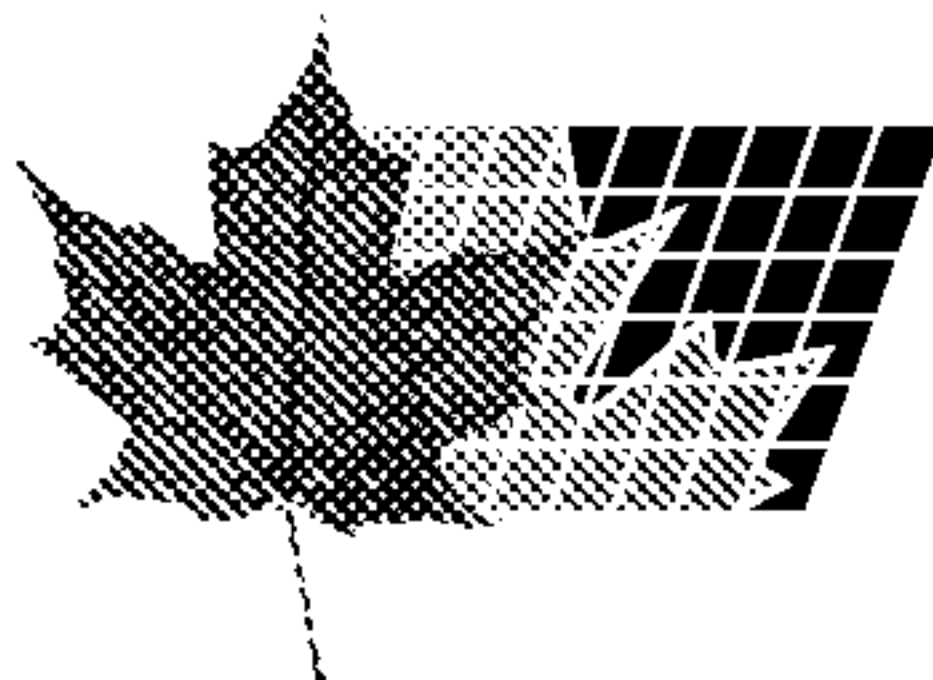




(72) MOROOKA, YASUNARI, JP

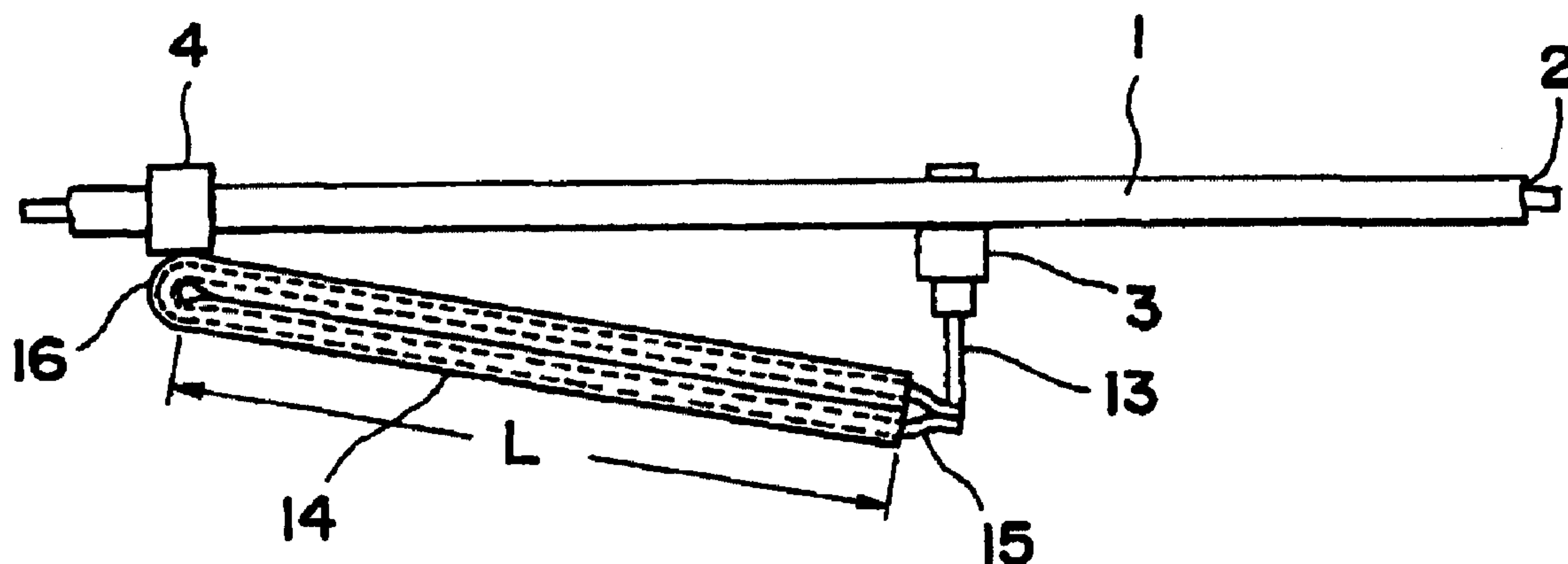
(71) KYUSHU ELECTRIC POWER CO., INC., JP

(51) Int.Cl.⁷ H01T 4/14, H02H 9/06

(30) 1999/05/25 (11/145634) JP

(54) **DECHARGEUR DE FOUDRE A DECHARGE RAMPANTE**

(54) **CREeping DISCHARGE LIGHTNING ARRESTOR**



(57) Inexpensive countermeasures against breaking of wire and momentary service interruption without using any ZnO device for reduction of the cost of lightning countermeasure for aerial lines are taken. A lightning arrester body (14) for an aerial line constituted of an insulated wire is formed of a double-folded insulated wire insulated to the same extent as that of a power cable. The conductor-exposed side (15) of the lightning arrester body (14) is connected to the insulator earthing side (13), and the insulating cover side (16) is disposed on the discharge electrode (4) side provided to an aerial line (1). The insulating cover of the aerial line (1) on the insulating cover side (16) is through-broken in advance by means of a needle electrode of the discharge electrode (4). Thus a creeping discharge lightning arrestor is provided. If the aerial line is a bare wire, the conductor-exposed side of the arrester body is connected to the insulator-earthing side, and the insulator cover side is disposed to the aerial line.

(12)特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局(43) 国際公開日
2000 年11 月30 日 (30.11.2000)

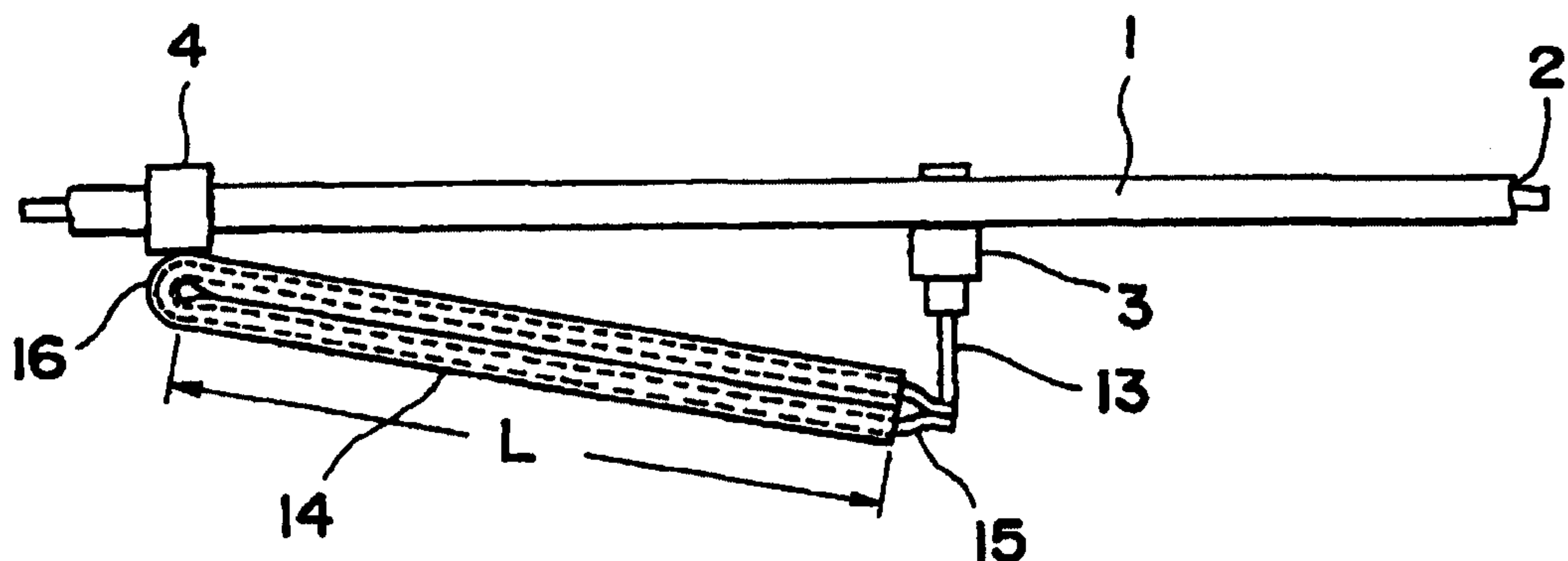
PCT

(10) 国際公開番号
WO 00/72417 A1

- (51) 国際特許分類: H01T 4/14, H02H 9/06 中央区渡辺通2丁目1番82号 九州電力株式会社内 Fukuoka (JP).
- (21) 国際出願番号: PCT/JP00/03286
- (22) 国際出願日: 2000 年5 月23 日 (23.05.2000)
- (25) 国際出願の言語: 日本語
- (26) 国際公開の言語: 日本語
- (30) 優先権データ:
特願平11/145634 1999 年5 月25 日 (25.05.1999) JP
- (71) 出願人 (米国を除く全ての指定国について): 九州電力株式会社 (KYUSHU ELECTRIC POWER CO., INC.) [JP/JP]; 〒810-0004 福岡県福岡市中央区渡辺通2丁目1番82号 Fukuoka (JP).
- (74) 代理人: 小堀 益, 外(KOHORI, Susumu et al.); 〒812-0011 福岡県福岡市博多区博多駅前1-1-1 博多新三井ビル401号 Fukuoka (JP).
- (81) 指定国 (国内): AU, CA, CN, KR, US.
- (84) 指定国 (広域): ユーラシア特許 (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), ヨーロッパ特許 (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).
- 添付公開書類:
— 国際調査報告書
— 請求の範囲の補正の期限前の公開であり、補正書受領の際には再公開される。
- (72) 発明者; および
(75) 発明者/出願人 (米国についてのみ): 諸岡泰成 (MO-ROOKA, Yasunari) [JP/JP]; 〒810-0004 福岡県福岡市
- 2文字コード及び他の略語については、定期発行される各PCTガゼットの巻頭に掲載されている「コードと略語のガイダンスノート」を参照。

(54) Title: CREEPING DISCHARGE LIGHTNING ARRESTOR

(54) 発明の名称: 沿面放電型避雷装置



(57) Abstract: Inexpensive countermeasures against breaking of wire and momentary service interruption without using any ZnO device for reduction of the cost of lightning countermeasure for aerial lines are taken. A lightning arrester body (14) for an aerial line constituted of an insulated wire is formed of a double-folded insulated wire insulated to the same extent as that of a power cable. The conductor-exposed side (15) of the lightning arrester body (14) is connected to the insulator earthing side (13), and the insulating cover side (16) is disposed on the discharge electrode (4) side provided to an aerial line (1). The insulating cover of the aerial line (1) on the insulating cover side (16) is through-broken in advance by means of a needle electrode of the discharge electrode (4). Thus a creeping discharge lightning arrester is provided. If the aerial line is a bare wire, the conductor-exposed side of the arrester body is connected to the insulator-earthing side, and the insulator cover side is disposed to the aerial line.

[続葉有]

WO 00/72417 A1

CREEPING DISCHARGE LIGHTNING ARRESTOR

Technical Field

The present invention relates to a creeping discharge lightning protection device (arrestor) for preventing breaking of insulated wire and momentary service interruption of power system due to lightning surge arising close on supporting insulator in overhead power lines.

Background Art

A breaking of insulated wire typically rises out of a mechanism such that a lightning surge first causes the destruction of an insulating sheath adjacent a supporting insulation, an AC dynamic then being caused by a flashover in a multiple-phase power line, this AC short-circuit current then passing regionally through the damaged portion via an metallic arm securing the supporting insulation, and a conductor layer of the insulated wire eventually being evaporated or broken by a heat caused by arcing. A momentary service interruption of a power system arises from a continuous earth current due to a flashover in the supporting insulation by the lightning surge. For preventing the breaking and momentary service interruption, it is important to interrupt the AC short-circuit current and earth current caused along a discharging path formed by the lightning surge.

Currently, a ZnO element is installed as a most typical measure to prevent the breaking and the momentary service interruption.

However, a great deal of expenditure is required to install a ZnO element. This approach may be not a perfect measure because the ZnO element tends to be burnt out by a direct hit of lightning to an overhead power line.

Disclosure of Invention

Therefore, it is an object of the present invention to provide a low-cost measure for

preventing the breaking and the momentary service interruption without the use of the ZnO element so as to reduce the cost of measures for lightning in overhead power lines.

In order to achieve the above object, the present invention provides a creeping discharge lightning protection device in an overhead power line formed of a insulating wire or a bare wire, the creeping discharge lightning protection device comprising a lightning protection device body formed of an insulated wire insulated to the same extent as a power cable and folded into two, the lightning protection device body including an exposed conductor portion and an insulating sheath portion, wherein either one of the exposed conductor portion and the insulating sheath portion is connected to an earth portion of an insulator. Further, in case that the overhead power line is formed of the insulating wire, another one of the exposed conductor portion and the insulating sheath portion is connected to a discharge electrode, wherein the discharge electrode includes a needle electrode which penetrates an insulating sheath of the overhead power line so as to bring about through-breakdown. In case that the overhead power line is formed of the bare wire, another one of the exposed conductor portion and the insulating sheath portion being arranged directly to the overhead power line.

The present invention also provides a creeping discharge lightning protection device in an overhead power line formed of a insulating wire or bare wire, the creeping discharge lightning protection device comprising a lightning protection device body having either one of an insulating layer including a back electrode so as to enhance flashover performance, an insulating tube the one end or both ends of which are opened around a flashover path so as to enhance arc-suppression performance, and combinations thereof so as to enhance flashover performance and arc-suppression performance, wherein the lightning protection device body is positioned between the overhead power line and an earth portion of an insulator.

Brief Description of Drawings

Fig. 1 is a schematic view of a test device for checking out creeping discharge characteristics;

Fig. 2 is a characteristic diagram showing a relationship between thickness of sheath and maximum applied voltage not to bring about through-breakdown;

Fig. 3 is a characteristic diagram showing a relationship between applied voltage and discharge voltage;

Fig. 4 is a characteristic diagram showing a relationship between voltage and time of creeping discharge;

Fig. 5 is a diagram showing a relationship between applied voltage and time to flashover;

Fig. 6 is a sectional view showing a first test example of the present invention;

Fig. 7 is a sectional view showing a second test example of the present invention;

Fig. 8 is a characteristic diagram showing a relationship between voltage and time of creeping discharge;

Fig. 9 is a schematic view showing a first embodiment of the present invention;

Fig. 10 is a detail view showing the first embodiment of the present invention;

Fig. 11 is a schematic view showing a second embodiment of the present invention;

Fig. 12 (a) is a schematic view showing a third embodiment of the present invention;

Fig. 12 (b) is a left side view of the third embodiment;

Fig. 12 (c) is a right side view of the third embodiment;

Fig. 13 (a) is a schematic view showing a fourth embodiment of the present invention;

Fig. 13 (b) is a left side view of the fourth embodiment;

Fig. 13 (c) is a right side view of the fourth embodiment;

Fig. 14 (a) is a schematic view showing a fifth embodiment of the present invention;

Fig. 14 (b) is a left side view of the fifth embodiment;

Fig. 14 (c) is a right side view of the fifth embodiment; and

Fig. 15 is a diagram showing a relationship between the sectional area of a tube

and the minimum value of gap length.

Best Mode for Carrying Out the Invention

Mode of embodiment of the present invention will now be described.

Upon lightning stroke, only lightning impulse voltage was discharged in a given distance on the surface of a lightning protection device, and an AC current was blocked off to prevent the breaking and the momentary service interruption. After checking out an AC current blocking characteristic, a discharge characteristic of the lightning protection device and an insulator, an affect on a creeping discharge characteristic by difference in polarity of lightning impulse voltage and its measures, and a required thickness of an insulation cover, a new creeping discharge lightning protection device has been invented in consideration of feasibility, i.e. economical efficiency, working property and the like.

According to one aspect of the present invention, a creeping discharge lightning protection device has a feature to allow a discharge in the surface of the lightning protection device to be occurred earlier than that of an insulator by effect of a back electrode. In addition, a space sandwiched by an insulated wire has a structure less subject to an electric field to the earth so that polar effect to creeping discharge may be reduced and thereby discharge characteristic may be enhanced.

In a creeping discharge lightning protection device according to a second aspect of the present invention, a discharge is yielded within a tube to increase the pressure in the tube, and a gas inside the tube is discharged from one open end or both open ends of the tube. This enables to enhance the AC arc-suppression performance and shorten the required gap length. Thus, upon lightning stroke, the discharge in the tube can be occurred earlier than that of the insulator.

According to a third aspect of the present invention, a creeping discharge lightning protection device has a feature to achieve an improved lightning protection performance and a compact structure by yielding some discharge of a back electrode within a tube to enhance the creeping discharge characteristic and AC arc-suppression performance. This lightning arrester may include a back electrode having a tubular shape less subject

to an electric field to the earth so that the polar effect of creeping discharge may further be reduced.

1. Outline of Test

A test was performed to determine an insulation performance of an insulated wire and an insulating tube, and a discharge voltage caused by creeping discharge. An outline of test device is shown in Fig. 1. The insulated wire 1 with a cover 2 was supported by a pin insulator 3, and both were secured to each other by a copper band of 1.2mm in diameter. A discharge electrode 4 was provided by putting in a nail at a portion spaced by 75 cm from this secured position. A lightning impulse voltage ($1.2/50 \mu s$) was applied to one end of the insulated wire 1 with varying its peak value. At this time, a voltage (discharge voltage) arising between the insulated wire and the earth in addition to a time to creeping discharge or through-breakdown was measured by a voltmeter 6. When a characteristic of the insulated wire itself was checked out (without the insulator), the test was performed with short-circuiting the insulator 3 by a copper band. When an insulating performance of the insulating sheath itself was checked out, the test was performed with providing no nail not to make creeping discharge arise.

2. Test Result

Fig. 2 shows a relationship between a thickness of the insulating sheath and a maximum applied voltage not to bring about through-breakdown in the insulating sheath, for both cases that only the insulated wire was provided and the creeping discharge electrode was additionally provided. From Fig. 2, when the creeping discharge electrode was additionally provided, higher voltage may be applied as compared to the case of the insulated wire itself. This proves that the creeping discharge limits the voltage acted upon the insulating sheath. It is also proved that this effect is noticeable in larger thickness of the insulating sheath and in a negative polarity of voltage (the voltage makes the conductor of the insulated wire have a negative pole and makes the earth side have a positive pole). When the negative polarity of voltage was applied, the maximum applied voltage was exponentially increased at 4mm or more thickness of the insulating sheath and the through-breakdown did not arise even at 6,200kV of applied

voltage. Fig. 3 shows a discharge voltage of the insulating sheath in creeping discharge. In respect that the discharge voltage is dispersed in the range of 120 to 180kV regardless of the applied voltage when the insulator is not combined, it may be understood with high possibility that the insulated wire having a particular level of insulating performance arises no through-breakdown even if the applied voltage is increased. The discharge voltage is dispersed in the range of 200 to 300kV when the insulator is combined. This may be caused by the extended time to creeping discharge due to the combined insulator and the increased voltage acting upon the insulating sheath during this extended time.

In order to check the affect of polarity of applied voltage in creeping discharge, a voltage - time characteristic of creeping discharge (Fig. 4) and a relationship between applied voltage and time to flashover (Fig. 5) were determined. It is proved that the positive polarity causes considerably higher voltage than that of the negative polarity (Fig. 4).

Since the time to flashover in the positive polarity is longer than that in the negative polarity (Fig. 5), it may be supposed that the creeping discharge in the positive polarity cannot be smoothly formed than that in the negative polarity. Thus, it is understood that the positive polarity of creeping discharge causes higher discharge voltage due to longer time to flashover (Fig. 4), resulting in lower maximum applied voltage (Fig. 2).

In view of practical applications, this affect cannot be ignored. Thus, two techniques has been invented to settle the affect of the polarity, and their advantage has also been confirmed through a test. In the positive polarity of creeping discharge, the electric field on the surface of the insulated wire is modified because free electrons in space is constrained due to the affect of electric field on the surface of the insulated wire and cannot contribute to develop creeping discharge.

< A First Test Example >

Fig. 6 is a sectional view showing a construction of the first test example. An insulated wire 7 for modifying electric field is positioned close to the insulated wire 1

between the insulated wire 1 and the earth. Each conductor portion 8 located in the both ends of the insulated wire 7 for modifying electric field is connected to the conductor of the insulated wire 1 at the position spaced by 75 cm from the insulator 3 and is insulated by an insulating cover 9.

< A Second Test Example >

Fig. 7 is a sectional view showing a construction of the second test example. An insulated wire 10 for an earth side back electrode is positioned on the earth side with respect to the insulated wire 1. A conductor portion 11 located in one end of the insulated wire 10 and having an un-insulated conductor is connected to an earth terminal of the insulator 3, while an insulated portion 12 located in another end of the insulated wire 10 and having an insulated conductor is insulated to the insulated wire 1 by an insulating member 12.

As shown in Fig. 8, according to the technique using the insulated wire 7 for modifying electric field, even in the positive polarity of creeping discharge, a voltage - time characteristic can be improved to show a similar to that in the negative polarity of creeping discharge so as to facilitate creeping discharge. According to the technique using the insulated wire 10 for an earth side back electrode, the flashover arises on the surface of the insulated wire 1 (main line) upon applying the negative polarity of voltage, while the flashover arises on the surface of the insulated wire 10 for an earth side back electrode upon applying the positive polarity of voltage. As a result, 4mm of the insulated wire which has otherwise arisen through-breakdown at 854kV upon applying the positive polarity of voltage does not arise through-breakdown even if applying the positive polarity of voltage 6,200kV as well as the case of the negative polarity of voltage.

< Direct Lighting Stroke Test with Actual Scale Simulated Distribution Line >

The technique of the present invention was applied to the simulated distribution line. Then, a lightning impulse heave - current (maximum current value 17kA, $1.5/11 \mu s$) generated by a large impulse generator (maximum generating voltage 12MV) was

applied to confirm whether creeping discharge can be formed over a required distance (75cm).

The test result is shown in Table 1

(see pages 14a to 14f)

From this test result, with respect to a required insulation thickness for 75cm of creeping discharge, the following facts can be remarked in case of the lightning stroke having about 17kA of lightning impulse current peak value (occurrence frequency: about 30%).

(1) In the case with overhead earth-wire, a creeping discharge can be formed without through-breakdown by 4mm or more of insulation thickness of power cable. In the case without overhead earth-wire, a creeping discharge can be formed without through-breakdown by 6mm or more of insulation thickness of power cable

(2) Using the technique to solve the problem on the polarity of lightning, a required thickness can be reduced to 3mm or more of sheath thickness of the insulated wire in the case with overhead earth-wire, and to 4mm or more of insulation thickness of power cable in the case without overhead earth-wire.

< Embodiment >

Embodiments of the present invention will now be described. Fig. 9 shows a structure of one embodiment of a creeping discharge arrester according to the present invention, and Fig. 10 shows its detail (in both cases, an overhead power line is an insulated wire). In the drawings, the reference number 1 indicates an insulated wire, the reference number 2 indicating a sheath, the reference number 3 indicating a pin insulator, the reference number 4 indicating a discharge electrode, the reference number 13 indicating a bolt portion (high voltage arm) of the pin insulator 3, the reference number 14 indicating a lightning protection device body, the reference number 15 indicating exposed conductor portions, the reference number 16 indicating an insulation sheath portion, the reference number 17 indicating a splicing fitting for connecting the exposed conductor portions mutually, the reference number 18 indicating a reinforcing cover for preventing a fatigue breaking of the exposed conductors portions 15, and the reference number 19 indicating an insulating/retaining cover for retaining the discharge electrode 4 and the insulation sheath portion 16 and reinforcing these portions.

The lightning protection device body 14 is formed of an insulated wire insulated to

the same extent as a power cable and is folded into two. Thus, the exposed conductor portions 15 locate at one end of the insulated wire and have exposed conductors, while the insulating sheath portion 16 locates at another end of the insulated wire and is insulated. Two of the exposed conductor portions 15 are connected and united by the splicing fitting 17, and are connected to an earth side, e.g. the bolt portion 13, of the pin insulator 3. The insulating sheath portion 16 is secured to the discharge electrode 4 mounted on the insulated wire 1 by the insulating/retaining cover 19. At this time, an insulated wire 1 is penetrated by a needle electrode of the discharge electrode 4 so as to bring about through-breakdown in advance,

In this embodiment, when a lightning over-current occurs at the insulated wire 1, a flashover arises on the surface of a creeping discharge type of the lightning protection device body 1 disposed between the discharge electrode 4 and the bolt portion (high voltage arm) of the pin insulator 3. However, since an AC short-circuit is not induced, any breaking of the insulated wire and momentary service interruption never arise.

While the overhead earth-wire is the insulated wire in the embodiment in Figs. 9 and 10, if the overhead earth-wire is a bare wire, the insulating sheath portion 16 of the lightning arrester 14 is positioned directly on the overhead earth-wire.

Fig. 11 shows a second embodiment, in which a discharge electrode is provided at both end of an insulating tube 20 the one or both ends of which are opened. One discharge electrode 21 is connected to the discharge electrode 4 mounted on the insulated wire 1, while another discharge electrode 22 is connected to the bolt portion 13 of the pin insulator 3.

In the lightning protection device of the second embodiment, a discharge is yielded within the tube 20 to increase the pressure in the tube 20, and a gas inside the tube is discharged from one open end or both open ends of the tube. This enables to enhance the AC arc-suppression performance and shorten the required gap length. Thus, upon lightning stroke, the discharge in the tube 20 can be occurred earlier than that of the insulator.

Fig. 12 shows a third embodiment, in which an insulating tube 23, the one end or

both ends of which are opened, covers outside the creeping discharge lightning protection device body 14 of the first embodiment of Figs. 9 and 10. As is the case with the first embodiment, one end of the lightning protection device body 14 is connected to the overhead power line (e.g. the insulated wire 1), while another end thereof is connected to the earth side (e.g. the bolt portion 13) of the pin insulator 3.

Fig. 13 shows a fourth embodiment, in which an insulating tube 24, the one end or both ends of which are opened, is sandwiched by the insulated wire of the creeping discharge lightning protection device body 14 of the first embodiment so as to position the insulating tube 24 on the inside of the insulated wire of the creeping discharge lightning protection device body 14, and an electrode 25 to be connected to the overhead power line is inserted into one open end of the insulating tube 24 located on the side of the insulating sheath 16. As is the case with the first embodiment, one end of the lightning protection device body 14 is connected to the overhead power line (e.g. the insulated wire 1), while another end thereof is connected to the earth side (e.g. the bolt portion 13) of the pin insulator 3.

Fig. 14 shows a fifth embodiment, in which a back electrode 28 is provided inside or within an insulating layer 27 of an insulating tube 26, the back electrode 28 being sufficiently insulated at one end of the insulating tube 26 and exposed at another of the insulating tube 26, an electrode 29 to be connected to the overhead power line being inserted into the one end of the insulating tube 26 which insulates the back electrode 28, an electrode 30 to be earthed being provided at the other end of the insulating tube 26 which exposes the back electrode 28 and also being connected to the back electrode 28, the electrode 29 being connected to the overhead power line, and the electrode 30 being connected to an earth side of an insulator 30.

According to the second to fifth embodiments, there is provided a feature to achieve an improved lightning protection performance and a compact structure by yielding some discharge of the back electrode within the tube to enhance the creeping discharge characteristic and AC arc-suppression performance. Particularly, in the lightning protection device of the fifth embodiment, the back electrode has a tubular

shape less subject to an electric field to the earth so that an affect of a polar effect of creeping discharge may further be reduced.

(1) Maximum value of gap length (L_{gmax})

In a direct lightning stroke having 17kA of lightning impulse current to the main wire, the maximum value of gap length not to make the pin insulator spark over is determined.

(see pages 14a to 14f)

From this test results, considering that No.6 insulator should be protected and the thickness of the insulating tube should be 6mm or less, L_{gmax} is set in 30cm.

(2) Inside diameter of tube and Minimum value of gap length (L_{gmin})

An affect of inside diameter of tube was checked on. The test was performed with 1m of tube the both end of which are opened. Test piece: EPR 4.8ϕ , glass 6ϕ , chloroethene 12ϕ , acrylic 18ϕ .

The result is shown in Fig. 15.

From the result of Fig. 15, it is proved that L_{gmin} becomes longer in direct proportion to the sectional area of the tube in the range of 6ϕ or more of inside diameter, and L_{gmin} becomes longer as the inside diameter is small (4.8ϕ).

(3) Condition in transition to AC

The condition in the transition to AC was observed. Even in the transition to AC (12ϕ , gap length 25cm), an arc caused by short-circuit current is suppresses within a half wave and thus have few affect to the system. An excellent force line charging can also be obtained, and it may be judged that any problem of power supply will be free from care even in the failure of lightning protection, because an arc caused by re-lightning stroke can be suppresses within a half wave

As described above, the present invention provides the following advantages.

(1) Since the breakdown voltage of the creeping discharge lightning protection device is lower than that of the insulator, it is not in association with the insulation performance of overhead power line. (It is possible to device a countermeasure to any existing equipment.)

(2) The discharge voltage can be limited lower because of the structure not to be combined with insulators. (Supposedly, the discharge voltage is equal to or less than that of No.10 insulation.)

(3) By arranging two insulated wires along each other, there is provide a space having modified electric field on the surface of aerial line so that stable flashover can be generated regardless the polarity of lightning over-current caused in the overhead power line.

- (4) This device can be applied not only to path portion but also arresting portion.
- (5) An excellent working property is provided to mount this device.
- (6) By thinning the conductor located inside the creeping discharge lightning protection device and using it as a fuse, the AC dynamic current can be blocked even in failure of creeping discharge (through breakdown).
- (7) The cost for measures to lightning protection can be reduced more than that of ZnO.
- (8) Free from the limited amount of resistance against discharge as in ZnO.

Industrial Applicability

The present invention can be utilized in a creeping discharge lightning protection device for preventing breaking of insulated wire and momentary service interruption of power system due to lightning surge arising close on supporting insulator in overhead power lines.

2. 実験結果

試験結果を表 1 に示す。

5
10
15
20
25

表 1

供試品	架空地線有り、雷撃箇所：柱頂部				架空地線無し、雷撃箇所：柱頂部				架空地線無し、雷撃箇所：本線			
	⑨ 正極性		⑪ 負極性		正極性		負極性		正極性		負極性	
	柱体	100Ω	50Ω	柱体	100Ω	50Ω	柱体	100Ω	50Ω	柱体	100Ω	50Ω
⑦ 碍子	○	○	○	○	○	○	○	○	○	○	○	○
⑧ 電線	○	○	○	○	○	○	○	○	○	○	○	○
⑫ 耐電圧	○	○	○	○	○	○	○	○	○	○	○	○
90kV	ケーブル 6mm	○	○	○	○	○	○	○	○	○	○	○
	ケーブル 4mm	○	○	○	○	○	○	○	○	○	○	○
	OE-5mm	○	○	○	○	○	○	○	○	○	○	○
60kV	OE-4mm	○	○	○	○	○	○	○	○	○	○	○
	OC-3.5mm	○	○	○	○	○	○	○	○	○	○	○
	OC-3.0mm	○	○	○	○	○	○	○	○	○	○	○
20kV	OE-2.5mm	○	○	○	○	○	○	○	○	○	○	○
	OE-2mm	○	○	○	○	○	○	○	○	○	○	○

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯

○：非破壊(沿面放電)
×：貫通破壊
☆：電界緩和用絶縁電線を用いることにより非破壊
＊：接地側背後電極を用いることにより非破壊

14b

片端には接地側電極 30 を設けて背後電極 28 と接続し、電線接続側電極 29 を架空線路、接地側電極 30 を碍子接地側に接続したものである。

以上の第 2 ～ 第 5 実施例によれば、背後電極のある放電をチューブ内で行うことにより、沿面放電特性と AC 消弧性能を向上させ、避雷性能の向上とコンパクト化が図れることを特徴としている。特に、第 5 実施例の避雷装置は、背後電極がチューブ形状をしているため、対地との電界の影響を全く受けない形状となっており、沿面放電の極性効果の影響をさらに低減している。

本発明の沿面放電避雷器のギャップ長 L_g を求める実験を次のように行った。

(1) ギャップ長最大値 (L_{gmax})

雷インパルス電流 17 kA の本線直撃において、ピン碍子がスパークオーバーしないギャップ長最大値 (L_{gmax}) を求める。

表 2

絶縁電線	沿面放電避雷器適用		(参考) 通常の沿面放電	
	正極性	負極性	正極性	負極性
ケーブル 6mm			○	○
ケーブル 4mm			x	○
絶縁電線 5mm	○	○	x	x
絶縁電線 4mm	○	○	x	x
絶縁電線 3.5mm	○	○		
絶縁電線 3mm	○	○		
絶縁電線 2.5mm	—	—		
絶縁電線 2mm	—	—		
裸電線	x	○		

○: 沿面放電 x: 貫通破壊 —: 試験未実施

この実験結果から、6 号碍子の保護と絶縁チューブ厚さ 6 mm 以下を考慮し、 $L_{gmax} = 30 \text{ cm}$ とする。

(2) チューブ内径とギャップ長最小値 (L_{gmin})

チューブ内径の影響を確認する。チューブ長 1 m、両端開放で実験を実施した。供試品: EPR 4.8 φ、ガラス 6 φ、塩化ビニル 12 φ、アクリル 18 φ。

その結果を図 15 に示す。

P.6

Table 1

14c

- ① 供試品 : test piece
- ② 架空地線有り : w overhead earth-wire
- ③ 雷撃箇所 : lightning stroke portion
- ④ 柱頂点 : top of pole
- ⑤ 架空地線無し : w/o overhead earth-wire
- ⑥ 本線 : insulated wire (=絶縁電線)
- ⑦ 碍子耐電圧 : withstand voltage of insulator
- ⑧ 電線 : wire
- ⑨ 正極性: positive polarity
- ⑩ 柱体: pole member
- ⑪ 負極性: negative polarity
- ⑫ ケーブル:cable
- ⑬ 非破壊 (沿面放電) : non-breaking
- ⑭ 貫通破壊: puncture
- ⑮ 接地 — — — — non-breaking by using earth side back electrode
- ⑯ 電界 — — — — non-breaking by using electric field modifying insulated wire

Table2

- ⑰ 絶縁電線 : insulated wire
- ⑱ 沿面放電 — — — — : w creeping discharge lightning arrester
- ⑲ (参考) — — — — : (c.f.) regular creeping discharge lightning arrester
- ⑳ 正極性 : positive polarity
- ㉑ 負極性 : negative polarity
- ㉒ ケーブル : cable
- ㉓ 絶縁電線 : insulated wire

14d

- ②③ 沿面放電 : creeping discharge
- ②④ 貫通破壊 : puncture
- ②⑤ 試験未実施 : no test

Fig. 1

- ②⑥ 絶縁電線 : insulated wire
- ②⑦ 放電電極 : discharge electrode

Fig. 2

- ②⑧ 貫通しない — — — — : maximum applied voltage not to bring about puncture
- ②⑨ 放電電極有り : w discharge electrode

- ③⑩ 絶縁電線単独 : only insulated wire
- ③⑪ 負極性放電 : negative polarity of discharge
- ③⑫ 正極性放電 : positive polarity of discharge

- ③⑬ 絶縁 — — — — : sheath thickness of insulated wire

Fig. 3

- ③⑭ 西電チューブ : Tube N
- ③⑮ 絶縁電線 : insulated wire
- ③⑯ レイケムチューブ : Tube R
- ③⑰ 高密度ポリ管 : high density polyethylene tube
- ✱ ③⑱ 10号がいし : insulator #10
- ✱ ③⑲ 6号がいし : insulator #6
- ③⑳ 制限電圧 : discharge voltage

14e

- ③⑨ 印加電圧 : applied voltage
- ④⑩ 印加電圧と — — — — — : relationship between applied voltage and discharge voltage

- ④① がいしと複合 : w insulator
- ④② がいしなし : w/o insulator

Fig.4

- ④③ 発生電圧 : voltage
- ④④ フラッシュ — — — — — : time to flashover
- ④⑤ 負極性 : negative polarity
- ④⑥ 正極性 : positive polarity

Fig. 5

- ④⑦ F.O — — — : time to flashover

- ④⑧ 貫通破壊 : puncture

- ④⑨ 負極性 : negative polarity
- ⑤⑩ 正極性 : positive polarity

- ⑤① 印加電圧 : applied voltage

Fig. 6

- ⑤② 絶縁カバー : insulating cover
- ⑤③ 電界 — — — — — : insulated wire for modifying electric field

Fig. 7

- ⑤④ 絶縁物 : insulation member

14f

⑤⑤ 接地 — — — — — : insulated wire for back electrode to be earthed

Fig. 8

- ⑤⑥ 電界緩和有り : w
- ⑤⑦ 電界緩和なし : w/o electric field modification
- ⑤⑧ 負極性 : negative polarity
- ⑤⑨ 正極性 : positive polarity
- ⑥① 発生電圧 : voltage
- ⑥② フラッシュオーバーまでの時間 : time to flashover

Fig. 14

- ⑥③ ギャップ長 : gap length
- ⑥④ AC 短絡 : AC short-circuit
- ⑥⑤ 消弧 : arc-suppression
- ⑥⑥ 断面積 : sectional area

Claims

1. In an overhead power line formed of an insulating wire, a creeping discharge lightning protection device comprising a lightning protection device body formed of an insulated wire insulated to the same extent as a power cable and folded into two, said lightning protection device body including an exposed conductor portion and insulating sheath portion, wherein either one of said exposed conductor portion and said insulating sheath portion is connected to an earth portion of an insulator, and another one of said exposed conductor portion and said insulating sheath portion is connected to a discharge electrode provided at said aerial line, wherein said discharge electrode includes a needle electrode which penetrates an insulating sheath of said overhead power line so as to bring about through-breakdown in advance.
2. In an aerial line formed of a bare wire, a creeping discharge lightning protection device comprising a lightning protection device body formed of an insulated wire insulated to the same extent as a power cable and folded into two, said lightning protection device body including an exposed conductor portion and insulating sheath portion, wherein either one of said exposed conductor portion and said insulating sheath portion is connected to an earth portion of an insulator, and another one of said exposed conductor portion and said insulating sheath portion is arranged to said overhead power line.
3. A creeping discharge lightning protection device comprising a discharge electrode provided on both sides of an insulating tube the one end or both ends of which are opened, respectively, wherein one of said discharge electrode is connected to an overhead power line, and another one of said discharge electrode is connected to an earth portion of an insulator.
4. A creeping discharge lightning protection device as defined in claim 1 or 2, which

further includes an insulation tube the one end or both ends of which are opened, said insulation tube covering the outside of said creeping discharge lightning protection device, wherein one end of said lightning protection device is connected to said overhead power line, and another end of said lightning protection device is connected to said earth portion of said insulator.

5. A creeping discharge lightning protection device as defined in claim 1 or 2, which further includes: an insulation tube the one end or both ends of which are opened, said insulation tube sandwiched by said insulated wire of said creeping discharge lightning protection device on the inside of said insulated wire of said creeping discharge lightning protection device; and an electrode to be connected to said aerial wire, said electrode inserted into one open end of said insulation tube located on the side of said insulation sheath of said lightning protection device, wherein one end of said lightning protection device is connected to said overhead power line, and another end of said lightning protection device is connected to said earth portion of said insulator.

6. A creeping discharge lightning protection device comprising: an insulation layer; a back electrode provided inside said insulation layer; an insulating tube the one end of which sufficiently insulates said back electrode and the another end of which exposes said back electrode; an electrode to be connected to an overhead power line, which is inserted into said one end of said insulating tube insulating said back electrode; and an electrode to be earthed, which is provided at said another end of said insulating tube exposing said back electrode, and connected to said back electrode, wherein said electrode to be connected to said overhead power line is connected to said overhead power line, and said electrode to be earthed is connected to an earth portion of an insulator.

1/8

FIG. 1

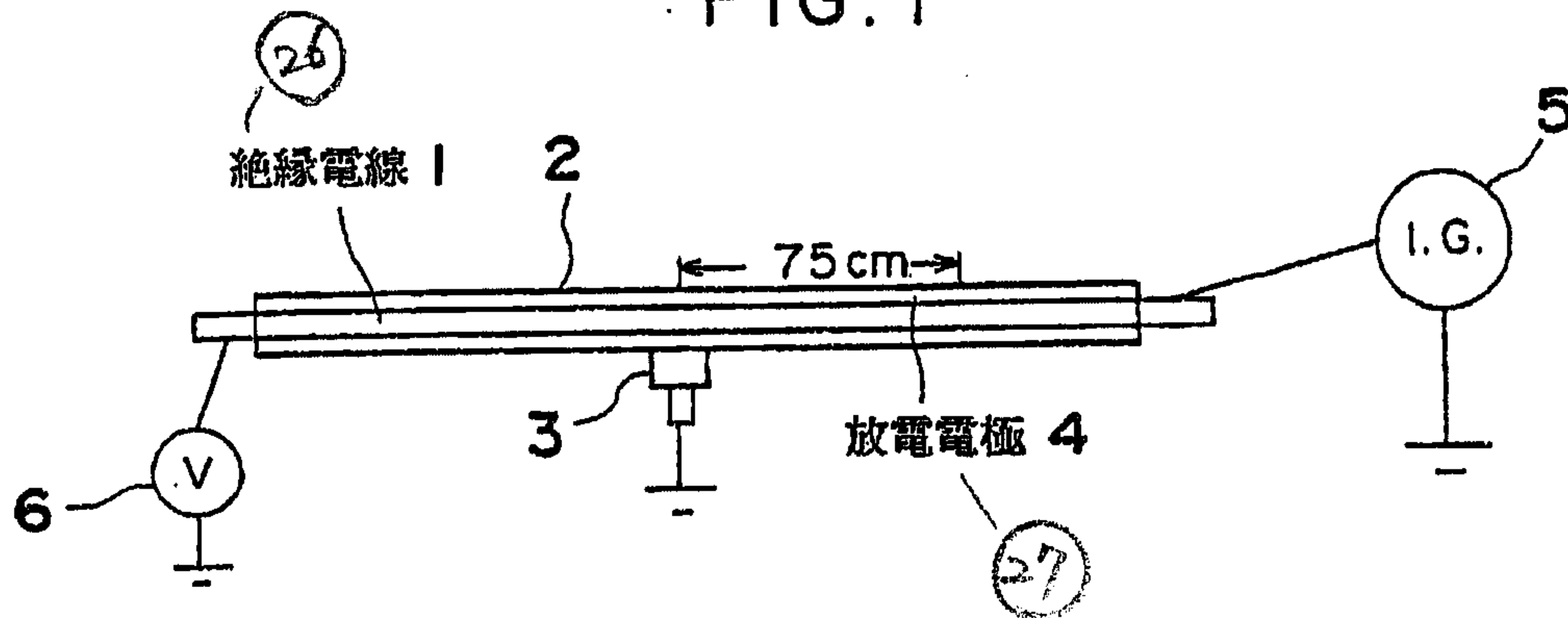
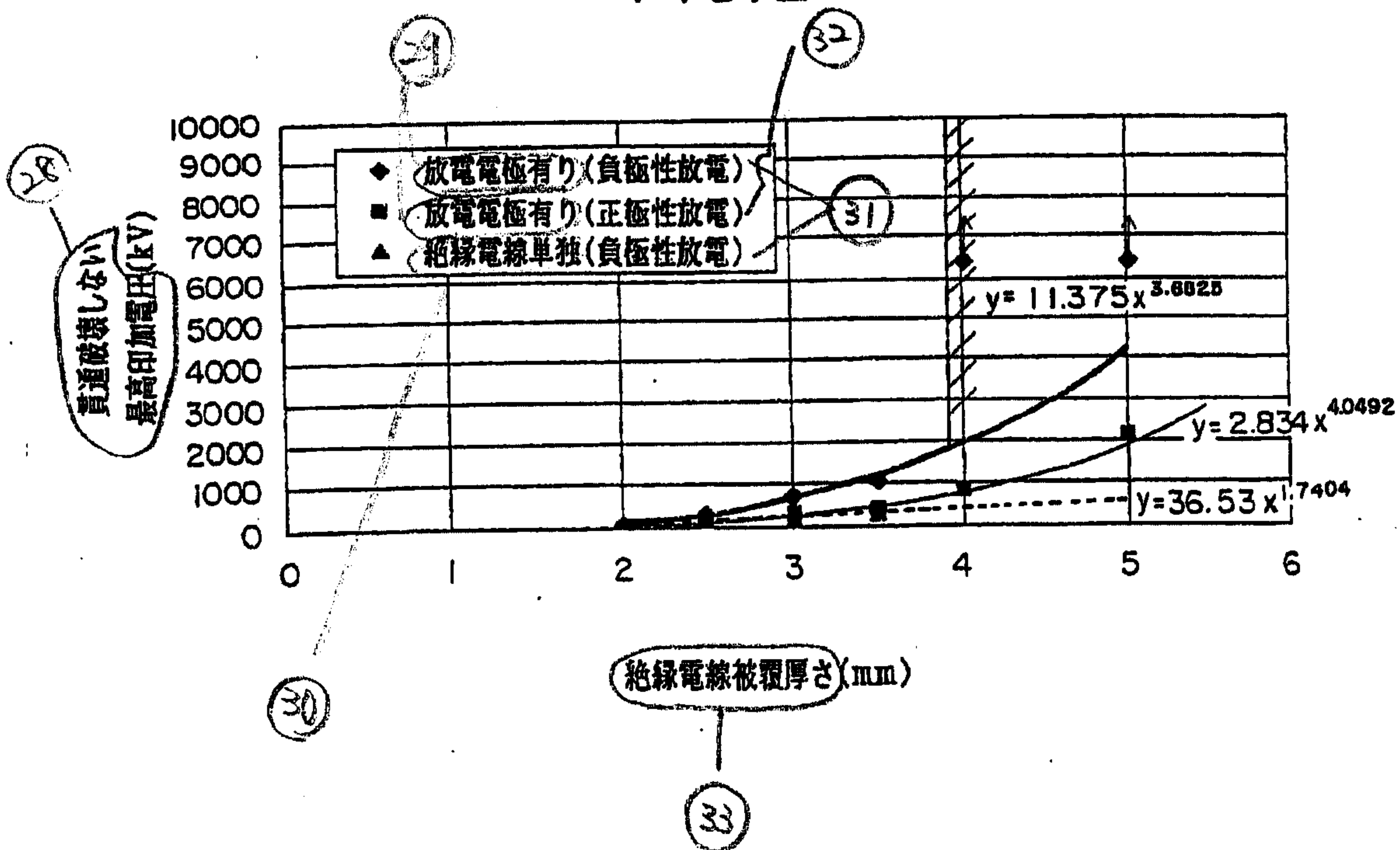


FIG. 2



2/8

FIG. 3

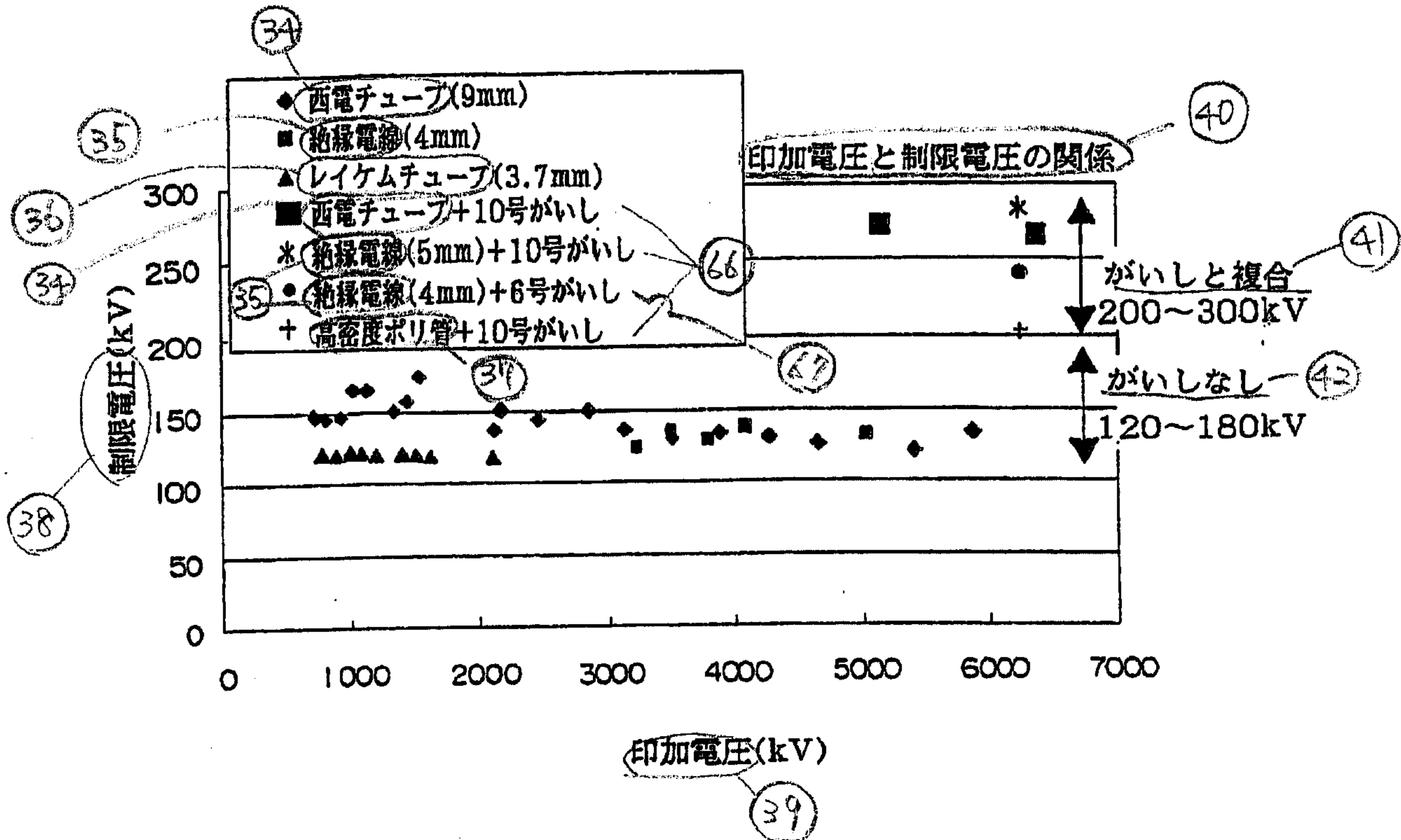
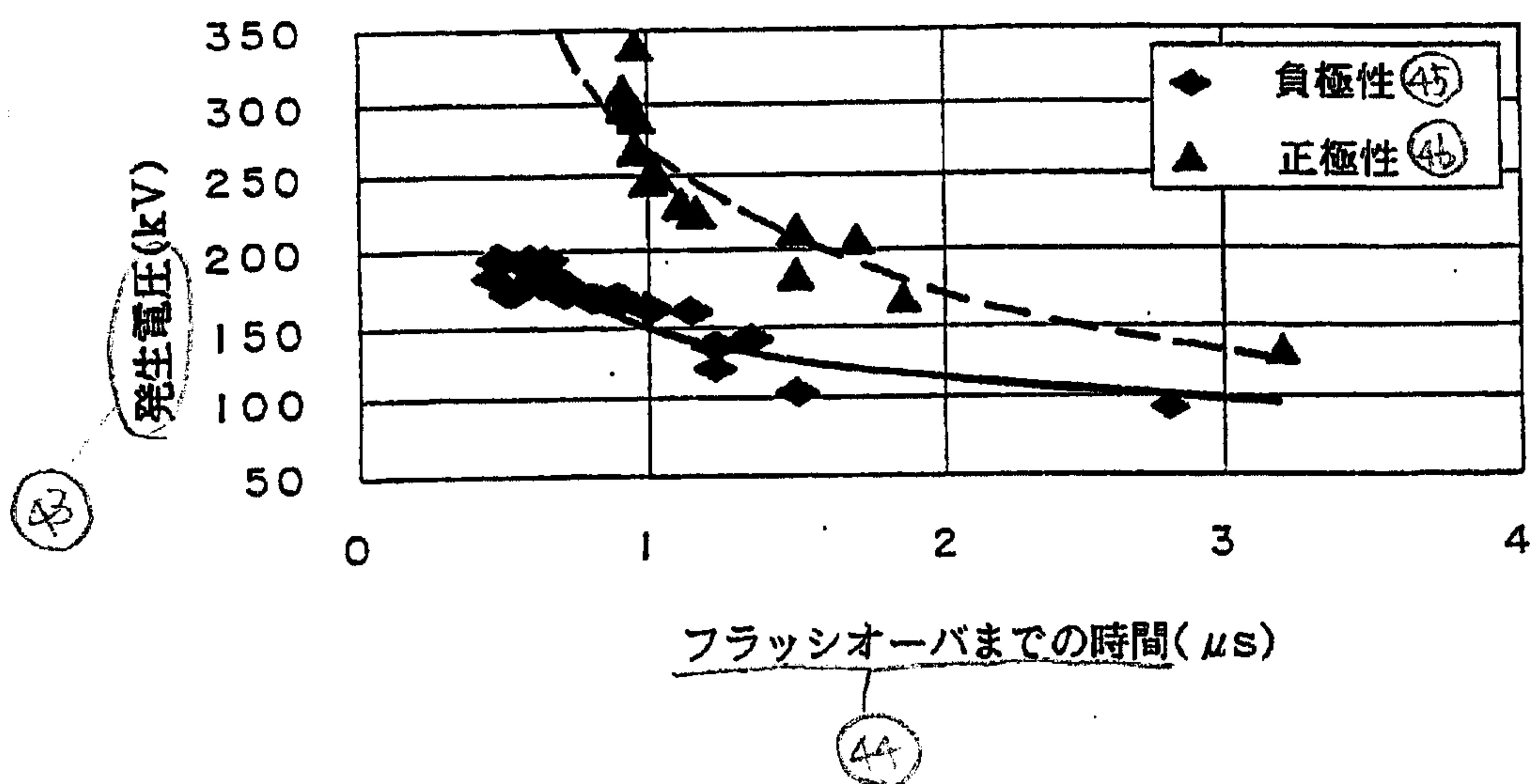


FIG. 4



3/8

FIG. 5

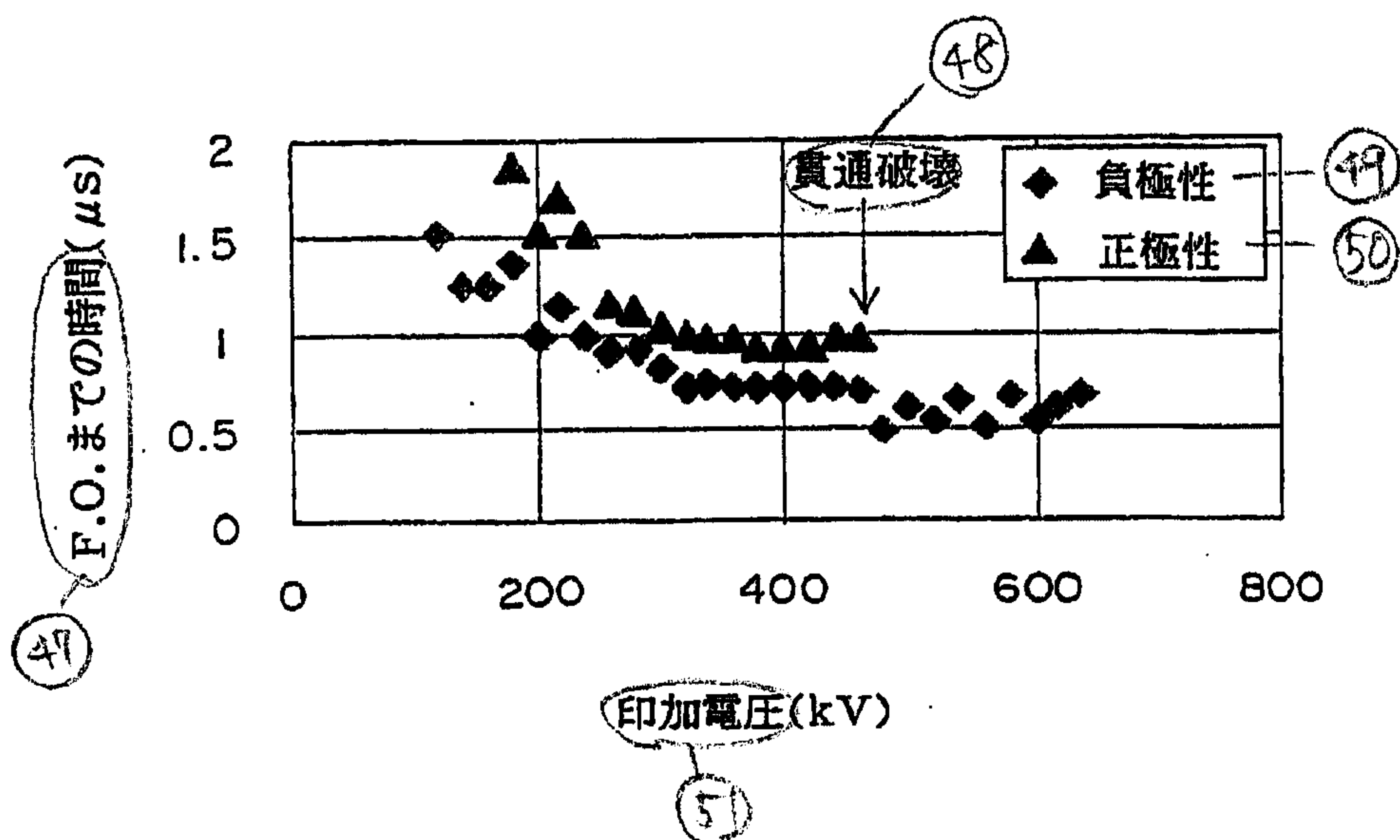
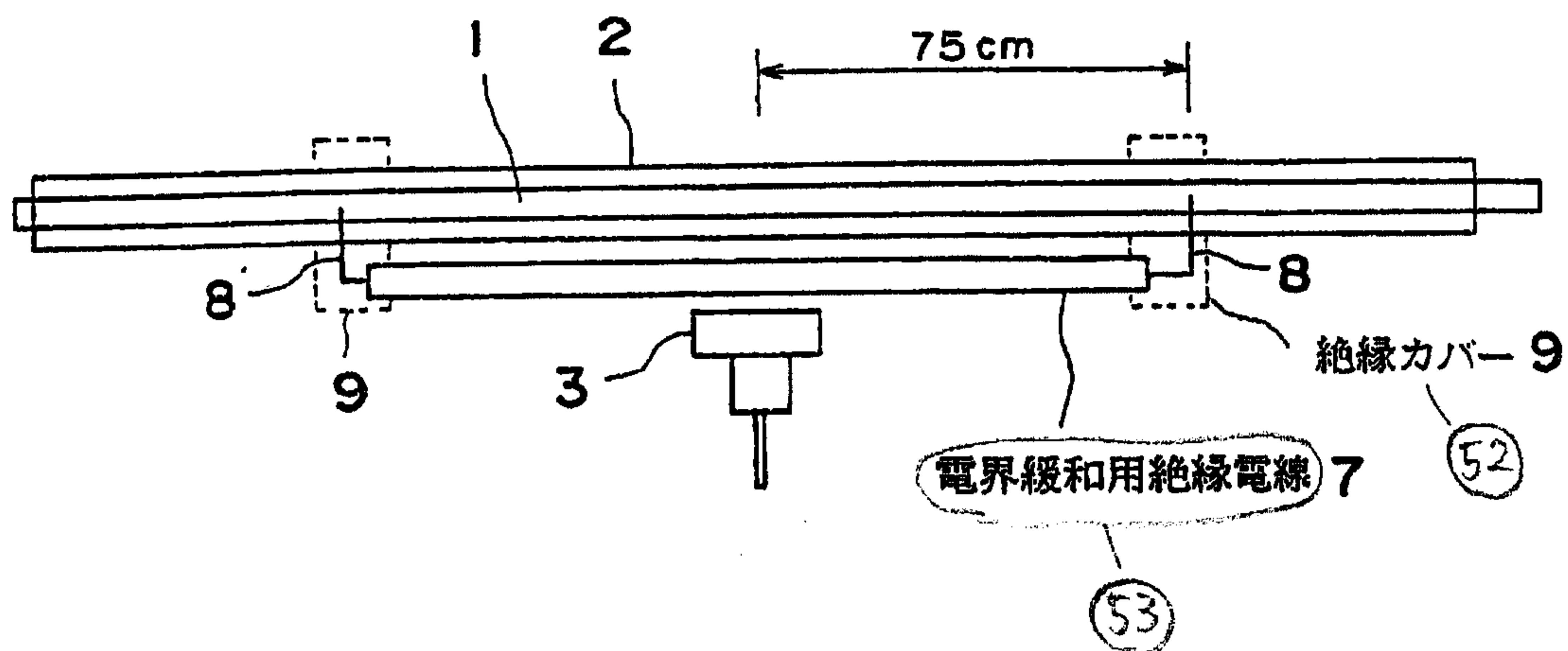


FIG. 6



4/8

FIG. 7

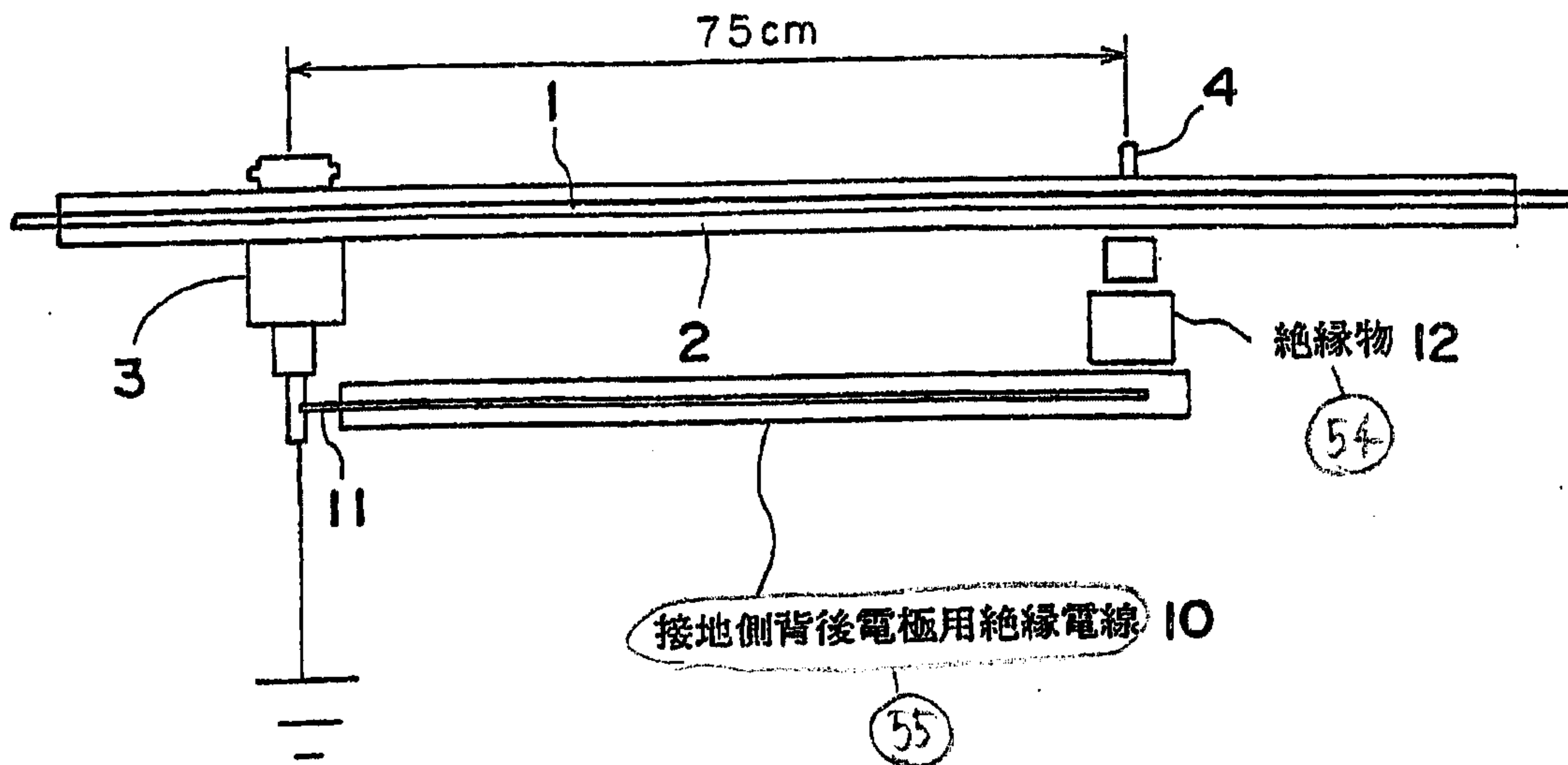
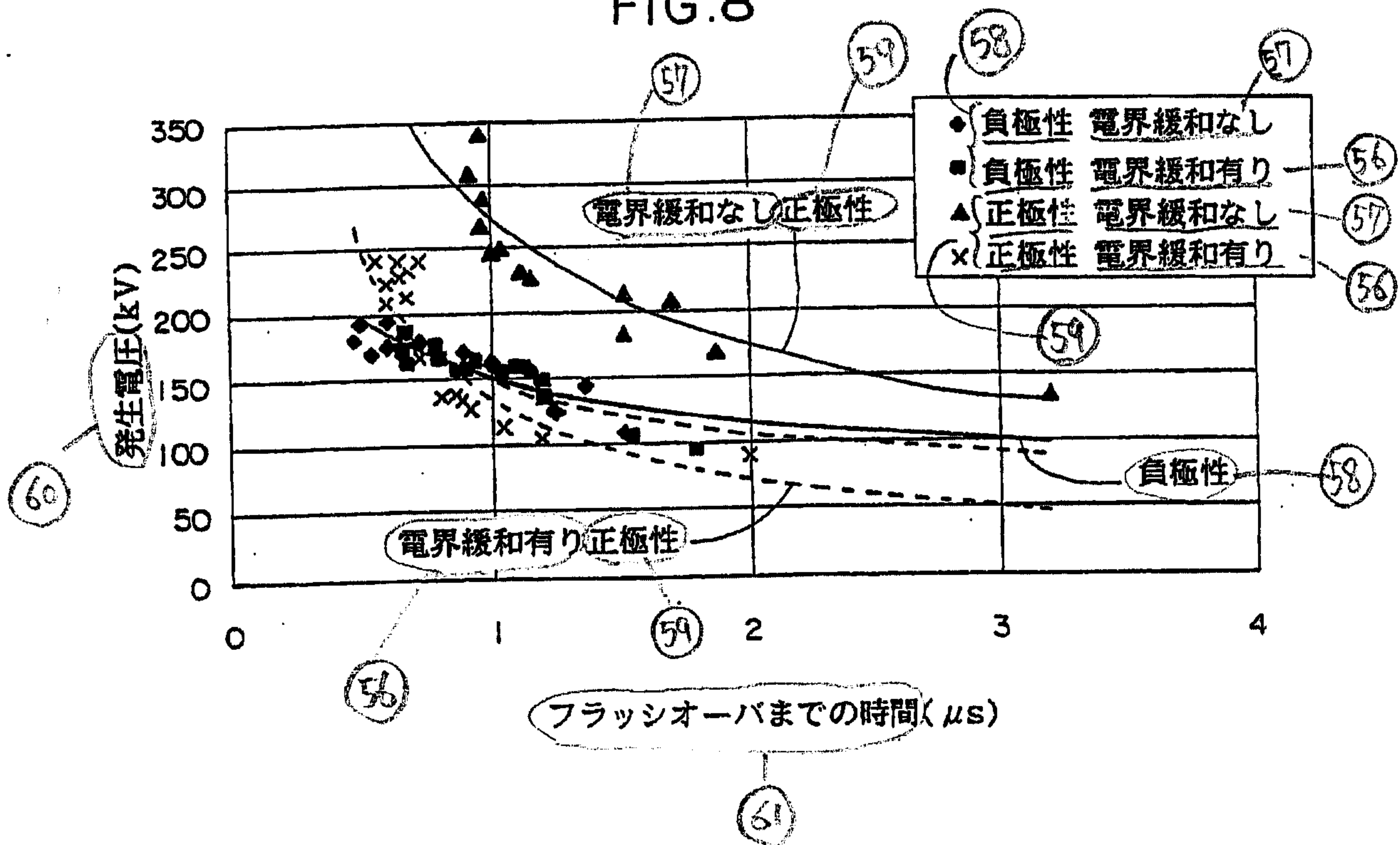


FIG. 8



WO 00/72417

PCT/JP00/03286

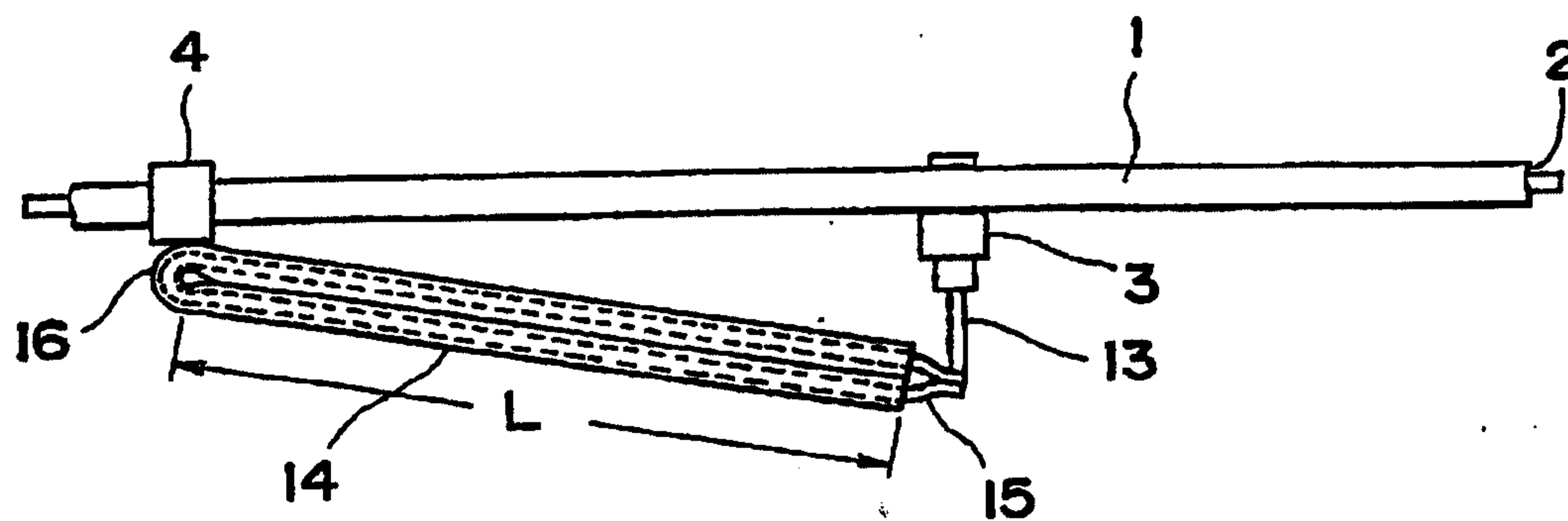
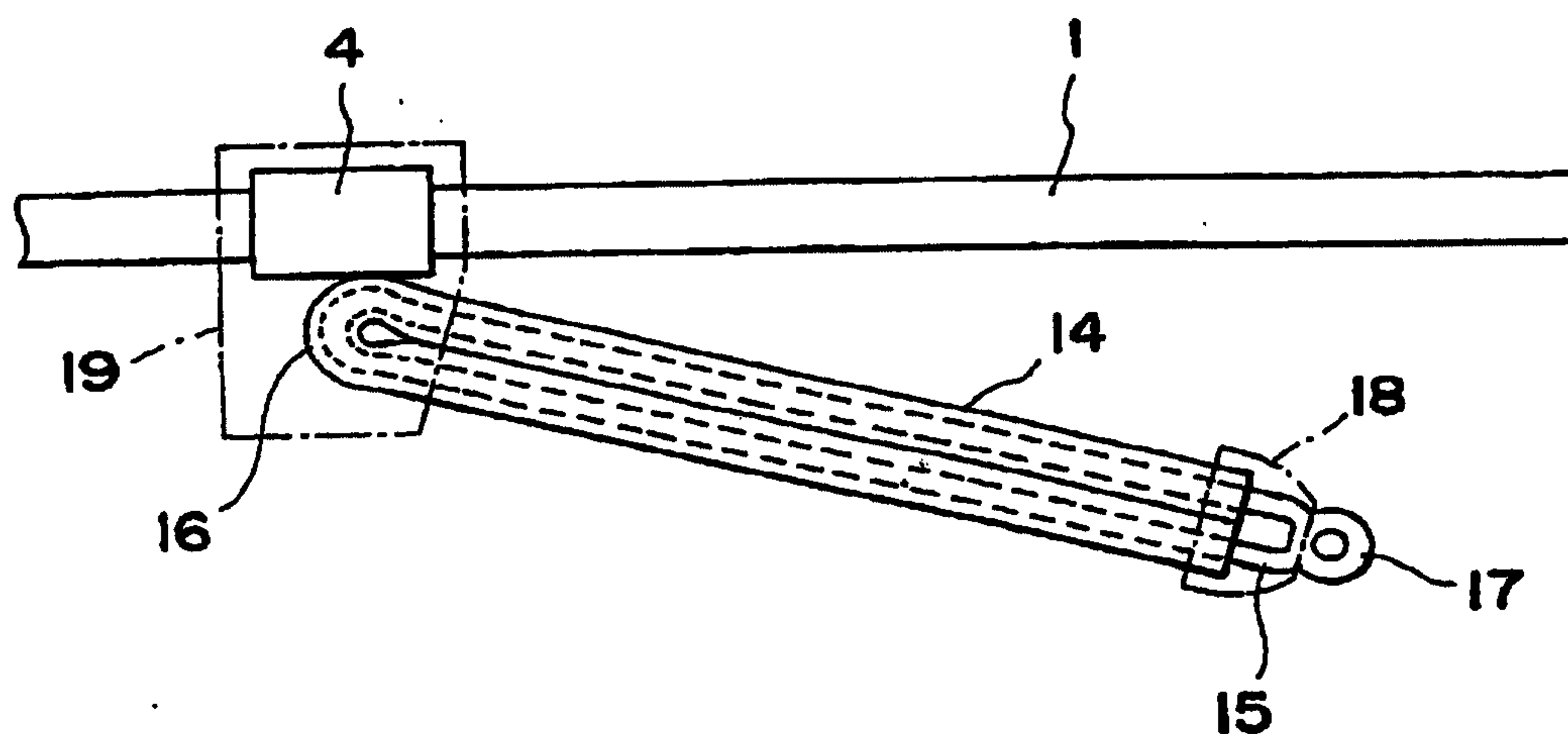
5/8
FIG.9

FIG.10



6/8

FIG. 11

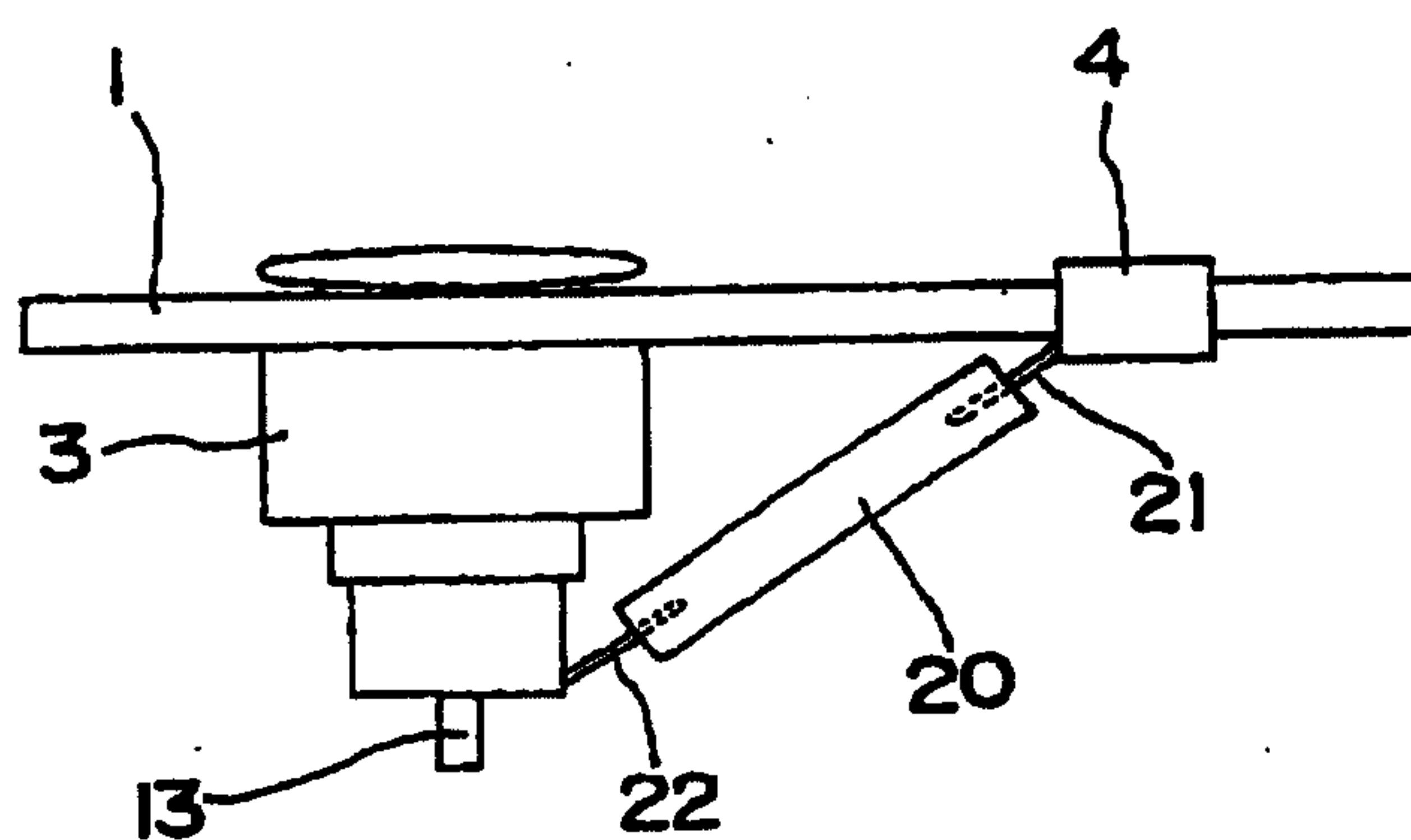
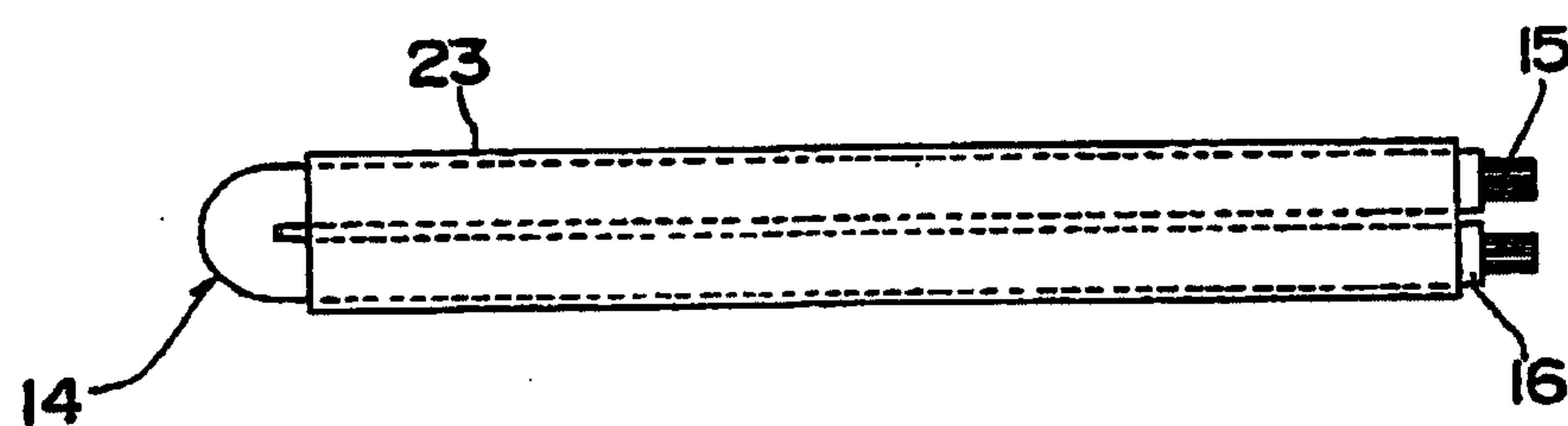


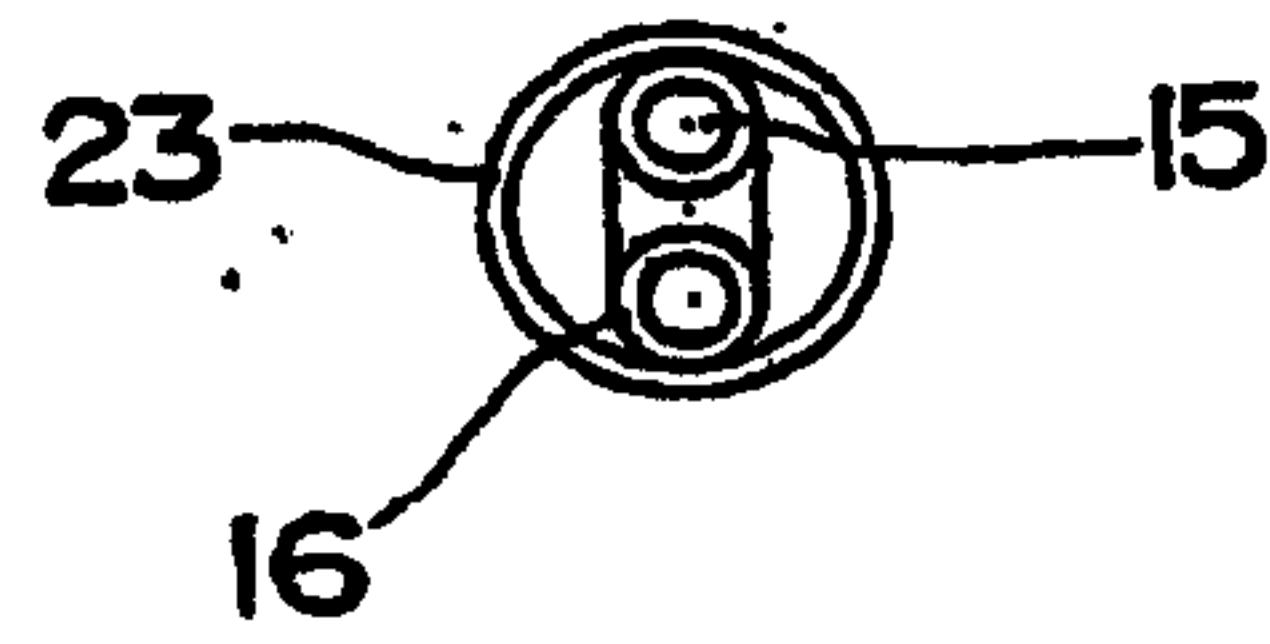
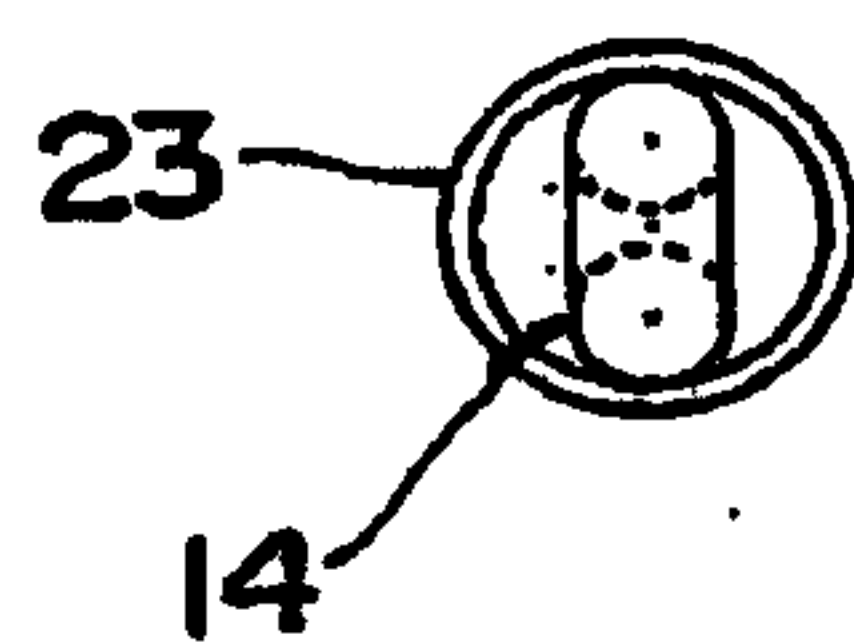
FIG. 12

(a)



(b)

(c)



7/8

FIG.13

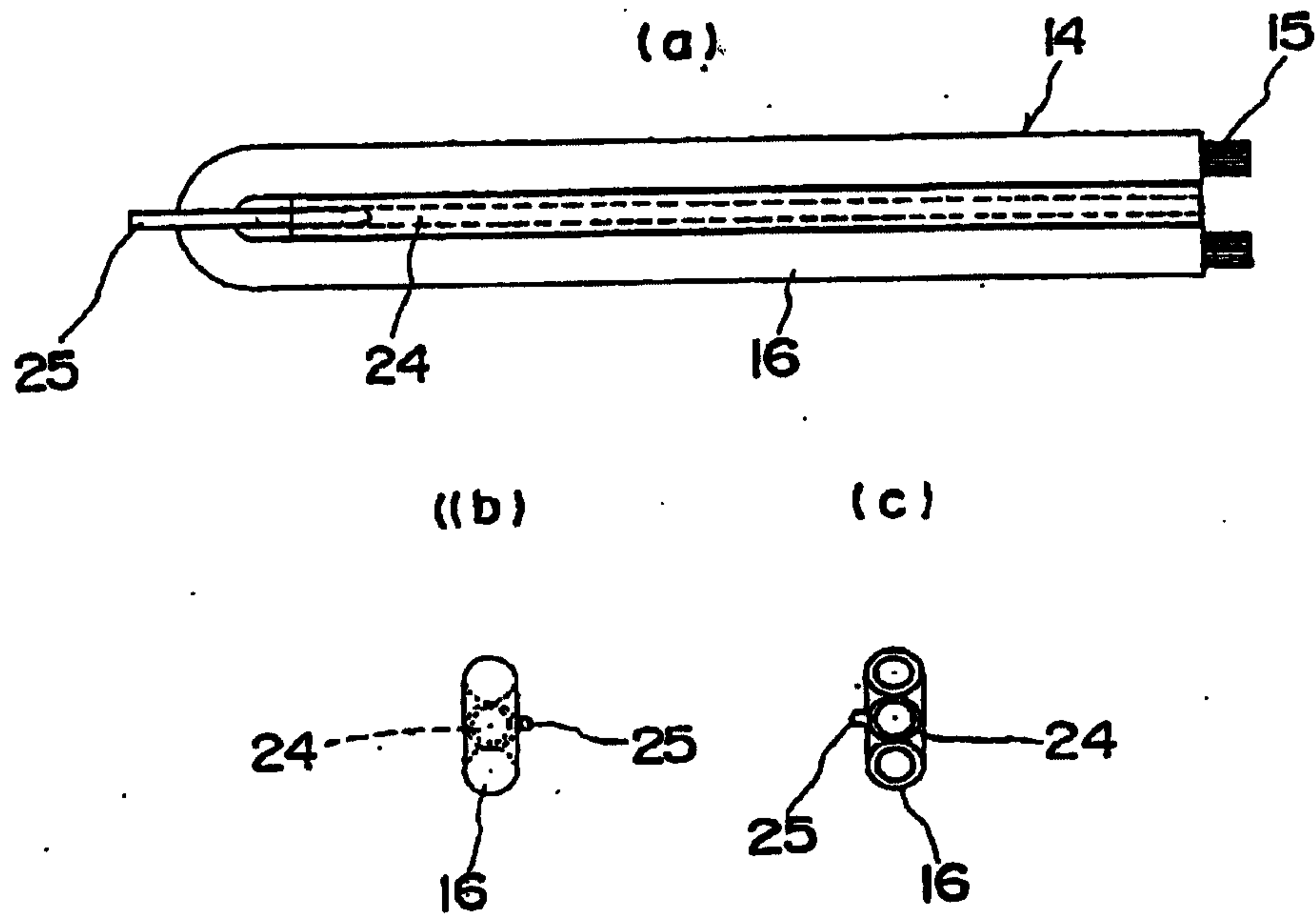
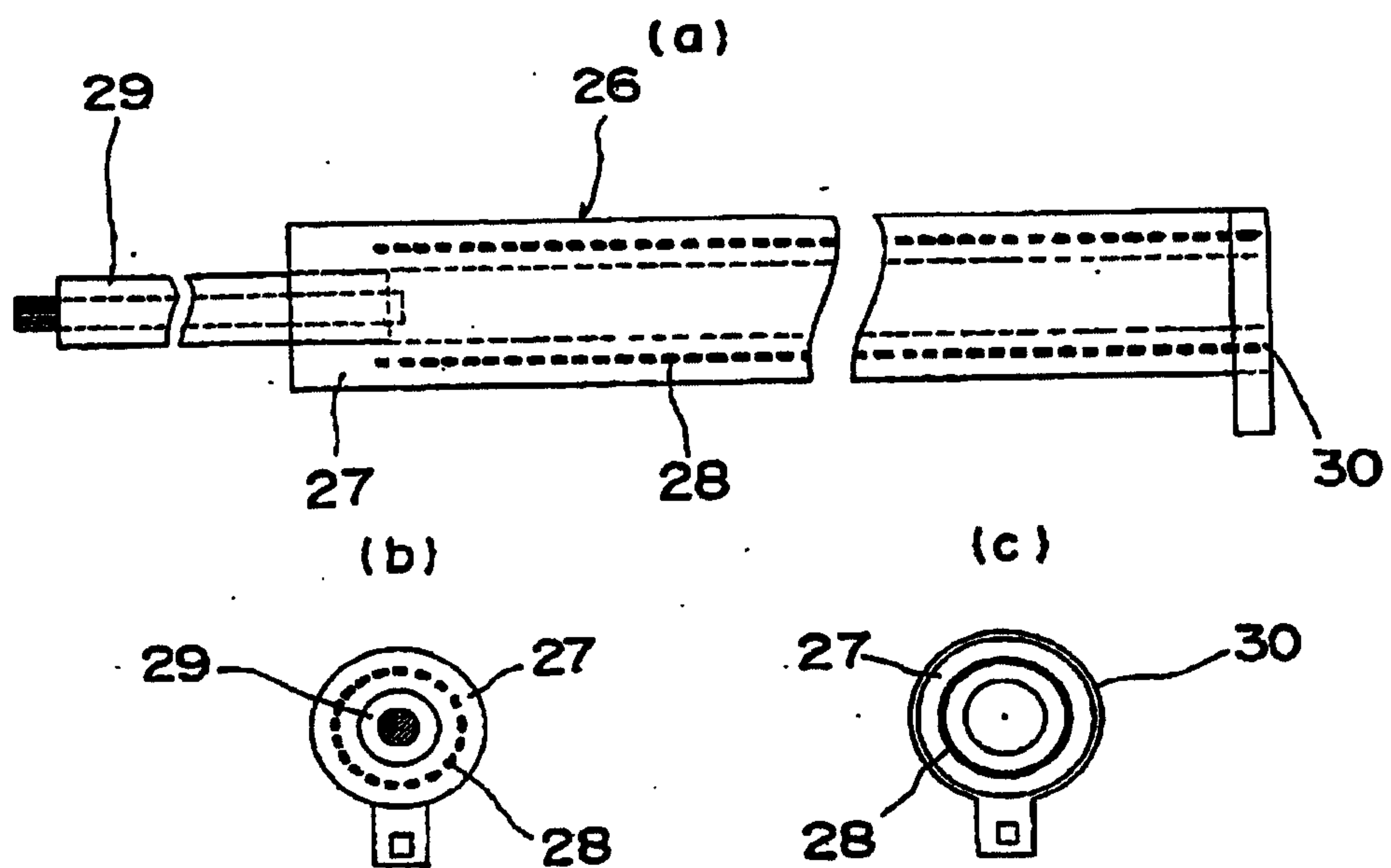


FIG.14



8/8

FIG. 15

