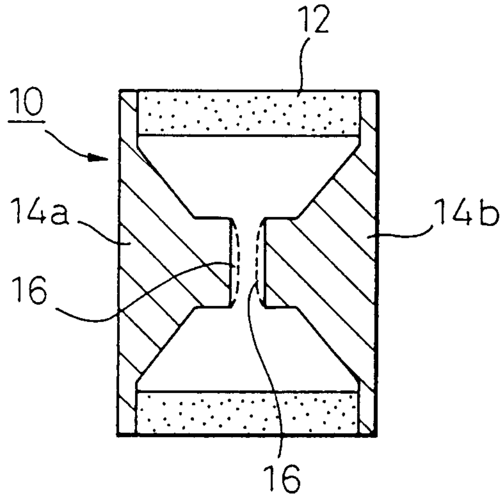
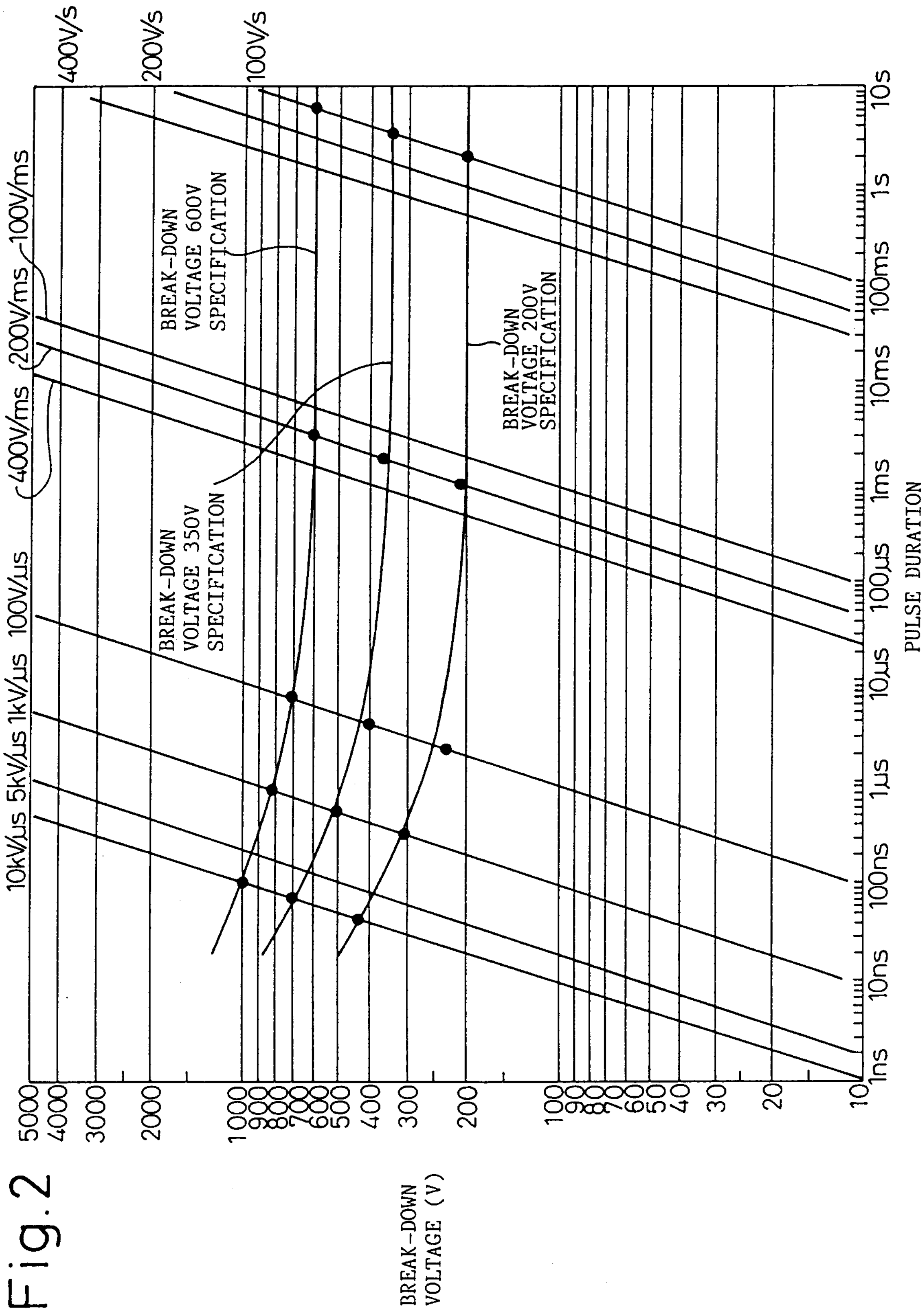


Fig.2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100V/s
BREAK-DOWN VOLTAGE 600V SPECIFICATION
BREAK-DOWN VOLTAGE 350V SPECIFICATION
BREAK-DOWN VOLTAGE 200V SPECIFICATION
BREAK-DOWN VOLTAGE (V)
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100ns
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1ms
10ms
100ms
1s
10s
PULSE DURATION

Fig.3

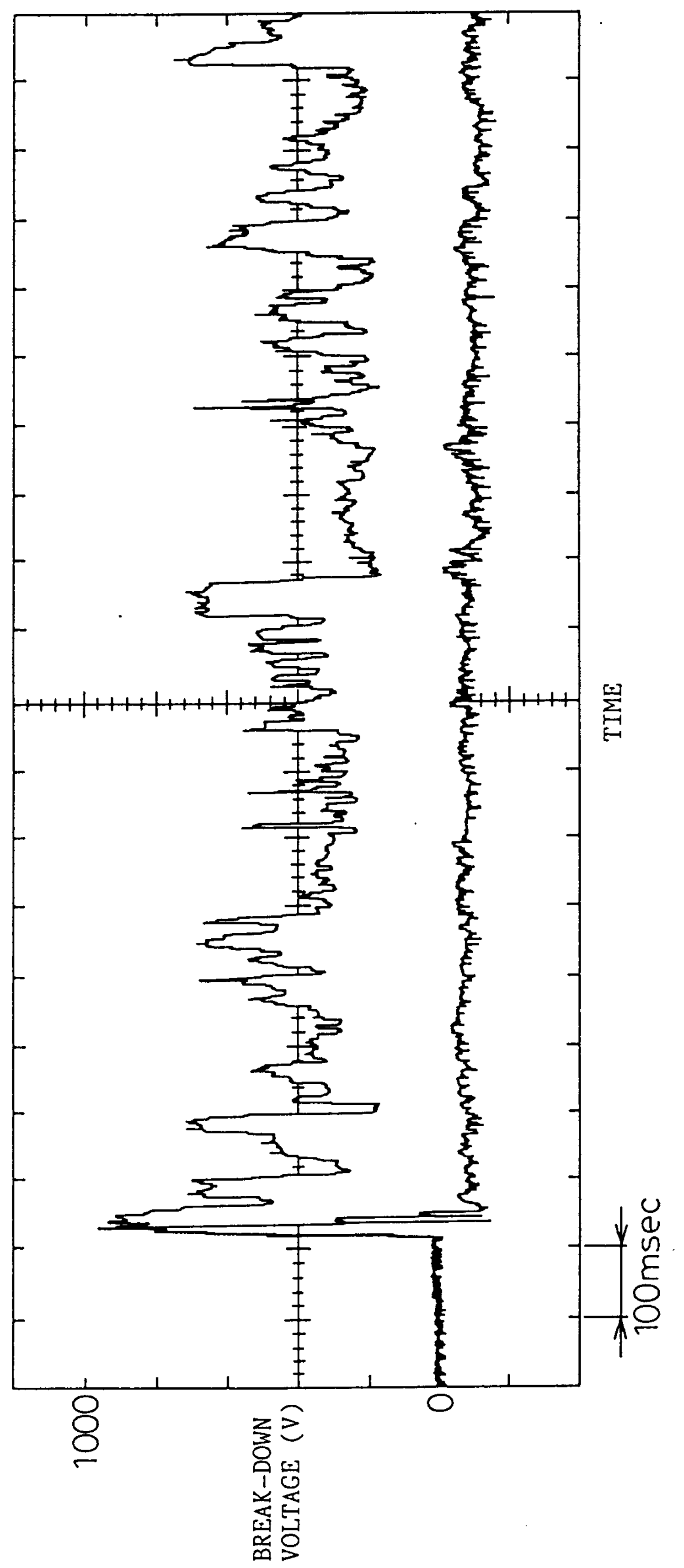
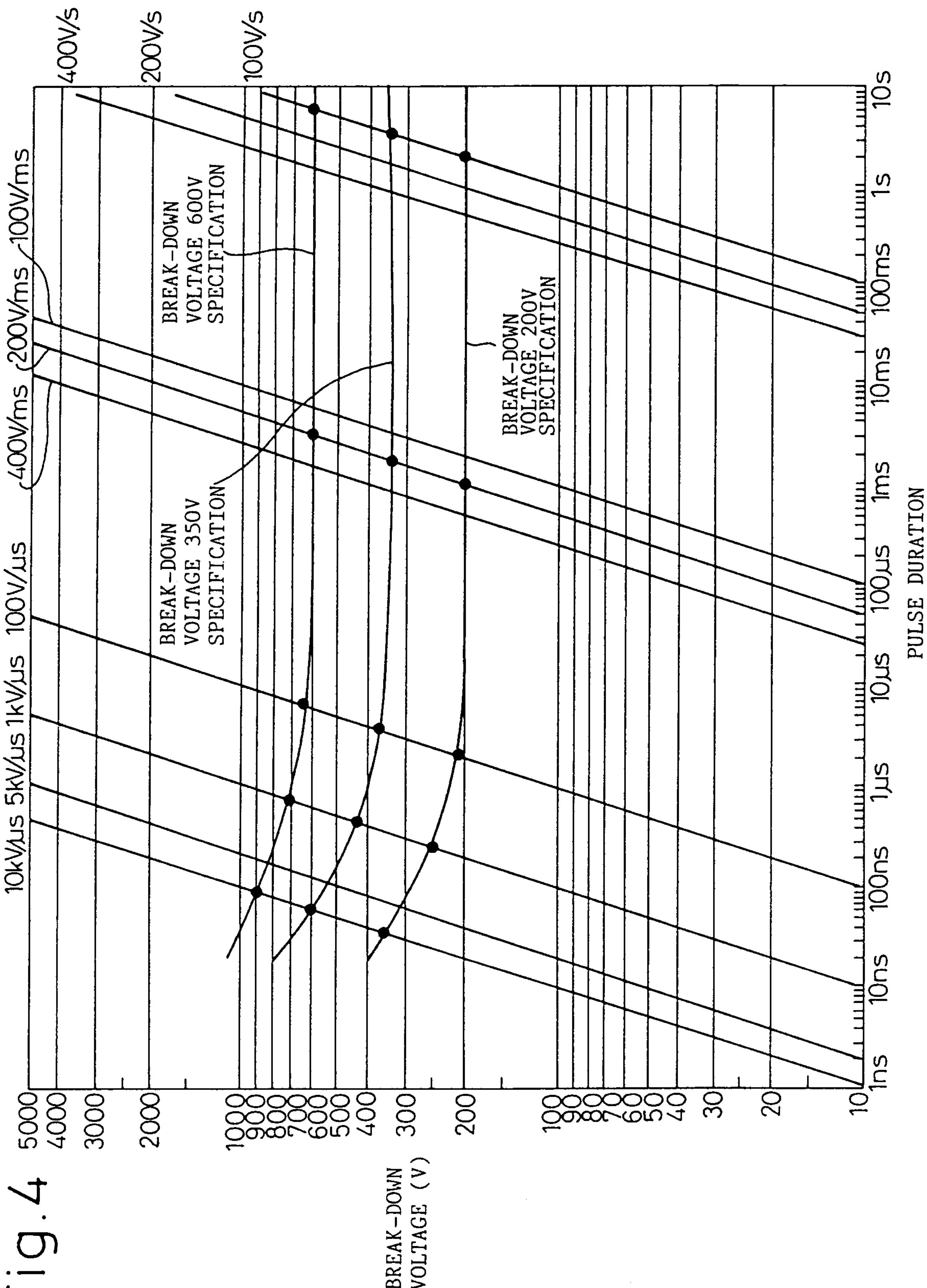


Fig.4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BREAK-DOWN VOLTAGE 600V SPECIFICATION
BREAK-DOWN VOLTAGE 350V SPECIFICATION
BREAK-DOWN VOLTAGE 200V SPECIFICATION
BREAK-DOWN VOLTAGE (V)
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30
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1ns
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100µs
1ms
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1s
10s
PULSE DURATION

Fig.5

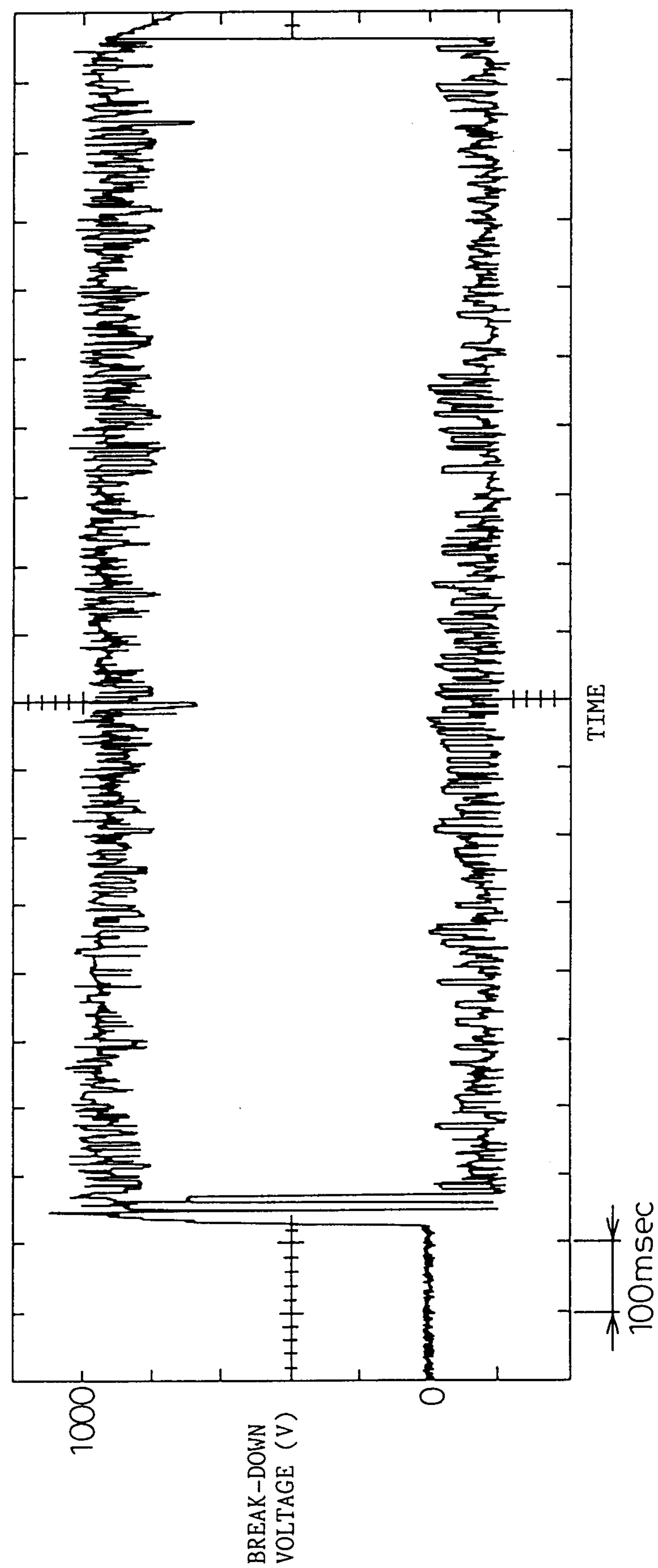


Fig.6

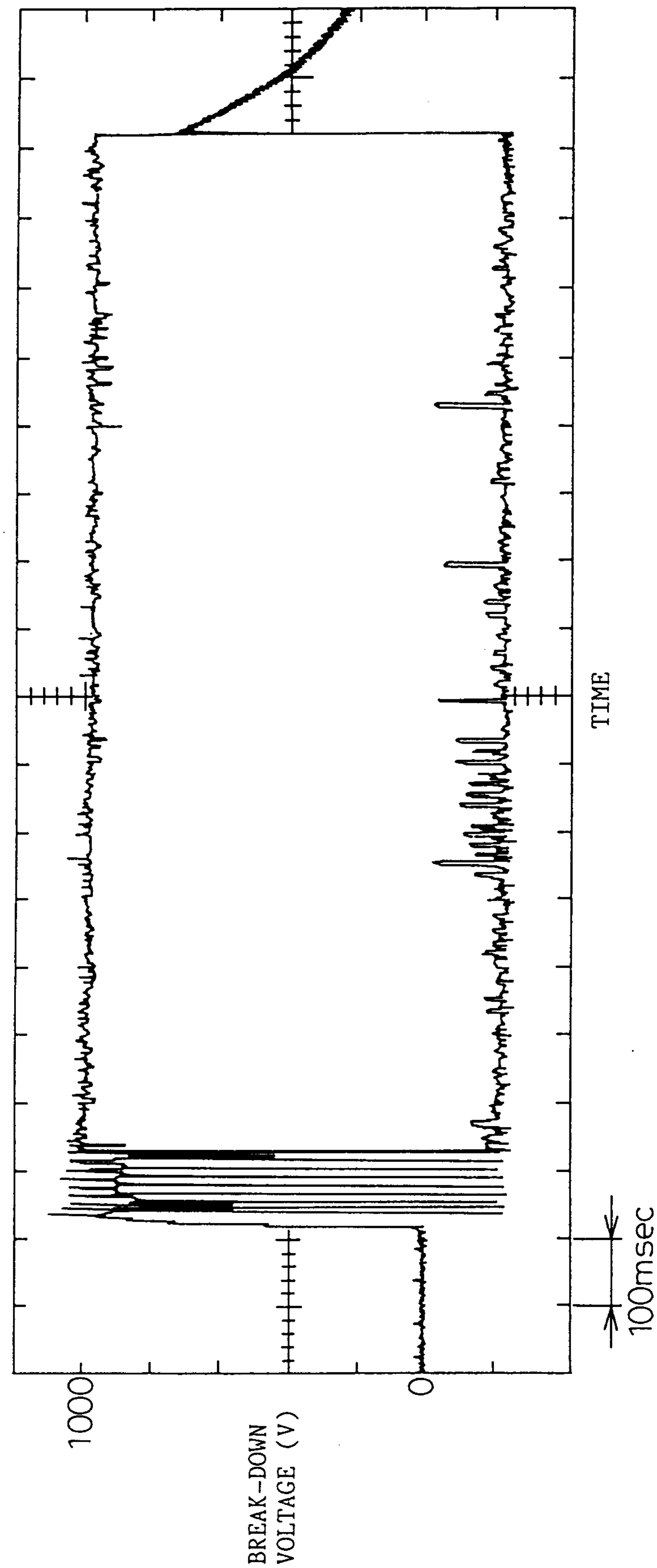


Fig.7

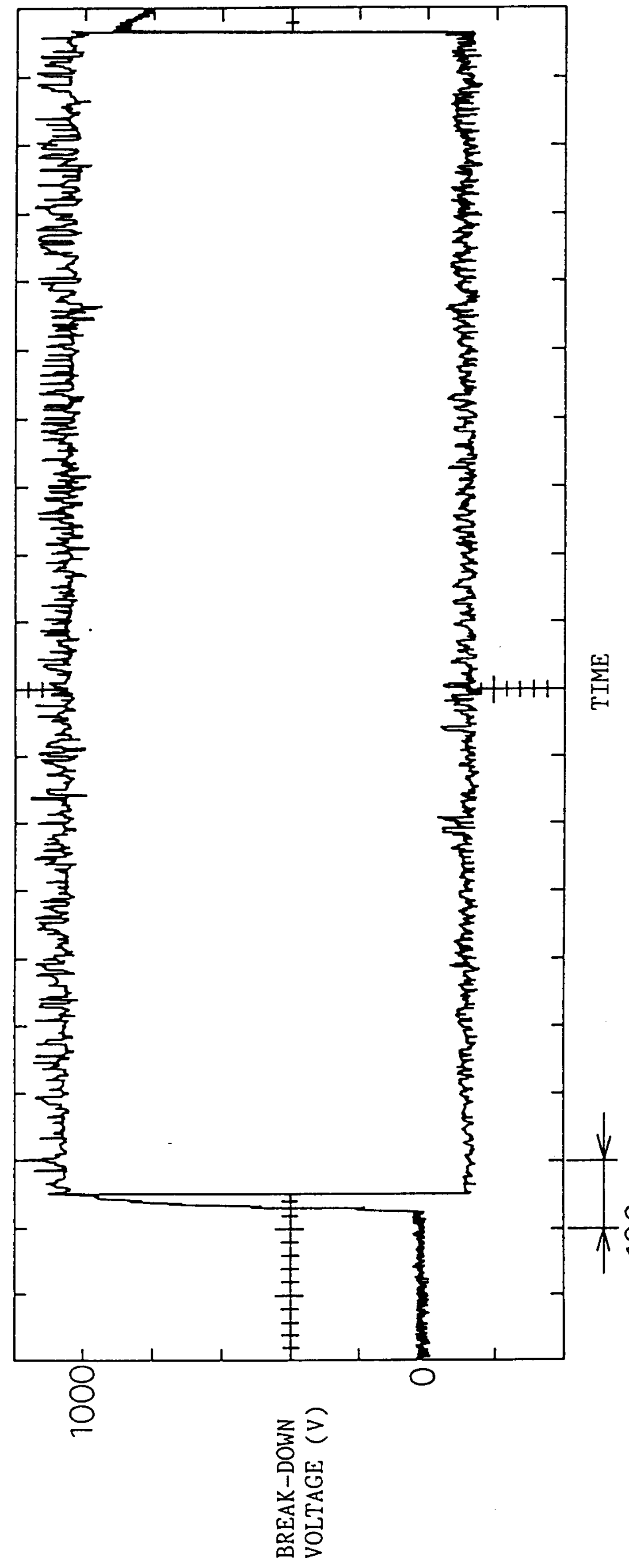


Fig.8

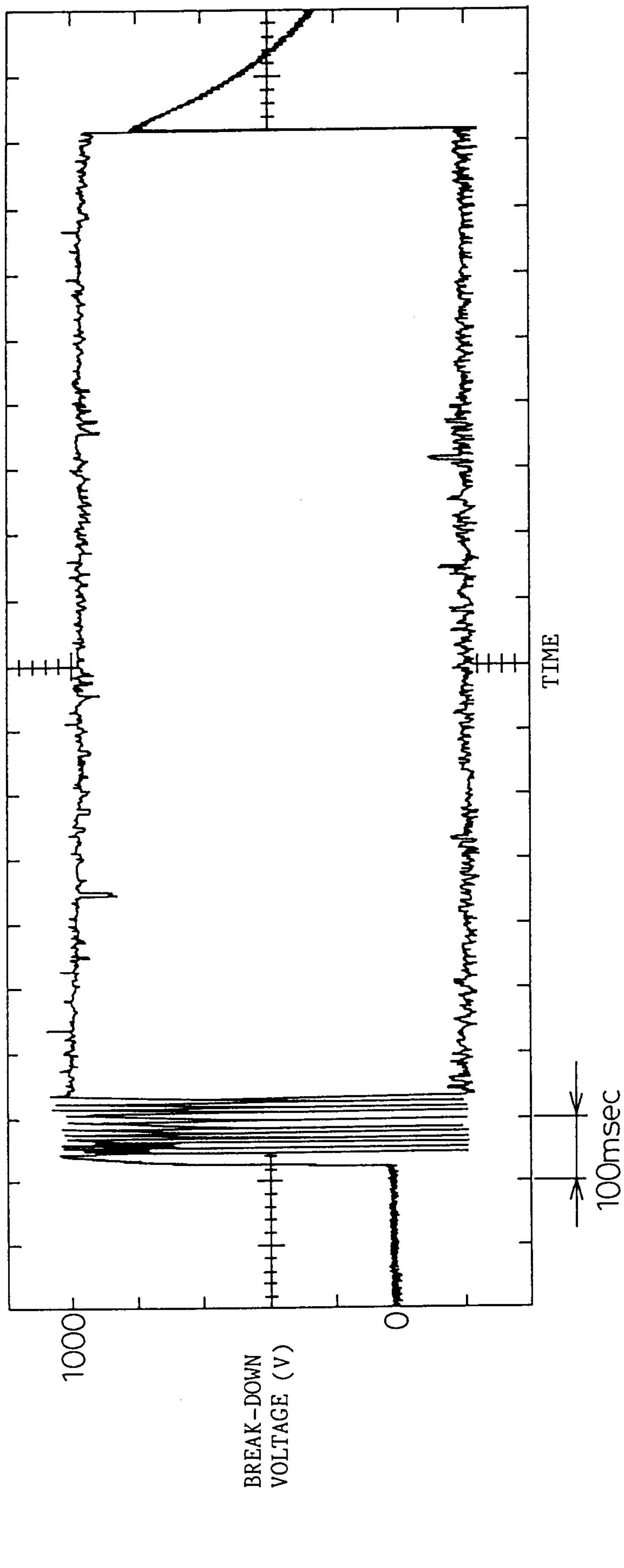


Fig.9

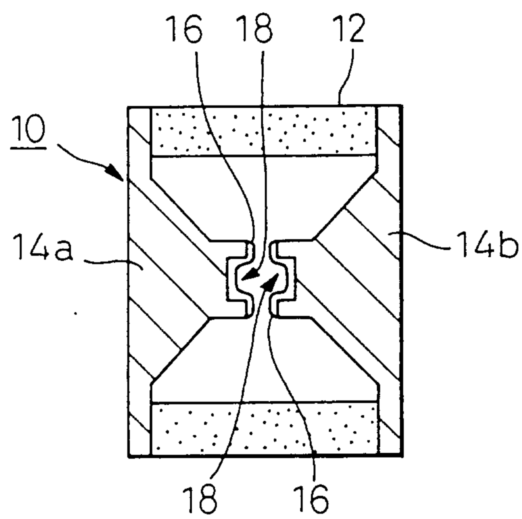
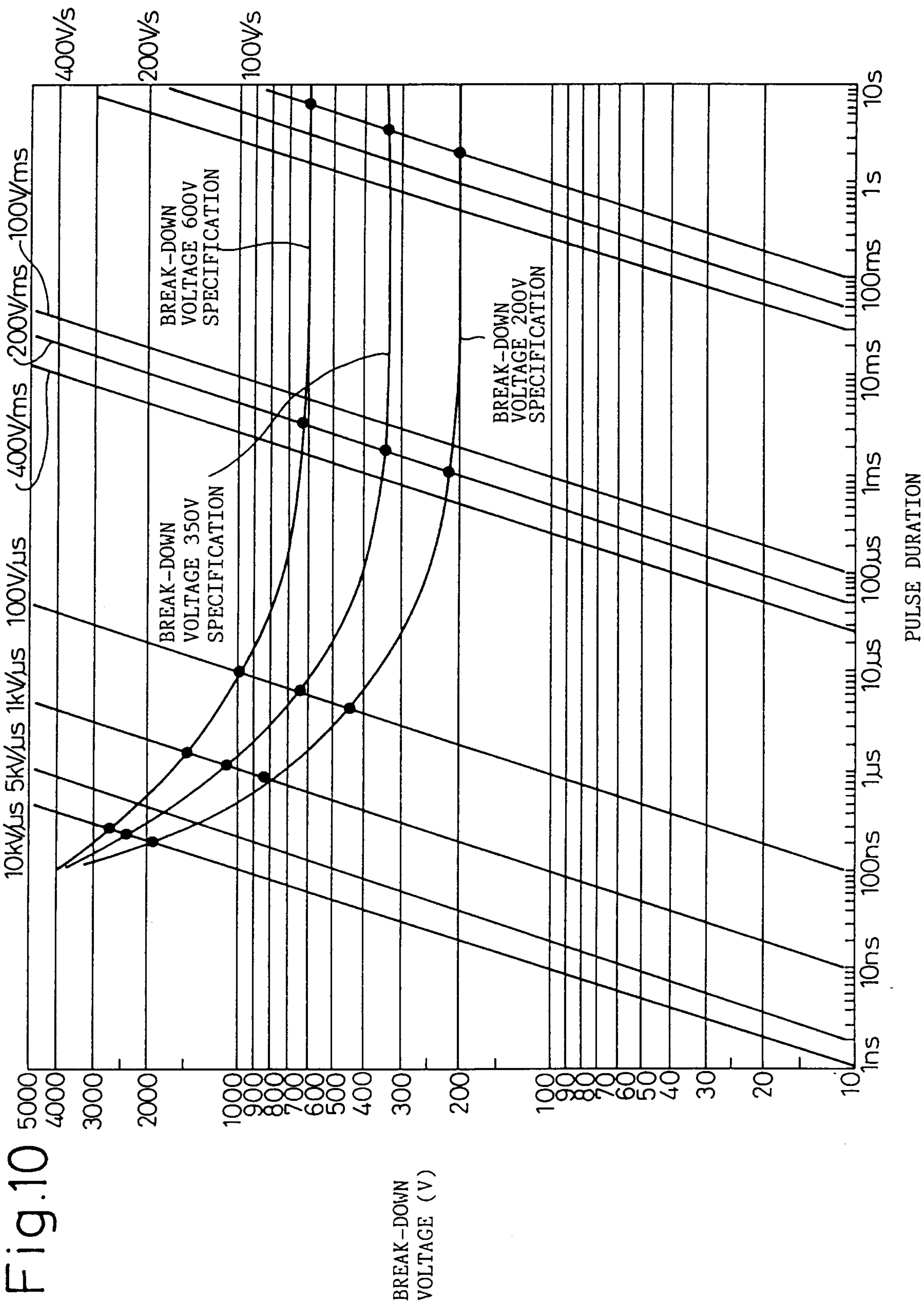


Fig.10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500
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60
50
40
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100ns
1µs
10µs
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1ms
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400V/ms
200V/ms
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400V/s
200V/s
100V/s
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BREAK-DOWN VOLTAGE 350V SPECIFICATION
BREAK-DOWN VOLTAGE 200V SPECIFICATION

Fig.11

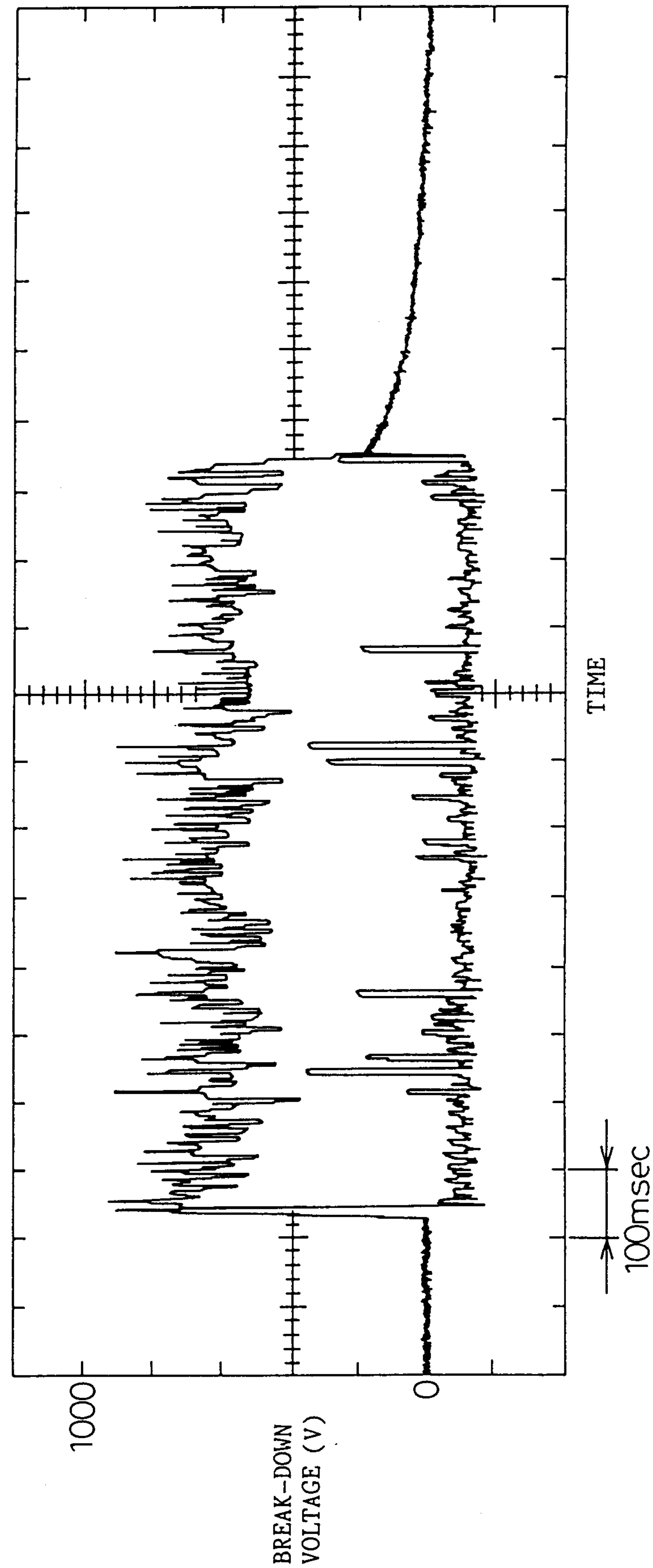
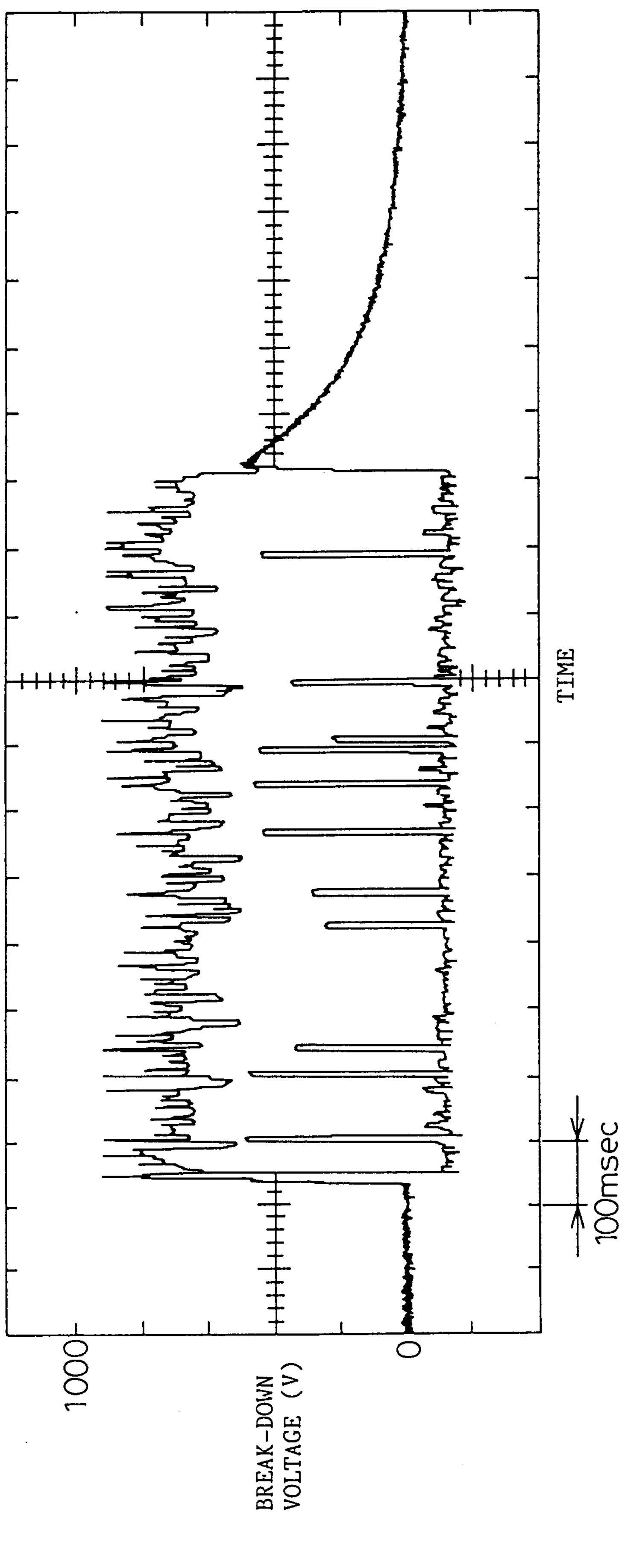


Fig.12



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP96/01200

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 H01T1/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 H01T1/00-H01T4/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926 - 1996
Kokai Jitsuyo Shinan Koho 1971 - 1996

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 2-23996, B2 (Siemens AG.), May 28, 1990 (28. 05. 90), Lines 3 to 12, column 6, page 3 & DE, 3335602, A1 & EP, 138082, A1 & US, 4665337, A & EP, 138082, B1	1 - 6
Y	JP, 55-37709, A (K.K. Hakusan Seisakusho), March 15, 1980 (15. 03. 80), Lines 18 to 20, upper right column, page 2 (Family: none)	1 - 6
Y	JP, 63-59513, B2 (Siemens AG.), November 18, 1988 (18. 11. 88), Lines 6 to 14, column 1, page 1 & FR, 2400254, A1 & FR, 2400254, B1 & DE, 2735865, C3 & CH, 621651, A & GB, 1591150, A	4 - 6
Y	JP, 63-13290, A (Siemens AG.), January 20, 1988 (20. 01. 88), Lines 13 to 16, lower right column, page 3	4 - 6

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
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International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	& DE, 3621254, A1 & EP, 251010, A1 & US, 4769736, A & EP, 251010, B1 & DE, 3766888, C0	
Y	JP, 6-33388, U (Yazaki Corp.), April 28, 1994 (28. 04. 94), Lines 6 to 9, column 1, page 2 (Family: none)	4 - 6

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