(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 878 829 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.11.1998 Bulletin 1998/47

(51) Int. Cl.[6]: **H01J 61/067**

(21) Application number: **98108867.7**

(22) Date of filing: **15.05.1998**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **16.05.1997 US 857257**

(71) Applicant: **OSRAM SYLVANIA INC.**
Danvers, MA 01923 (US)

(72) Inventors:
- **Jankowski, John T.**
  Contoocook, New Hampshire 03229 (US)
- **Ernest, Brad**
  Concord, New Hampshire 03301 (US)
- **Flanagan, Robert W.**
  Weare, New Hampshire 03281 (US)

(74) Representative:
Lemke, Jörg-Michael, Dipl.-Ing.
Schmiedstrasse 1,
Hausen
86447 Aindling (DE)

(54) Discharge lamp electrode

(57) A discharge lamp electrode with a conductive coating having a substantial portion of graphite particles is disclosed. The coating has been found to substantially increase starting reliability, to reduce starting voltage and to generally reduce starting time. The coating is formed as mixture of a bonding matrix and graphite particles that is baked to bond it to the electrode.

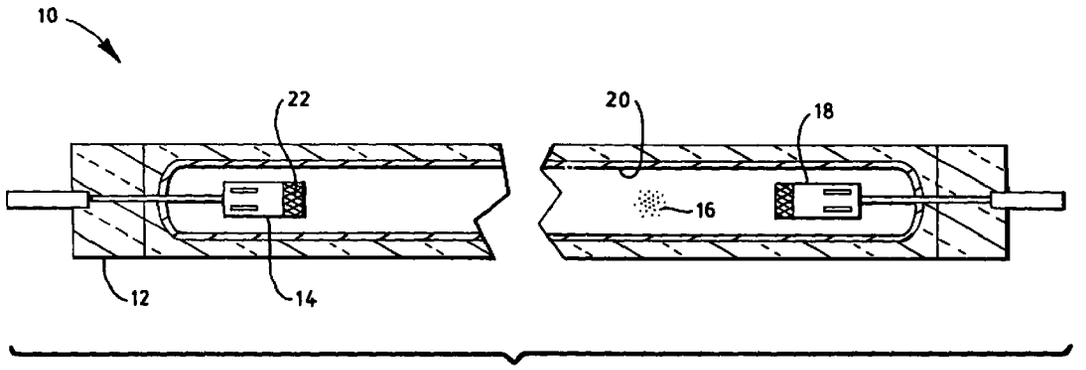

FIG. 1

EP 0 878 829 A2

Description

1. Technical Field

The invention relates to electric lamps and particularly to discharge electric lamps. More particularly the invention is concerned with a coating for electric discharge lamp electrodes.

2. Background Art

Cold cathode discharge lamps are started by applying sufficient voltage and current across the electrodes to jump an arc from one electrode to the other through the intermediate fill material, commonly a gas. Starting is clearly essential to lamp operation, and discharge lamp starting can always be assured by providing sufficient voltage. After starting, the arc is controlled by a ballasting device to limit the voltage and current. If the starting arc power is excessive or if it is allowed to run without regulation, the arc would destroy the electrodes. Preserving the electrodes is clearly important to lamp life. There is then a trade off in trying to provide assured starting with a minimum electrode injury. Since the regulating ballast is a costly item in a discharge light system, this trade off is frequently made with an eye to reducing ballast cost. There is then a need in a cold cathode electrode lamp to lower starting voltage while preserving electrode life.

In cold cathode lamps, (common in the neon sign industry) the starting voltage is applied without the aid of a high electrode temperature. The abundance of preionization electrons found in the hot cathode lamps is absent, so the starting process is more difficult. Typically, the starting voltage must be maintained for many milliseconds until an ionizing event occurs near the cathode. Usually the ionizing event is the result of a photoelectron produced by ambient light striking the cathode surface, or by a cosmic ray or background radioactive decay passing through the lamp.

Some cold starting schemes make use of a coating of radioactive material, for example, isotopes of cesium or americium, both nuclear reactor by-products. These components are known health hazards and require special handling. Other schemes involve illuminating the electrode with light from a spark of an auxiliary lamp (sometimes referred to as a glow lamp) to produce photoelectrons from the cathode surface. These glow lamps may exhibit a more rapid start owing to higher electric fields afforded by their design, but since they are themselves cold cathode lamps, glow lamps suffer from the same probabilistic time lag. Without ambient light or ionizing radiation, cold cathode lamps are difficult to start reliably, especially in a darkened room. There is then a need to increase the starting reliability of cold cathode lamps.

There is another mechanism for producing electrons at the cathode surface: the phenomenon of field emission. Field emission occurs when the applied electric field becomes so large (about 10 million volts per centimeter) that electrons are pulled out of the metal. In fact, the application of such a field distorts (lowers) the barrier containing the electrons in the metal, allowing the electrons to thermally jump over or tunnel through the barrier and into the surrounding gas. Normally, such large electric fields are not found in lamps, but circumstances can cooperate to manifest such fields at relatively modest voltages. If a rather ordinary potential drop is placed on an extremely sharp point, the electric field in the vicinity of the point can become concentrated enough to produce field emission. On a cold cathode surface, the small feature sizes of scratches. burrs, or finely divided getter material of a few microns radius can, in combination with an applied starting voltage of a few thousand volts, cause field emission and the subsequent ionization of the gas fill.

Unfortunately cold cathode lamps have a sputtering problem. Sputtering is the gradual erosion of the cathode surface caused by the bombardment of the electrode by ions of the fill gas molecules. Sputtering is particularly serious in the cold cathode case where the cathode attracts the ions close to the electrode surface. The close proximity of the layer of positively charged ions and the negatively charged electrode creates a sizable potential difference (called a cathode fall or cathode drop) through which ions are accelerated. This drop can be of the order of several hundred volts in a neon lamp, while the drop in a hot cathode lamp may be only a few volts. The hot, emissive surface of the hot cathode readily gives up electrons to the ions, maintaining a reasonable charge neutrality in the vicinity of the cathode and significantly reducing cathode fall. The cold cathode on the other hand experiences sputtering erosion at the surface.

Cathode sputtering can destroy the electrodes in times ranging from several hours to several tens of thousand hours depending on the gas pressure, surface area of the electrode, the form of the applied voltage, and the proximity of the electrode to the glass enclosure. This large-scale damage, to a major extent, can be controlled by a judicious choice of the design parameters. Unfortunately, what is more difficult to control is the erosion of exactly the same fine electrode features that promote field emission and aid starting. Because the local electric field near these points is so high, ions are accelerated toward them and can develop significant kinetic energy before striking these points, and since these features are small they are easily altered. The emission points are then rounded off, reducing their special capacity to emit electrons. There is then a need for cold cathode electrodes with fine points that can maintain their sharpness without sputtering.

It should be understood that electrode surfaces change in other ways. Lamp pollutants, and fill constituents may vary from lamp to lamp, and may change in concentration as a lamp ages. Further, the electrode

may be conditioned by its most recent operation states, (time, temperature, voltage, current). All of these can effect the surface character of the electrode, and therefore the starting of the lamp system. There is then a need for an electrode with stable surface conditions.

The lamp system design is usually made in regard to the final use, and the lamp makers statistical experience with the electrode, lamp and ballast. Where slow or irregular starting can be tolerated, a less expensive design may be used. In vehicle lamps, where fast, reliable starting is important to safety, expensive systems have assured, rapid reliable starting, but the higher price may limit consumer acceptance of the product. There is then a particular need to develop lamps with fast, reliably starting vehicle lamps at low cost.

Electrodes have been made in numerous forms. Tungsten rod electrodes are commonly used, and they may have additional features such as sleeves, baffles, coatings and so forth. The complex tungsten electrodes are difficult to construct in small sizes, particularly for a reasonable cost. There is consequently a need for a discharge lamp that offers fast starting, good life and easy manufacture.

Disclosure of the Invention

An improved discharge lamp electrode may be formed with a metal electrode having a coating formed on at least a portion of the inner most end, having sputtering resistant conductive particles providing a multitude of sharp points forming a substantial portion of the exposed surface area, and an adjacent matrix mechanically coupling the particles to the electrode. Graphite particles have been found to be particularly useful in this structure.

Brief Description of the Drawings

FIG. 1 shows a cross sectional view of a preferred embodiment of a discharge lamp.

FIG. 2 shows a perspective view of the innermost end of a preferred embodiment of a discharge lamp electrode, partially broken away.

FIG. 3 shows a cross sectional view of the innermost end of a preferred embodiment of a discharge lamp electrode, partially broken away..

FIG. 4 shows a chart of neon lamp start times with graphite free electrodes.

FIG. 5 shows a chart of neon lamp start times with graphite coated electrodes.

Fig. 6 shows a bar chart of the starting voltage frequencies for lamps with graphite free electrodes.

Fig. 7 shows a bar chart of the starting voltage frequencies for lamps with graphite coated electrodes.

Best Mode for Carrying Out the Invention

FIG. 1 shows a cross sectional view of a preferred embodiment of a discharge lamp 10. The lamp 10 may be made with an envelope 12, and a first electrode 14, a fill material 16, and a second electrode 18. The envelope 12 is formed from a light transmissive material, such as glass, hard glass, or quartz, with a interior wall defining an enclosed volume. The interior wall may be coated for example with a phosphor layer 20. In one embodiment tubular 1724 hard glass was used with an inside diameter of 3 millimeters and an outside diameter of 5 millimeters. The inner most end of the electrode 14 has an outer coating 22. The second electrode 18 may be similarly formed. The fill material 16 may be any of numerous combinations of gases and dopants. Commonly, rare gases are used at pressures from a few torr to several hundred torr. In the present embodiment, the Applicants used pure neon, at about 50 torr. Lamps varying from a few centimeters to over a meter long have been made in this general format.

FIG. 2 shows a perspective view of the interior portion of a preferred embodiment of the discharge lamp electrode partially broken away. FIG. 3 shows a cross sectional view of a preferred embodiment of the discharge lamp electrode of FIG. 2. The first electrode 14 has an inner most end 24. The inner most end 24 is exposed to the fill material 16 contained in the enclosed volume. The Applicants have used a molybdenum rod 26 supporting a metal can or sleeve 28 as the basic interior portion of the electrode 14. The sleeve 28 is usually nickel, but may be made from tantalum, steel, or other metals. The inner most end of rod 26 is enclosed in the sleeve 28. The sleeve 28 is then fixed to the rod 26, for example by crimping an outer most end of the sleeve 28 to the rod 26. The rod 26 end and the sleeve 28 interior are usually coated with an inner coating 30 of an emitter material, a getter material or a combination thereof. Emitter materials improve electron emission, while getters absorb contaminating gases. The preferred inner coating 30 is a mixture comprising zirconium and aluminum. Other electrode end structures, and other getters and emitters may be used.

In the preferred embodiment, an inner most end 24 of the electrode 14 is coated with a conductive matrix 32 including conductive particles 34 with a multitude of sharp edges, points, fractures and other electron emission points, which will be referred to as emission points here. The conductive particles 34 are exposed at the surface of the outer coating 22 to present a multitude of electron emission points facing outwards from the inner most end 24 of the electrode 14. Preferably, the matrix 32 coating is positioned at, or around the inner most end 24 of the electrode 14, in the region where the arc attaches to the first electrode 14 during lamp operation. Where a sleeve 28 is used to enclose the rod 26 end, the inner most portion would be the rim of the open end of the sleeve 28. Portions of both the inner surface and the outer surface of the innermost end of the sleeve 28 (rim) may then be coated with an outer coating 22 of the matrix 32. It is simple to dip coat the sleeve 28 rim.

Coating the interior surface of sleeve 28 may be resisted somewhat by the gas pocket held in the sleeve 28. Nonetheless, some portion of the sleeve 28 interior is generally coated in dipping. The preferred matrix 32 includes a bond material, such as aluminum, that wets when melted, and thereby mechanically bonds to the metal electrode end for example the sleeve 28, and the conductive particles 34. The conductive particles 34 are also electrically coupled to the underlying metal base (e.g. rod or sleeve.) The electrical coupling may be achieve by direct contact between the metal base and the exposed conductive particles, through chained contacts between conductive particles, or indirectly through the adjacent support matrix if the matrix is conductive. The conductive particles 34 are then effectively cemented, soldered or brazed in place on the sleeve 28. Chemical bonding is not necessary. The Applicants use aluminum as an initial bonding material.

The matrix 32 may additionally include refractory particles to resist erosion of the coating and the underlying electrode. The refractory particles may have the form of ground or powdered refractory metals or conductive ceramics. A conductive ceramic, such as the oxide emitter, BaO:CaO:SrO, sometimes called a triple carbonate, is believed to be functional also. Metal particles are inherently conductive and therefore preferred for that, while ceramics can be more resistant to erosion, and are preferred for that. The conductive matrix 32 may also include getter or emitter components, again to enhance the general performance of the coating. The Applicants use zirconium metal as a refractory, and getter material in the conductive matrix 32. The zirconium is conductive, reasonably resistant to high temperatures, absorbs or reacts with oxygen, and has a low work function resulting in easier electron emission.

Graphite, is the preferred material for the conductive particles 34. Graphite is a soft form of the element carbon, that is easily crushed to cause shearing along crystal planes with the attendant creation of sharp edges and points. Graphite is also electrically conductive, and has the unusual property of being transformed from the solid phase directly to the gas phase without melting (sublimation), but only at an extremely high temperature. This feature acts to preserve the electron emission points of graphite better than would be the case for meltable metals. In addition, graphite has one of the lowest sputtering yields of all the elements and is largely insensitive to ion erosion. Given these attractive attributes, graphite is the preferred material to be used as an erosion-resistant starting aid in overcoming the drawbacks inherent in cold cathode lamps. The graphite particles should be of sufficient size and quantity to present a significant percentage of the coated electrode surface area in the region of the arc attachment. It is believed the graphite then provides a multitude of points of highly concentrated electric fields, thereby easing electron emission.

The Applicants make the preferred embodiment from a molybdenum rod 26 with one end dipped in the inner coating material 30. The rod 26 is then positioned in and attached to a surrounding nickel sleeve 28. The rod 26 end and the sleeve 28 interior are then additionally coated up to about the inner most end of the rod 26 with the inner coating material 30. The inner most end 24 of the electrode is then dipped in a slurry of the components forming the conductive matrix 32 (outer coating 22).

The slurry may be formed from particles of the various coating material components (conductive particles, bond material, and any others), and a liquid chosen to wet the various coating components. The liquid is also chosen to evaporate or disintegrate cleanly during baking. The chosen liquid should not chemically react with the various coating components. The Applicants use an organic solvent, amyl acetate, mixed with a nitrocellulose binder as the slurry base. The amyl acetate provides a liquid base. The nitrocellulose acts to bind the other coating components after drying, but it then disintegrates (combusts) harmlessly on baking. It has been found that if a mixture (by volume) of about 4 to 8 percent aluminum, 28 to 32 percent zirconium, 20 percent graphite and 40 to 44 percent solvent (and binder) is used, there is insufficient graphite in the final outer coating, and lamp starting is only helped a small amount. It has also been found that if a mixture of about 2.5 to 5 percent aluminum, 17 to 20 percent zirconium, 50 percent graphite and 25 to 30 percent solvent is used, there is insufficient bonding and the outer coating tends to flake off. Between these ranges effective lamp starting and good bonding have been found. The preferred slurry is then a mixture by volume of about 3.5 to 7 percent aluminum, 25 to 29 percent zirconium, 29 percent graphite and 35 to 40 percent solvent. By calculation, after the solvent and binder are removed by baking in air, the relative proportions (by volume) in the baked coating should then be 6 to 10 percent aluminum with 8 percent preferred, 43 to 48 percent zirconium with 45.5 percent preferred, and 44 to 50 percent graphite with 46.5 percent preferred.

The inner most end 24 of the electrode 14 is dipped to a depth sufficient to cover the inner most end 24 of the electrode 14, and an additional region, approximately equal to the area covered by the arc attachment during lamp operation. The dip coating may coat a small portion of the inside surface of the sleeve 28. The Applicants used an outer coating 22 that had an axial extension of about 1 millimeter. The electrode 14 was then baked in air, thereby driving off the solvent and binder, and mechanically bonding the outer coating 22 to the electrode end. Lamps tested with the graphite coated electrodes have shown the same or slightly better photometry during life testing, indicating electrode life is the same or perhaps somewhat improved over those with standard (graphite free) electrodes.

FIG. 4 shows a chart of neon lamp start time performances using a standard electrode. The standard

electrode was made without the graphite coating on the sleeve rim. The horizontal axis shows the results for 176 different lamps. Each lamp was started ten times and the ten starting times are shown on the vertical axis (logarithmic) in microseconds. It can be seen that there is a band of lamp starts in the 200 to 400 microsecond region, indicating the best expected value for the lamp. There are however many points above this band, indicating lengthy, erratic starting, and numerous starts that are more than a tenth of a second. Statistically the mean for this group was 9486 microseconds, the standard deviation was 28,359 microseconds, and most importantly there were 50 attempts at starting when lamps failed to light up ("no-starts"). To meet or exceed a six sigma design criterion, the lamp system must be designed with respect to the worst starting condition. It is then the upper group of data points for which the ballast must be designed.

FIG. 5 shows a chart of neon lamp start time performances for lamps using the improved electrode. The improved electrode was the same as the standard electrode, except that the sleeve rim had an outer coating including graphite. 197 lamps of the same mechanical construction as the previous 176 lamps but using a graphite dip coating were tested. The lamps were tested in the same fashion as the lamps with standard electrodes. It can be seen that there is a tight band of lamp starts in the 100 to 300 microsecond region, indicating the best expected value for the lamps with graphite coated electrodes was about 100 microsecond better than the lamps with standard electrodes. This reduction in average start time is of itself valuable. With such a lamp used as a vehicle stop lamp, a trailing driver would get an earlier warning. More importantly, there are only few points above this band, indicating very reliable lamp starting. Statistically the improved electrode had a mean starting time of 235 microseconds, reducing the average starting time by about a factor of forty. The standard deviation for the improved electrode was about 432 microseconds, reducing the average starting time deviation by about a factor of sixty-five. Most importantly there were no lamps that failed to light. The improved lamp system, can now be designed around the vastly improved starting conditions resulting from the improved electrode.

In another sample, 94 neon lamps with arc gaps of 46.0 centimeters at pressures of 50 torr with standard electrodes were made. On the same equipment, and on the same day 100 neon lamps were made also with arc gaps of 46.0 centimeters at pressures of 50 torr with standard electrodes, but also having a graphite outer coating. Both sets of lamps were tested using a ramped sinusoidal starting waveform. The lamps were placed on the tester and the voltage was ramped up from 0 to 2000 volts at a rate of 10,000 kilovolts per second. A photodiode was used to signal the time of arc ignition. Each lamp was tested ten times. A computer recorded the data in a file of voltage outputs and ignition times.

The results of the testing the unimproved lamps are shown in FIG. 6. Fig. 6 shows a bar chart of the frequencies of the lamps starting within various 100 volt bands. FIG. 6 also charts a line of the cumulative percentage of lamps starting at each voltage level. For the first group, (unimproved) the average starting voltage was 1444.46 volts, with a standard deviation of 389.52 volts. The minimum open circuit voltage required to specify ballast starting voltage is defined to be the average starting voltage plus six times the standard deviation (six sigma design criteria). In this first group, there were seventy-two lamp start attempts that failed to give a lamp start. Since the test configuration had a limit of 2000 volts, this figure was used as the start value for the no-start attempts. This method underestimates the actually observed average. The actual starting voltages were most likely much higher, which would raise both the average and the sigma substantially. The specified six sigma starting voltage was then conservatively calculated to be 3781.55 volts.

The results of the testing the improved lamps are shown in FIG. 7. Fig. 7 shows a bar chart of the frequencies of the lamps starting within various 100 volt bands. FIG. 7 also charts a line of the cumulative percentage of lamps starting at each voltage level. The second group (improved), had an average starting voltage of 1065.99, and a standard deviation of 284.74 volts. There was one no-start in this group. The single no-start was also assigned a 2000 volt value. The specified starting voltage was then calculated to be 2774.48 volts. This is about a 36% decrease in the specified starting voltage due to the improved electrode. Comparing FIG.s 6 and 7, it can be seen that lamps with graphite free electrodes have irregular starting, require a higher average starting voltage, and may not have reached a reliable starting voltage, even at 2000 volts. In comparison, the improved lamps with graphite coated electrodes, show a higher percentage of starting events with lower starting voltages, and a more regular distribution, indicating the lamps with graphite coated electrodes are more likely to start reliably at a lower voltage. The disclosed operating conditions, dimensions, configurations and embodiments are as examples only, and other suitable configurations and relations may be used to implement the invention.

While there have been shown and described what are at present considered to be the preferred embodiments of the invention, it will be apparent to those skilled in the art that various changes and modifications can be made herein without departing from the scope of the invention defined by the appended claims.

Claims

1. A discharge lamp comprising:

   a) a light transmissive envelope defining an enclosed volume,

b) a lamp fill enclosed in the defined volume,

c) at least one electrode having an exterior end, a seal portion and an inner end, sealed through the envelope with the inner end in contact with the fill material in the enclosed volume, and

d) a coating formed on at least a portion of the inner end, having a multiplicity of electrically conductive particles, mechanically and electrically coupled to the electrode, and having numerous exposed electron emission points forming a substantial portion of the exposed coating surface area.

2. The lamp in claim 1, wherein the conductive particles are graphite particles.

3. The lamp in claim 2, wherein the graphite particles comprise from 44 to 50 percent of the coating material by volume.

4. The lamp in claim 3, wherein the graphite particles have an average mesh size not more than 325.

5. The lamp in claim 1, wherein the matrix further includes a metal bonding component.

6. The lamp in claim 5, wherein the metal bonding component is aluminum.

7. The lamp in claim 6, wherein the aluminum comprises 6 to 8 percent of the coating material by volume.

8. The lamp in claim 6, wherein the conductive matrix includes a refractory metal component.

9. The lamp in claim 8, wherein the refractory metal component is zirconium.

10. The lamp in claim 9, wherein the zirconium comprises 43 to 48 percent of the coating material by volume.

11. The lamp in claim 1, wherein the carbon includes a plurality of points facing away from the coating surface.

12. The lamp in claim 1, wherein the coating comprises 8 percent aluminum, 45.5 percent zirconium, and 46.5 percent graphite by volume.

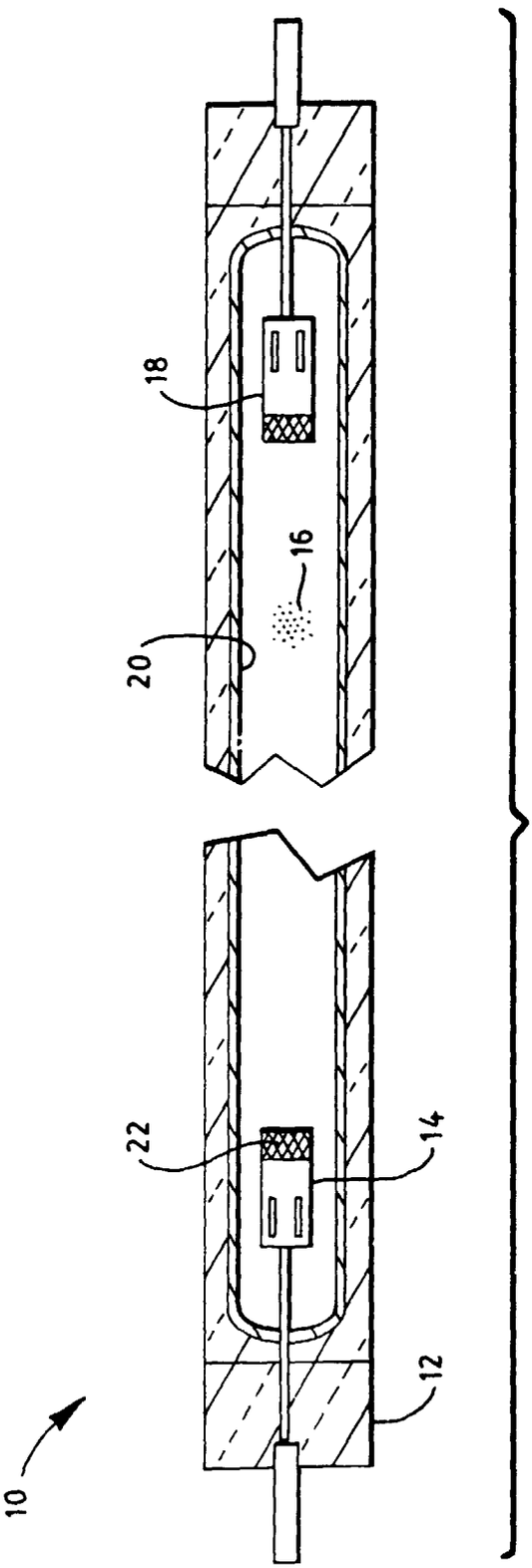

FIG. 1

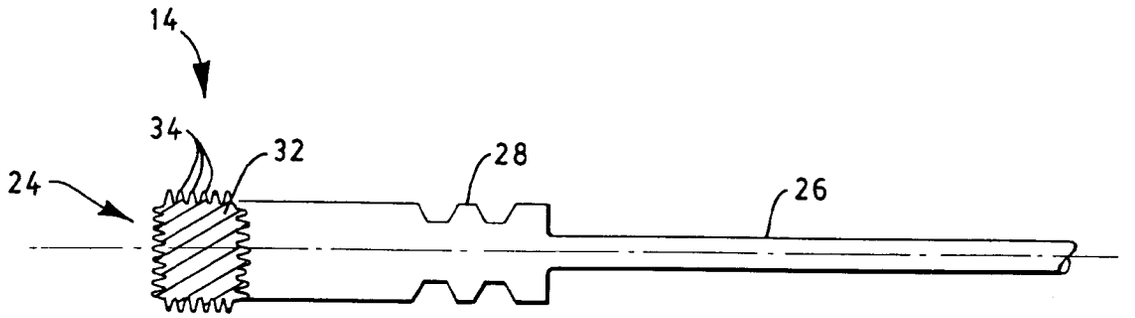

FIG. 2

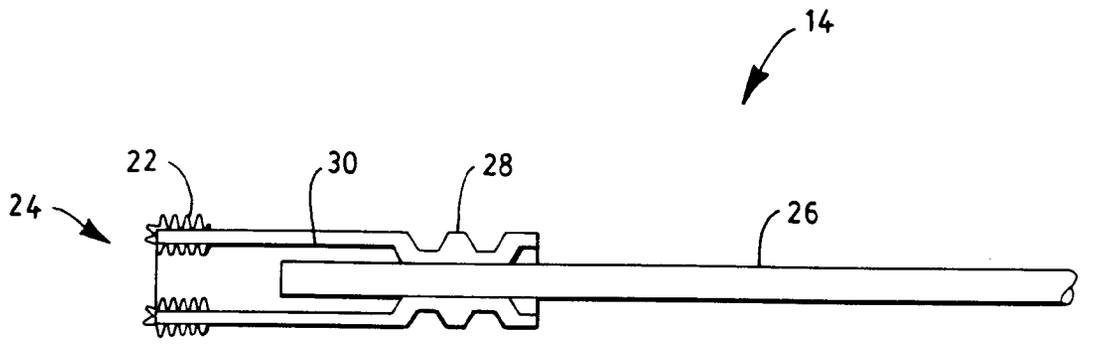

FIG. 3

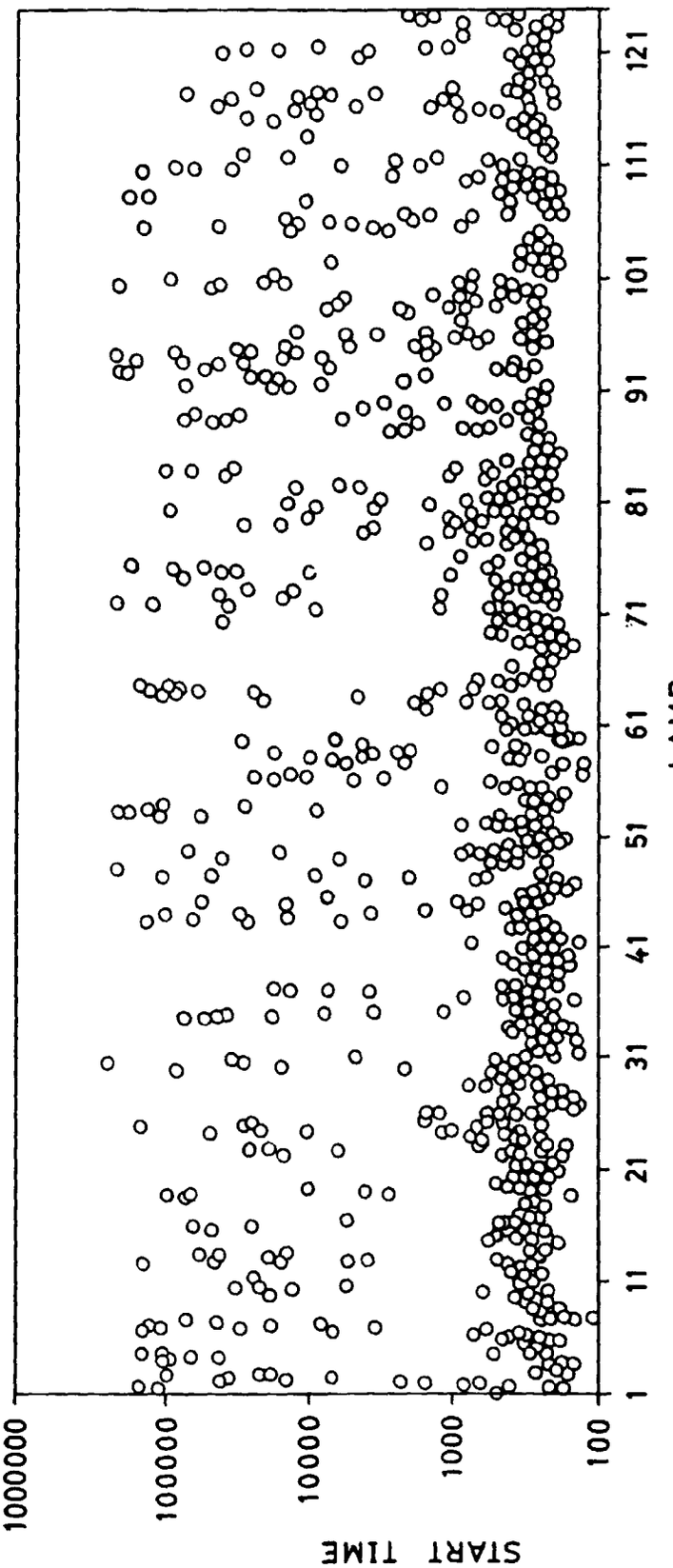
START TIME
1000000
100000
10000
1000
100
LAMP
1
11
21
31
41
51
61
71
81
91
101
111
121

FIG. 4

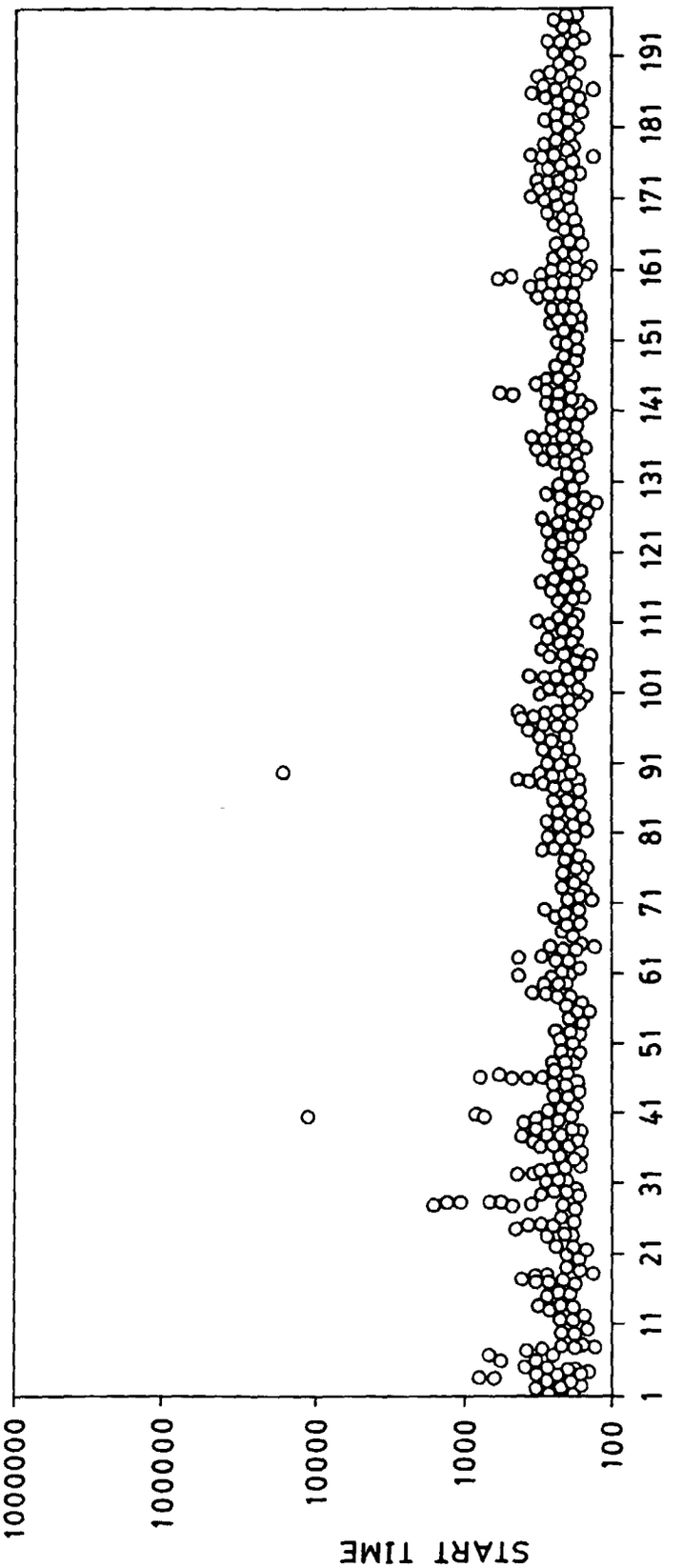
START TIME
1000000
100000
10000
1000
100
LAMP
1
11
21
31
41
51
61
71
81
91
101
111
121
131
141
151
161
171
181
191

FIG. 5

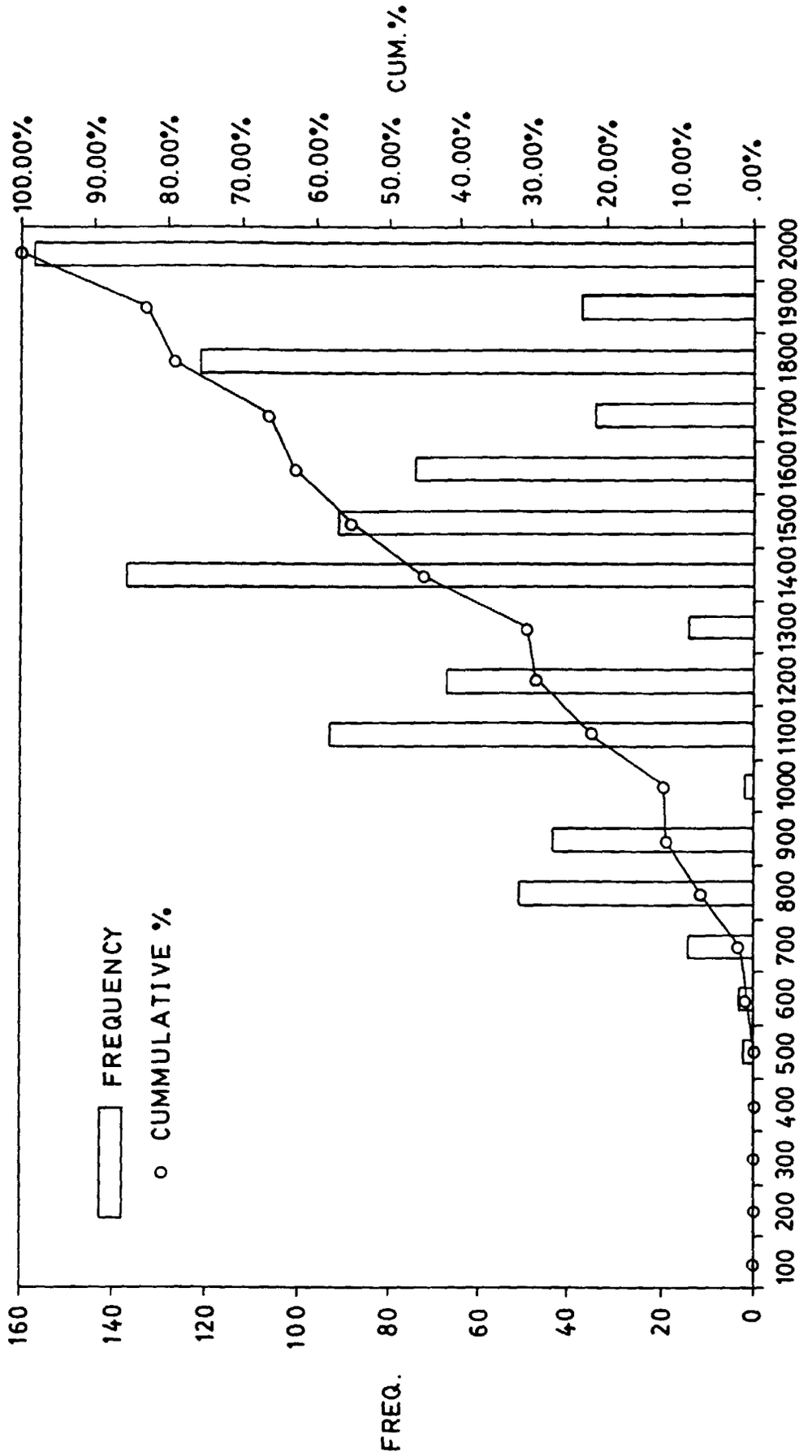
FREQUENCY
CUMMULATIVE %
FREQ.
CUM.%
VOLTAGE
0
20
40
60
80
100
120
140
160
.00%
10.00%
20.00%
30.00%
40.00%
50.00%
60.00%
70.00%
80.00%
90.00%
100.00%
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

FIG. 6

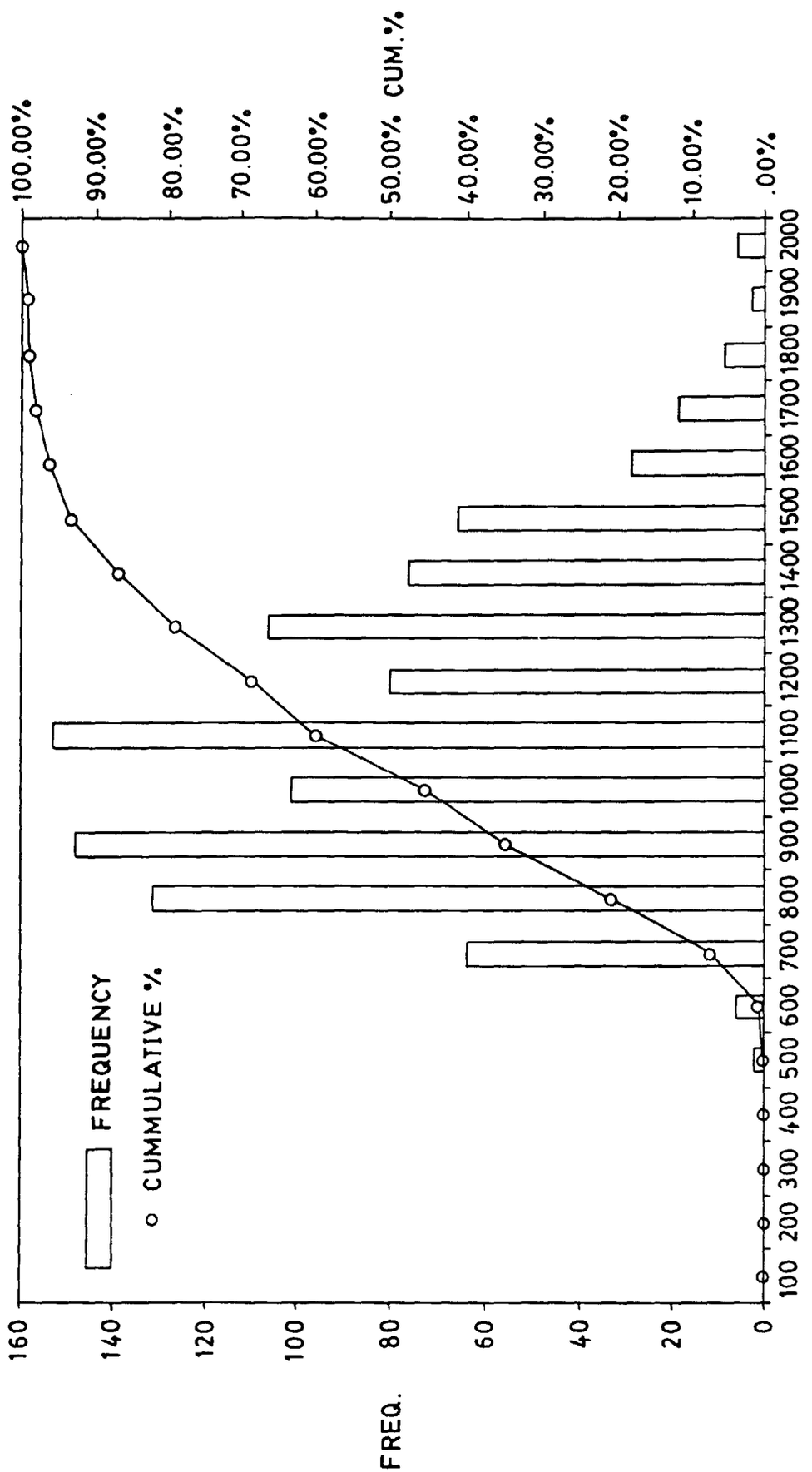
FREQ.
160
140
120
100
80
60
40
20
0
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
.00%
CUM.%
FREQUENCY
CUMMULATIVE %
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
VOLTAGE

FIG. 7