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EFFECT OF ENVIROMENTAL MOISTURE AND POLLUTION ON VISUAL CORONA VOLTAGE.

BY

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ABSTRACT:

The paper presents experimental investigations to study the effect of enviromental moisture and pollution on the visual corona voltage for parallel wires of different diameters and at various distances from each other. It has been found experimentally that enviromental moisture and wet pollution have a reduction effect on visual corona voltage.

The empirical equation given by Peek for such voltage is modified with the aid of the obtained experimental results. The proposed modification takes into consideration the effect of enviromental moisture and pollution on the voltage of visual corona formed between parallel conductors. The results using this modification match those obtained experimentally for both solid and stranded conductors. The maximum percentage error attained on applying the proposed modification does not exceed ± 8% of the experimental values.

Discussion of the results and corona modes in atmospheric air are also included and explained according to the modern concepts of this phenomenon.

I. INTRODUCTION:

In high voltage transmission systems, corona discharges may be formed on conductors, high voltage equipment and insulators as a field sustained electrical breakdown of atmospheric air. Such discharges result in energy loss,

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radio interference, chemical action and mechanical vibrations. All these effects are undisirable for electrical power systems. On a long high voltage tran smission line the loss due to corona formation may be high as that wasted dùe to the resistance of the line conductors. Therefore, corona has been studied intensively.

Corona discharges in air take several distinctive forms, depending on many factors including gap distance, conductor diameter and weather conditions. The present work is aimed to study the effect of these factors on the voltage at which the visual corona is formed along metal wires. With the aid of experimental investigations, a modification for Peek's emperical equation is proposed to consider the effect of enviromental moisture and pollution. This modification can be used in practice to determine the visual corona voltage in transmission systems under different weather conditions.

II. EXPERIMENTAL INVESTIGATIONS:

1. Test Set-Up:

Corona discharges are investigated in atmospheric air between two rectangular loops of wire having different diameters and each measuring 5x15 cm. The wire diameters are choosen in the range from 0.3 mm to 4.5 mm. Both solid and stranded conductors are used in this work to investigate their effect on corona voltage in air. The two loops are arranged such that the lower one is fixed and the other is movable to form gap distances up to 15 cm. The two loops are contained within a glass container to control the surrounding atmospheric conditions. When perform ing corona test under moistened conditions, a hand operated sprayer of 500 cubic cm. in capacity is used. The artificial pollution used here is a solution of 50 gram gypsum dissolved in 500 c.cm of distilled water.

All tests are carried out in atmospheric air under normal temperature and pressure (N.T.P.); namely 20°C and 760 mm Hg. The test A.C. voltage is obtained from a high voltage generating circuit consisting mainly of a low voltage control unit, high voltage transformer and electrostatic voltmeter. The applied voltage can be increased smoothly up to 80 kv (R.M.S.) and measured by means of a resistive potential divider and electrostatic voltmeter. The voltage is raised smoothly to that value at which the visual corona is formed. The formation of visual corona is acertained visually and by means of an osciloscope connected across a 300 Ohm resistor with the earthed wire loop. Many osciloscope current traces are recorded during tests and investigations of corona modes in air under different conditions.

2. Observations :-

When the voltage across the gap is gradually increased to a certain value, depending on the gap length and wire diameter, a glow starts to appear. This glow is known as burst pulses and takes the form of unstable irregular luminous dots wandering along the wire. Increasing the applied voltage beyond this value the dots are increased in both luminous intensity and number. A partial transition from dots to streamers is observed to start at a higher value of the applied voltage. Any slight increase in the applied voltage causes some of the dots to take the form of stable glow and a single-channel spark may occur across the gap. This discussion briefly explains the sequence of events of corona modes in air.

3. Results:

The experimental results of the visual corona voltage presented here are obtained from 25 voltage applications for each reading. Thus each value mentioned or given on a curve, represents the mean value of these applications with a standard deviation of up to 10%, depending on the values of gap distance and wire diameter.

The gap distance between the two wire loops affects the voltage of the visual corona and is found to have a great effect on this voltage. Figure (1) shows the experimental values of the voltage (R.M.S.) at which the visual corona is formed in air between wire loops of different diameters and for gap distances of up to 15 cm (solid lines). It is clearly seen that the thicker conductor gives higher visual corona voltage at the same gap distances.

The enviromental moisture and pollution affect the voltage of visual corona formed between parallel wires. This also is investigated and found to have a strongly reduction effect on the voltage of visual corona. It is found that the wet pollution has higher reduction effect on this voltage than pure moisture only. The effect of the enviromental moisture and pollution is shown clearly in Figures (2) and (3), solid lines, indicating the voltage of visual corona versus the percentage relative humidity. As a comparative example, the visual corona voltage is reduced from 20 kv to 15 kv as the relative humidity is raised to 60% about conductor of diameter 2 mm. The corresponding value under wet pollution conditions is 10 kv under the same relative humidity.

III. COMPUTED CORONA VOLTAGE:

1. Peek's Formula:

The visual corona voltage between two parallel conductors can be calculated by Peek's emperical equation. This equation is well known for electrical engineers and has the following form:

$$V_v = 30\, m\delta r \left(1 + \frac{0.301}{\sqrt{\delta r}}\right) \ln \frac{D}{r} \qquad \ldots(1)$$

where,

- V_v = visual corona voltage to neutral, kV (peak)
- m = surface condition factor
  - = 0.9 for solid conductors
  - = 0.8 for stranded conductors
- δ = air density factor = 1 at N.T.P.
- r = conductor radius in cm
- D = gap distance in cm.

2. Computed Visual Corona Voltages:

As a comparison, Peek's emperical equation is applied to calculate the visual corona voltage for the mentioned conductor diameters and gap distances. The computed values obtained on applying Peek's equation are also illustrated in Fig.(1) by the dotted lines. The percentage error obtained on applying Peek's equation does not exceed $\pm$ 8% of the experimental values for the mentioned conductors and gap distances. This error is resulted from factors related to both the measuring technique and Peek's formula. In the former, visual corona is checked visually and by means of an oscilloscope while in the second only visually. Therefore the experimental values of corona voltage may be considered as more exact values than those given by Peek's formula.

IV. PROPOSED MODIFICATION:

The effect of enviromental conditions are not considered in Peek's equation to compute the voltage of visual corona formed between parallel wires. Therefore this formula gives higher corona voltages than the actual values. As a proposed modification for Peek's equation, the enviromental conditions are considered to give exact values of visual corona voltage between parallel wires. The proposed modification can be applied in two cases namely pure moisture and wet pollution as follows.

1. Pure Moisture:

In this case the modified equation gives the voltage of visual corona as a function of the relative humidity of air in exponential form as follows:

$$V_v = 30\, m \delta r\, w^{-a} \left(1 + \frac{0.301}{\sqrt{\delta r}}\right) \ln \frac{D}{r} \qquad \ldots(2)$$

where,

w = the percentage relative humidity

a = constant depending on the power system.

The value of this constant is found to be $a = 0.18$ under the experimental conditions and for the prementioned conductors.

As a comparison, the proposed modification is checked by computing the corona voltage at different relative humidities. Figure (3) illustrates these values (dotted curves) compared with those obtained experimentally (solid curves). The percentage error is calculated for different values of relative humidity for the given conductor diameters and found to be of comparatively low values. The maximum percentage error attained on applying Eqn. (2) is sprayer of 500 cubic cm. in capacity is used. The artificial pollution used here is a solution of 50 gram gypsum dissolved in 500 c.cm of distilled water.

All tests are carried out in atmospheric air under normal temperature and pressure (N.T.P.); namely 20°C and 760 mm Hg. The test A.C. voltage is obtained from a high voltage generating circuit consisting mainly of a low voltage control unit, high voltage transformer and electrostatic voltmeter. The applied voltage can be increased smoothly up to 80 kv (R.M.S.) and measured by means of a resistive potential divider and electrostatic voltmeter. The voltage is raised smoothly to that value at which the visual corona is formed. The formation of visual corona is acertained visually and by means of an osciloscope connected across a 300 Ohm resistor with the earthed wire loop. Many osciloscope current traces are recorded during tests and investigations of corona modes in air under different conditions.

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3. Results:

The experimental results of the visual corona voltage presented here are obtained from 25 voltage applications for each reading. Thus each value mentioned or given on a curve, represents the mean value of these applications with a standard deviation of up to 10%, depending on the values of gap distance and wire diameter.

The gap distance between the two wire loops affects the voltage of the visual corona and is found to have a great effect on this voltage. Figure (1) shows the experimental values of the voltage (R.M.S.) at which the visual corona is formed in air between wire loops of different diameters and for gap distances of up to 15 cm (solid lines). It is clearly seen that the thicker conductor gives higher visual corona voltage at the same gap distances.

The enviromental moisture and pollution affect the voltage of visual corona formed between parallel wires. This also is investigated and found to have a strongly reduction effect on the voltage of visual corona. It is found that the wet pollution has higher reduction effect on this voltage than pure moisture only. The effect of the enviromental moisture and pollution is shown clearly in Figures (2) and (3), solid lines, indicating the voltage of wisual corona versus the percentage relative humidity. As a comparative example, the visual corona voltage is reduced from 20 kv to 15 kv as the relative humidity is raised to 60% about conductor of diameter 2 mm. The corresponding value under wet pollution conditions is 10 kv under the same relative humidity.

not higher than 8%, which can be considered as good accepted value.

2. Wet Pollution:

Here, the proposed modification can be also used to estimate the voltage of visual corona in air between the parallel conductors. This voltage can be expressed under wet pollution as:

$$V_v = 30\, m\delta r\, w^{-b} \left(1 + \frac{0.301}{\sqrt{\delta r}}\right) \ln \frac{D}{r} \qquad \ldots(3)$$

where,

b = constant depending on the power system and type of pollution.

The constant (b) is found to be b = 0.22 under the experimental conditions discussed before.

Figure (3) illustrates both the experimental and computed values of the voltage of the visual corona formed in humid polluted air between parallel wires of different diameters and at 15 cm spacing from each other. Here, also the thicker conductor gives higher voltages of visual corona under the same relative humidity. As a numerical example at 50% relative humidity under artificial polluted conditions, the visual corona voltage is 25 kV for gap 15 cm long and conductor diameter 4.5 mm while the corresponding value is only 10 kV for conductor diameter 0.3 mm under the same conditions. The percentage error attained on applying the proposed modification under wet polluted conditions is comparatively higher than under dry conditions. The maximum error in this case does not exceed ± 10% of the experimental values of the visual corona voltage.

V. CONCLUSIONS:

The visual corona voltage of atmospheric air is strongly reduced by the environmental moisture and pollution. This reduction effect is taken into account and a proposed modification for Peek's equation is given. The visual corona voltage can be calculated in terms of the percentage relative humidity of air between parallel wires. Under polluted humid conditions the reduction effect will be higher. The proposed modification gives values of visual corona voltage close to those obtained experimentally in high voltage laboratory. The maximum percentage error attained on applying this modification does not exceed ± 10% of the corresponding experimental values.

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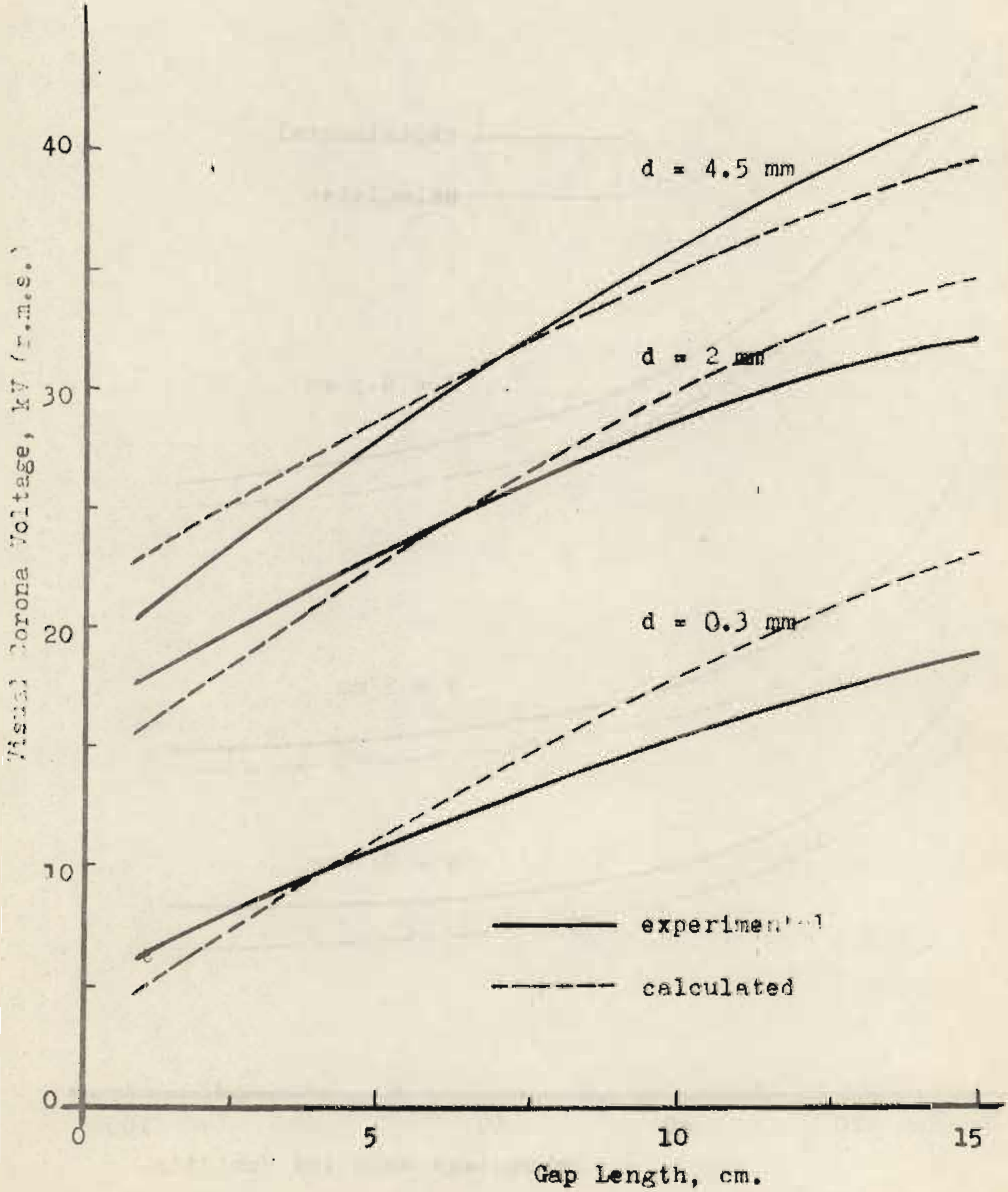

Fig. 1: The visual corona voltage of air versus the distance between parallel wires having different conductor diameters.

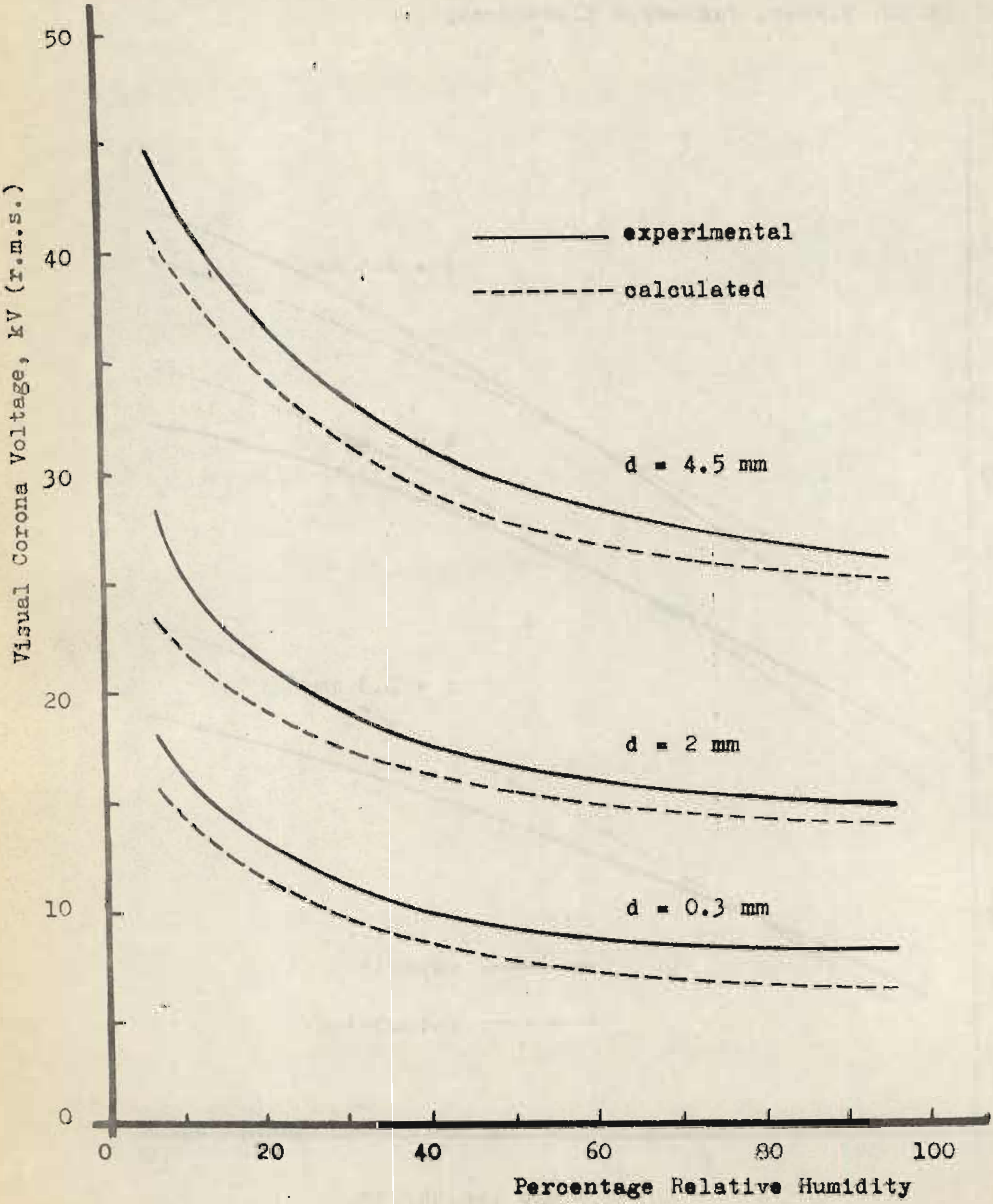

Fig. 2: The effect of moisture on visual corona voltage of air gap 15 cm long between parallel wires of different diameters.

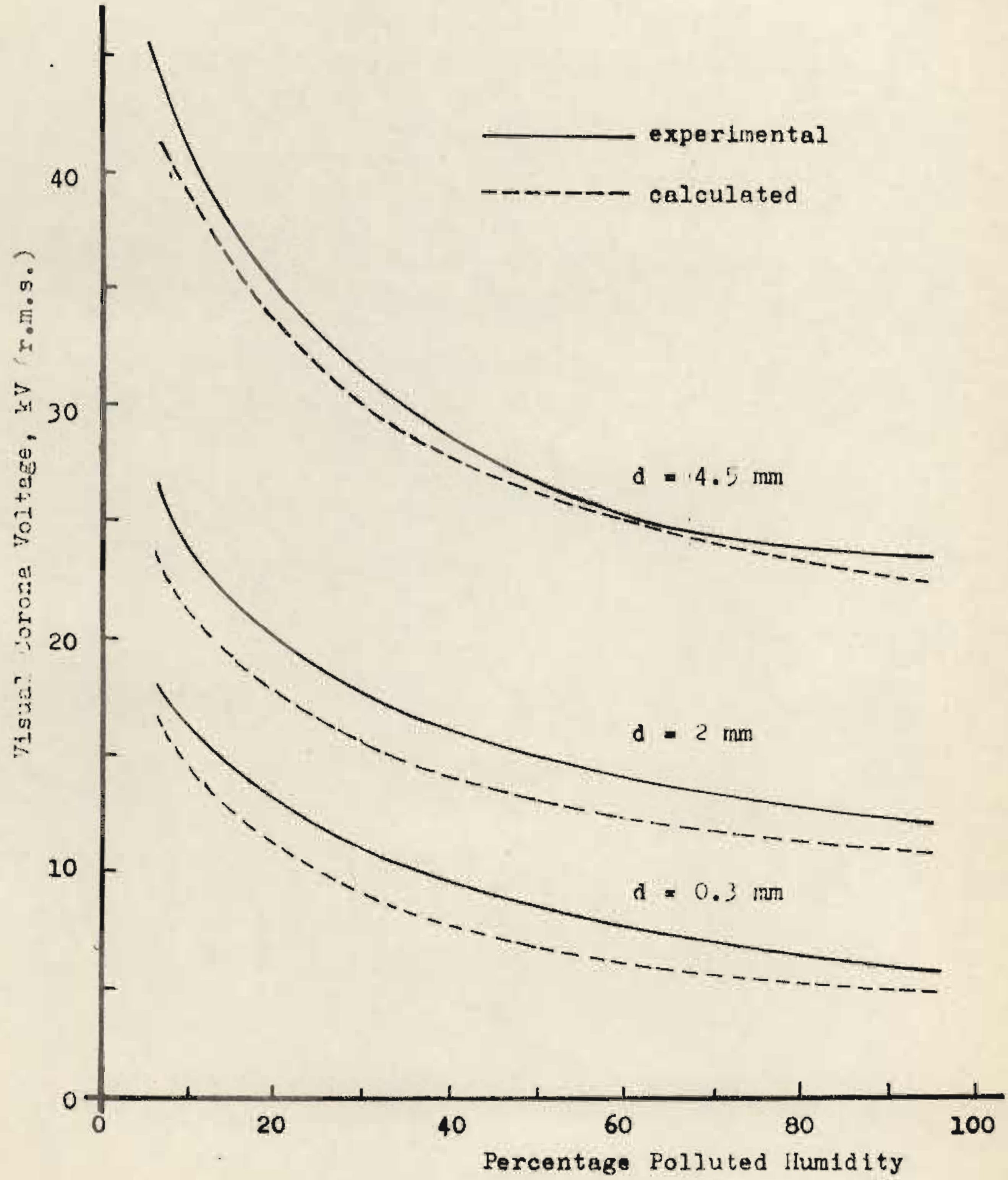

Fig. 3: The effect of moistened pollution on visual corona voltage of air between parallel wires of different diameters at 15 cm spacing from each other.

in Fig.(3), for switching impulses a critical rise-time is found for which the sparkover voltage is a minimum. This critical rise-time increases with gap length. Similar results were obtained by Harada, Aihara, and Aoshima[7]. It is worthy of somment that this is also approximatly the rate of increase of formative timelag with gap length. For impulses of rise-time shorter than the value of the critical rise-time, sparkover occurs on the decaying tail of the impulse. In this case the sparkover voltage is normally• defined as the prospective peak value.

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