CONF-791028--2

LA-UR-79-1655

MASTER

TITLE: OVERVOLTAGE PROTECTION BY POINT-PLANE SPARK GAPS

AUTHOR(S): W. R. Scarlett and Kenneth B. Riepe

SUBMITTED TO: 1979 Conference on Electrical Insulation and Dielectric Phenomena
White Haven, PA
October 22, 1979

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545
An Affirmative Action/Equal Opportunity Employer

OVERVOLTAGE PROTECTION BY POINT-PLANE SPARK GAPS*

W. R. Scarlett and Kenneth B. Riepe
University of California
Los Alamos Scientific Laboratory
Los Alamos, NM 87545

ABSTRACT

In electron-beam-controlled discharge CO_2 lasers, such as those used in the Antares and Helios laser-fusion drivers at the Los Alamos Scientific Laboratory (LASL), protection needs to be provided against possible damage due to overvoltage. A passive (self-breakdown) point-plane spark gap has been developed and successfully used in the Helios power amplifiers which operate at voltages up to 300 kV. A gap of simi r design is planned for use in the Antares power amplifiers which operate at 550 kV. These gaps must reliably hold off the normal discharge voltage, but break down with short delay if overvoltaged, diverting the discharge energy to a resistor.

A prototype of the Antares gap has been built and is undergoing tests. Parameters being investigated include voltage polarity, gap spacing, gas composition, and gas pressure. Results of these measurements and the operational experience of the Helios gaps will be presented.

---

*Work performed under the auspices of the U.S. Department of Energy

Introduction

The Los Alamos Scientific Laboratory (LASL) is engaged in a program of fusion research utilizing electron-beam controlled discharge CO_2 lasers.[1] Electrical energy is delivered to the laser gas at several hundred kilovolts for several microseconds. The conductivity of the laser gas is controlled by the electron beam. Several fault conditions including prefire in a discharge pulser or vacuum breakdown in the electron gun can lead to the discharge voltage being applied to a high impedance due to absence of the electron beam. In such cases the discharge voltage will rise to a high level in a fraction of a microsecond. Although the systems are designed to make such occurrences unlikely, either the spacing between corona rings and the radii of those corona rings must be large enough to withstand the fault voltages or a protection system must be utilized to prevent damage.

The most economical solution is to use a protective device which will remove the voltage from the system and divert the energy into a resistive load. Such a system could be active, with sensors to detect the fault conditions and a trigger system to fire a diverter gap. The speed with which a fault must be detected and the gap fired makes such an active system difficult to implement. Thus we have undertaken the development of a passive overvoltage protection device.

The ideal overvoltage protection gap would have a zero probability of breakdown at normal operational voltage but would immediately break down with 100% probability if overvolted. We determined that a field-enhanced gap of the point-plane type was the most likely of the self-breakdown gaps to operate with the short delay required. Such a gap has been successfully developed for and used in the Helios laser system and development of a similar device for Antares is underway.

Helios Gap Development and Operation

The Helios power amplifiers operate at voltages up to 300 kV. Development testing has been carried out on a point-plane gap having one hemispherical electrode and one counter-bored cylindrical electrode with a sharp edge to provide field enhancement (Fig. 1). For the initial tests, an air-insulated Marx generator with 0.07-μF capacitors and up to 500-kV output voltage was used. The risetime was less than 50 ns with a 100-μs decay time constant. A 100-ohm resistor was used between the Marx and the spark gap to damp oscillations and limit the arc current.

At a given voltage and pressure, the shorter delays and narrow gap spacing are obtained with the point at negative polarity. Figure 2 shows the self-breakdown vs pressure curves for both polarities at several spacings. Also shown is a curve measured with a slow (1 μs) rising pulse. Note the extreme nonlinearity of the positive point gap at about 60 psia.

With a 5-cm gap spacing, negative point, and gap pressure of 53 psia of air, the hold-off voltage is 360 kV. With the Marx charged to 400 kV, the breakdown delay is less than 50 ns. Shorter delays are found at increasing pressures (and voltages).

Similar point-plane gaps having a negative point and 5-cm gap spacing have been installed on the Helios power amplifiers. The pumping voltage is supplied by a two-mesh Guillemin-Marx pulse-forming network, which has a relatively flat-topped pulse.[2] These gaps have performed well, always firing in case of fault, but holding off the normal operating voltage.

Antares Gap Development

The Antares power amplifiers must be capable of operation at voltages up to 550 kV. The prototype of a gap designed for this sytem has been undergoing test. The same point-plane geometry employed in Helios has again been used but, in this case, the diameter of both the point and the plane electrodes is 10 cm. Also, the length of the gap body has been reduced to 46 cm to allow testing in our high-voltage test vehicle. The voltage pulser is a Marx generator with output voltages of up to 1 MV.

The first measurements have been made with a positive point geometry, 11.3-cm gap spacing, and gap pressures between 40 and 60 psia of air. At 51 psia the gap breaks down consistently at 405 kV while holding off 350 kV. The delay between the peak voltage and breakdown is 200-300 ns. A framing camera operating at 2×10^7 frames/s was employed to study the time history of the event. In some cases an anode glow was observed followed in the next frame by a streamer propagating from cathode to anode. The following frame always shows an arc. In some cases the anode glow did not appear, but the streamer development always occurred within one frame (50 ns).

The next set of data was obtained with the point at negative voltage. As opposed to the results obtained with the Helios gap, the breakdown voltage is not sharply defined. Figure 3 shows the probability of breakdown as a function of voltage with a spacing of 12.6 cm and a pressure of 51 psia of air.

Each point represents 10-20 shots and thus is of low statistical weight; however, there is an indication that the probability of breakdown is not Gaussian.

Another result of the negative point measurements is that the delay to breakdown is usually very short (<50 ns) but occasionally long (1-2 μs).

One measurement has been made with nitrogen, a non-electronegative gas. With a negative polarity gap spacing of 12.6 cm and a nitrogen pressure of 51 psia we observed a sharp breakdown curve at 480 kV, however the breakdown was consistently delayed for 2-3 μs.

Discussion

At lower voltages (<300 kV) we have demonstrated the usefulness of the point-plane gap in preventing overvoltage damage in laser amplifiers.

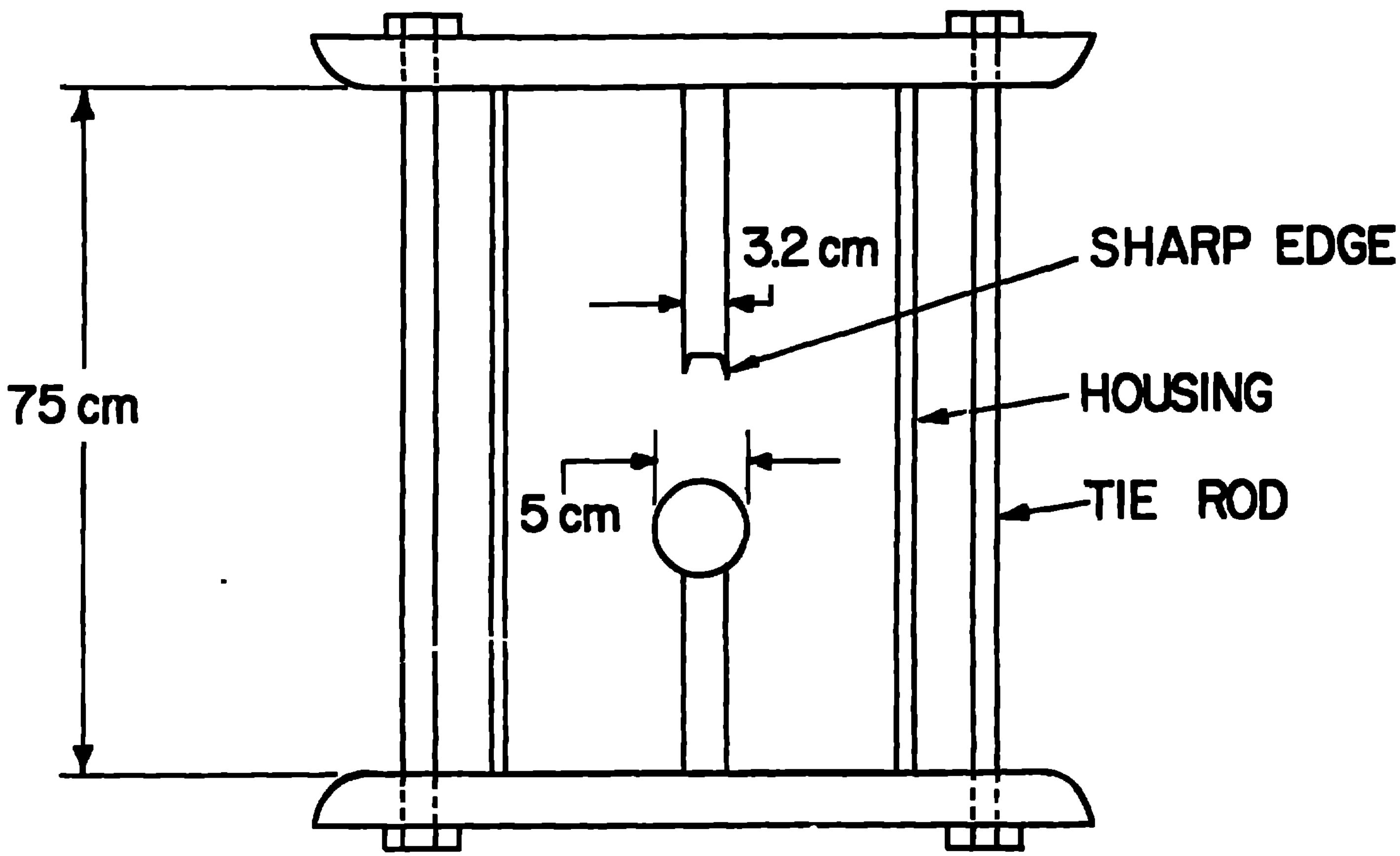
The Antares gap development program is continuing since an acceptable design has not yet been found. To determine if we can extend the successful Helios design to higher voltages a smaller gap spacing and electrode diameter will be tried. If this is not successful other designs such as an irradiated symmetric gap may be tried. The use of SF_6 is precluded because even a small leak into the laser gas would seriously affect the amplifier gain and discharge characteristics.

References

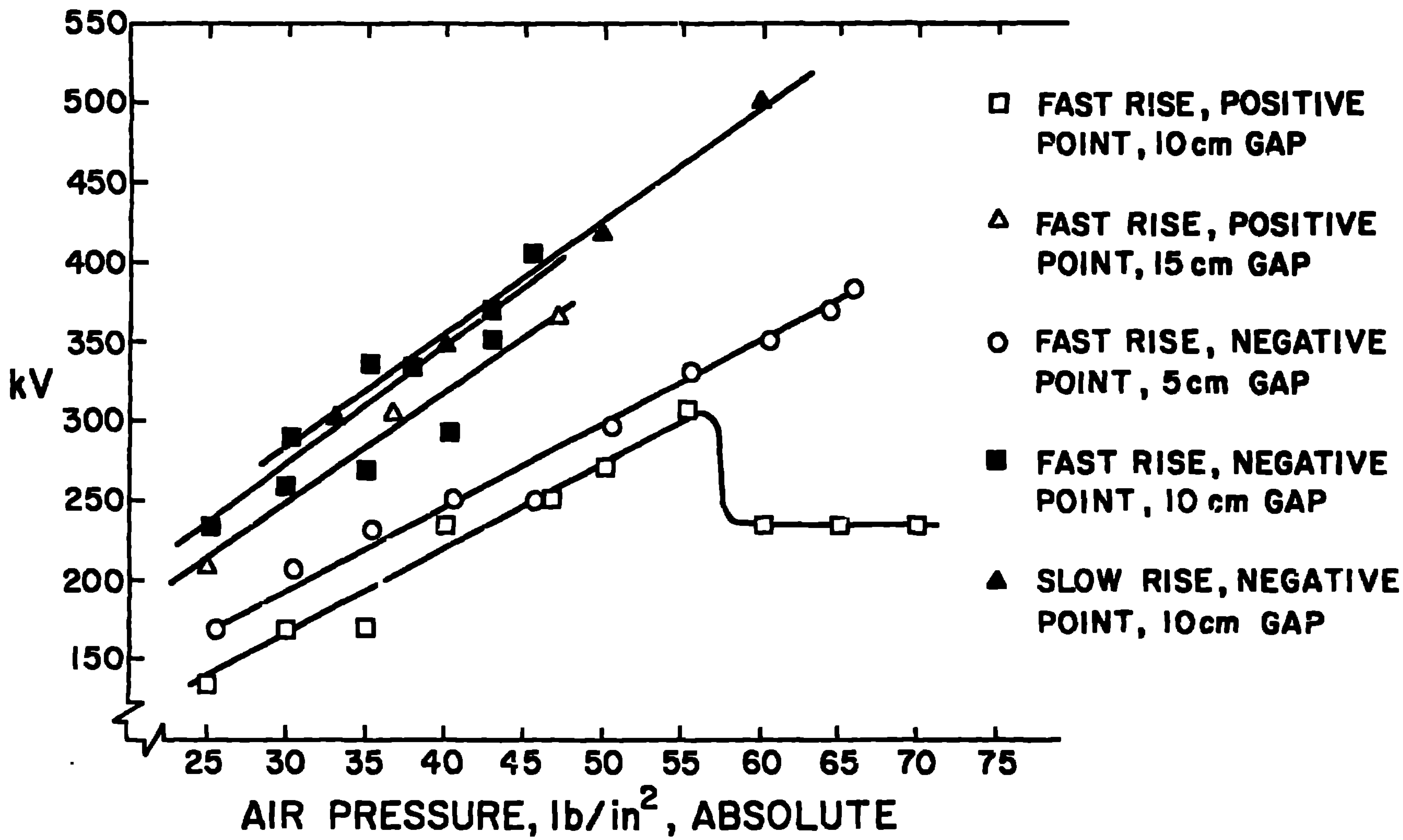
1. T. F. Stratton, "CO_2 Short-Pulse Laser Technology," in High-power Gas Lasers, 1975, E. R. Pike, Ed. (The Institute of Physics, London, England, 1976), pp. 284-311.
2. Kenneth B. Riepe, "High-Voltage Microsecond Pulse-Forming Network," Rev. Sci. Instruments, Vol. 8, No. 8, August 1977, pp. 1028-1030.

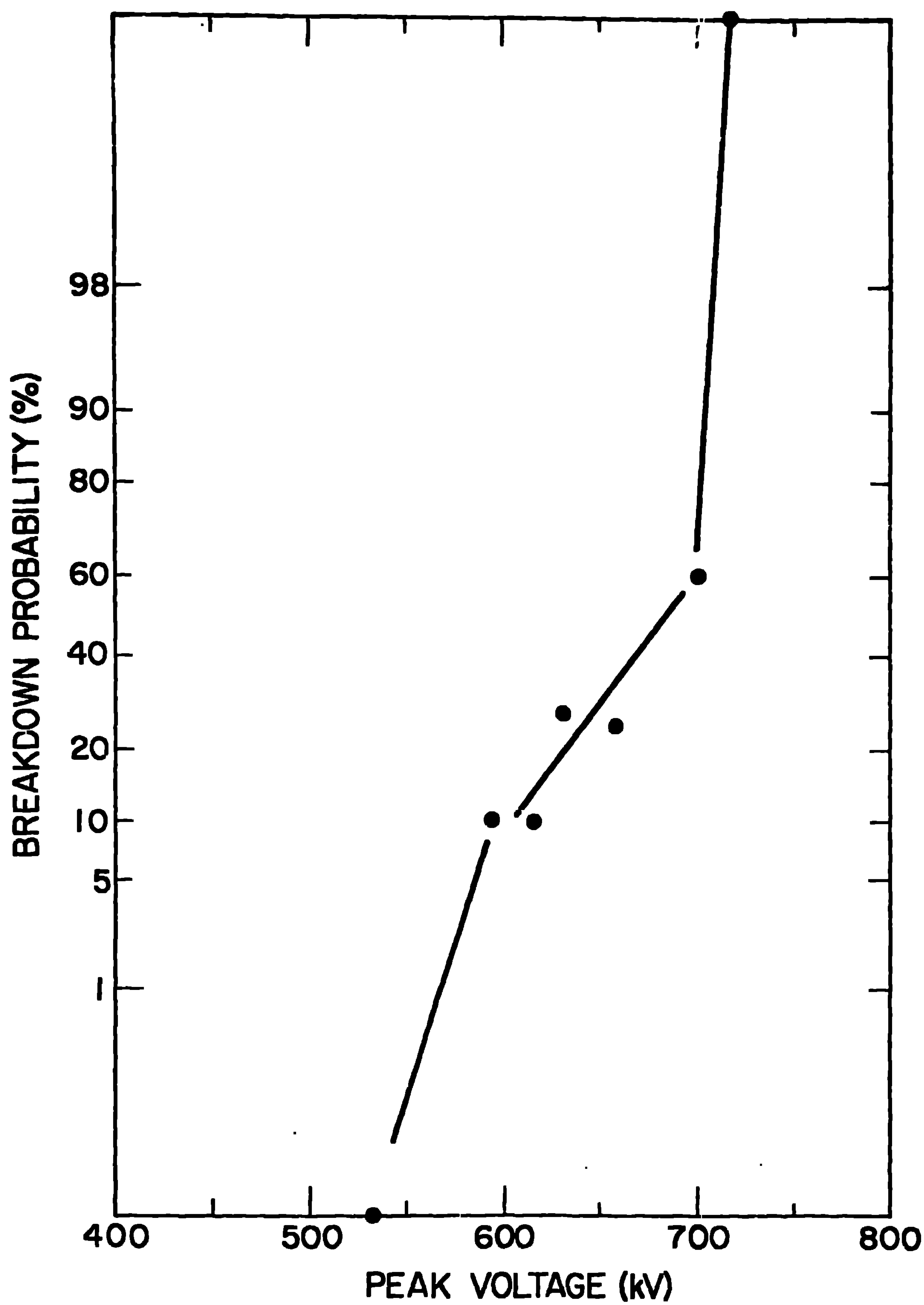
Figure Captions

1. Cross section of the Helios prototype overvoltage gap.
2. Breakdown voltage curves for the Helios prototype gap.
3. Breakdown probability curve for the Antares prototype gap with gap spacing 12.6 cm, air pressure 51 psia, and negative point electrode polarity.



3.2 cm
SHARP EDGE
75 cm
HOUSING
5 cm
TIE ROD


550
500
450
400
350
300
250
200
150
kV
25
30
35
40
45
50
55
60
65
70
75
AIR PRESSURE, lb/in², ABSOLUTE
FAST RISE, POSITIVE POINT, 10 cm GAP
FAST RISE, POSITIVE POINT, 15 cm GAP
FAST RISE, NEGATIVE POINT, 5 cm GAP
FAST RISE, NEGATIVE POINT, 10 cm GAP
SLOW RISE, NEGATIVE POINT, 10 cm GAP



BREAKDOWN PROBABILITY (%)
98
90
80
60
40
20
10
5
1
400
500
600
700
800
PEAK VOLTAGE (kV)