EFFECT OF HUMIDITY ON BREAKDOWN VOLTAGES OF GAPS AND INSULATORS

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ABSTRACT

With the increase in power transmission in tropical countries, the study of the effect of high humidities on the flashover characteristics of line and station insulation assumes great importance. In this paper, the study of the variation of breakdown voltages of gaps and different types of insulators with varying humidity at two constant temperatures of 20 °C and 27° C, is reported. The range of humidity variation obtained in a controlled atmosphere room was between 9 and 25 g/m^3, corresponding to a relative humidity range of 60 to 90 per cent. The results point out to the inaccuracies of the humidity correction factors as presently specified in the standards. The study points out that no uniform correction factor could be applied to the flashover voltages of insulators. The characteristics show three regions—the first similar to those of a rod gap, the second, a rapid rising region, and the third, a falling region. Thorough investigations are proposed for future work.

Key words: Humidity effect, Breakdown, insulator testing, sphere gap breakdown, rod-gap breakdown, dielectric breakdown.

INTRODUCTION

The humidity and air-density variations of the atmosphere cause considerable deviation in the flashover voltages obtained for any type of line and station insulation. Considerable work has been done in determining the effect of these parameters on power frequency voltage breakdown of gaps and insulators [1, 2, 3] and on impulse voltage breakdown of gaps [4, 5]. Both international and national organizations have evolved, based on the extensive laboratory work, correction factors for humidity and air-density in order to refer the values obtained at the prevailing conditions to those at standard conditions [6, 7, 8]. All these corrections assume that the power frequency flashover voltage of an insulator increases almost linearly with the humidity of air by eight to twelve per cent for an increase in moisture content from four to eleven grams per cubic metre of air.

I.E.C. and British Standards have adopted the standard conditions of temperature and humidity as 20° C and 11 g/m³ respectively. In tropical countries, the temperature and humidity values are very high. Indian Standards are adopting 27° C and 11 g/m³ as the standard conditions. To adopt a different set of standard conditions, it is necessary to have sufficient knowledge of the behaviour of the insulators under varying conditions. Smee and Edwards [9] after a limited number of experiments in the humidity range of 4–12 g/m³ doubted the accuracy of the humidity corrections provided by the specifications. Standring *et al.* [10] after an extensive work have published quite useful data on humidity effect and have proposed certain correction curves. Prabhakar *et al.* [4] studied the influence of high humidities on impulse flashover voltages of gaps and insulators. The results indicated a completely different trend at high humidities and it was thus found necessary to investigate the effect of high humidities and high temperatures on the flashover voltage of insulators and rod gaps.

2.0 EXPERIMENTAL ARRANGEMENT

Experiments were conducted in 6 m² controlled atmosphere room. Inside the room the relative humidity could be controlled over the range of 50 to 100 per cent and the temperature from 0° to 50° C. Assman psychrometer was used for the measurement of absolute humidity of the air inside the chamber. An additional set of dry and wet bulb thermometer was used to note the temperature in and around the test gap or insulator. Sufficient time was allowed so that the conditions at all the sections of the room attained stability.

The investigations were carried out on (i) sphere gaps using 25 cm diameter spheres at gap spacings of 5·0, 7·5, 10·0 and 12·5 cm, (ii) ½ inch square standard rod-rod gaps horizontally mounted at spacings of 25, 40, 50, 60 and 70 cms, (iii) Porcelain insulators—pin type 11, 22 and 33 kV, post type 11 kV and 22 kV from 1 to 3 units, disc type 11 kV from 1 to 4 discs. The spheres were arranged according to IS.1876–1961. The surfaces were cleaned with alcohol and well polished. The rods of the rod-gap arrangement were mounted on a 300 cm high pedestal. The pin, post and disc insulators were mounted in accordance with IS 2544–1963.

The 50 Hz test voltage was applied by means of a 350 kV, 1,000 kVA testing transformer. The applied voltage was measured by a r.m.s. meter connected to the voltmeter winding provided in the testing transformer. The high voltage lead-in to the controlled atmosphere chamber was through a 1 cm hole in a double walled 2·5 m square glass window.

The overall arrangement view is shown in Fig. 1.

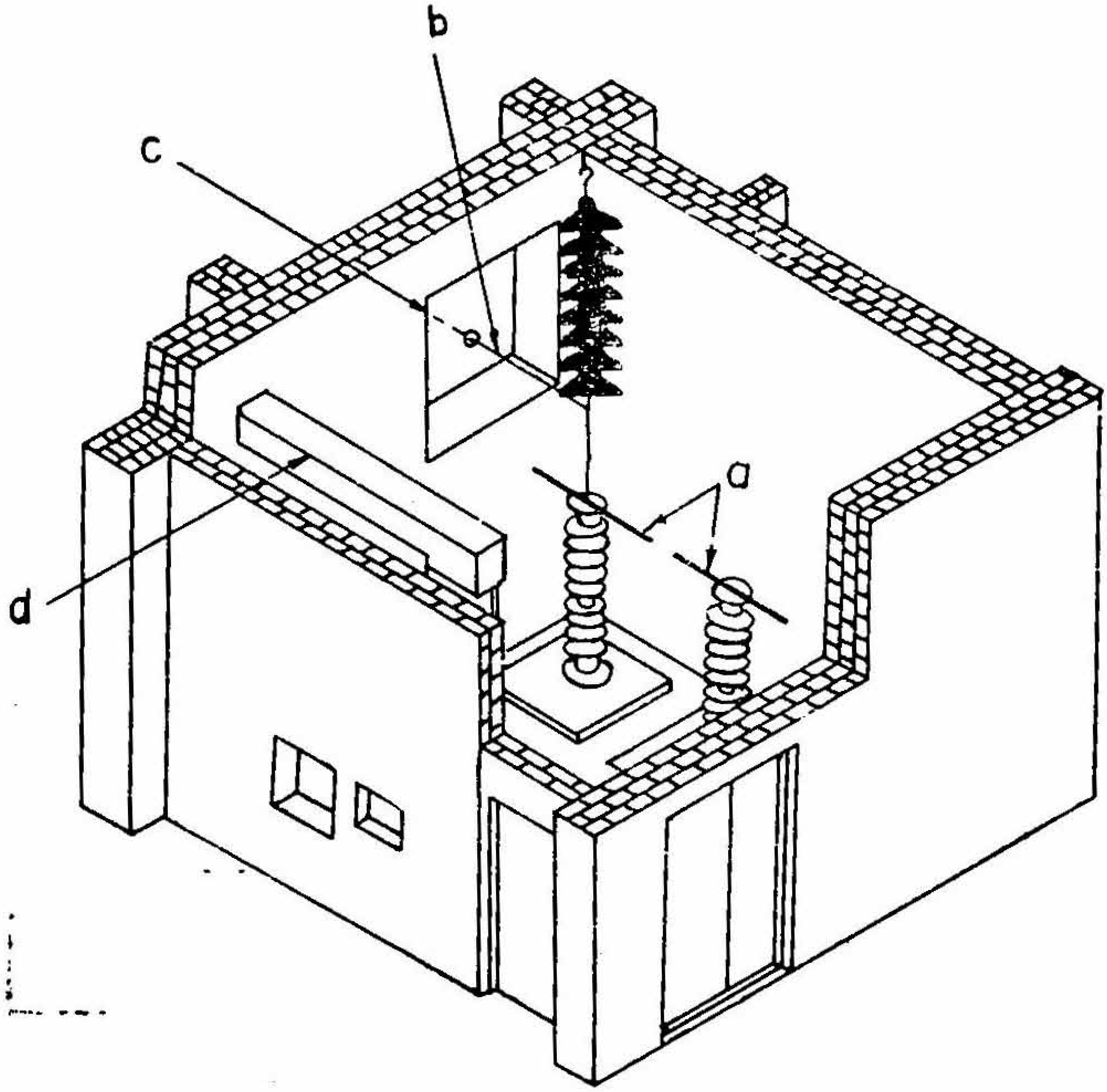

FIG. 1. The overall experimental arrangement in the controlled atmosphere room: (*a*) testgap; (*b*) high voltage lead; (*c*) glass window; (*d*) air duct.

3.0 RESULTS AND DISCUSSIONS

The effect of humidity on different gaps and insulators was studied by varying the humidity, holding the temperature constant first at 20° C, and next at 27° C. Indian Standards specifications have laid down 27° C as the standard temperature. Previous to the revision, the standard temperature was 20° C. Thus, for comparison, results at both the temperatures were taken. The atmospheric pressure during all the experiments was 680 $\pm$ 2 mm of Hg. Thus while studying the effect of humidity, no corrections for air density were applied as by so applying, they only change all the results uniformly by a constant factor. The range of humidity variation at 20° C was from 11 g/m^3 to 16 g/m^3 corresponding to 65 per cent to 90 per cent relative humidity. The same at 27° C was from 13 g/m³ to 25 g/m³ corresponding to 55 per cent to 90 per cent relative humidity.

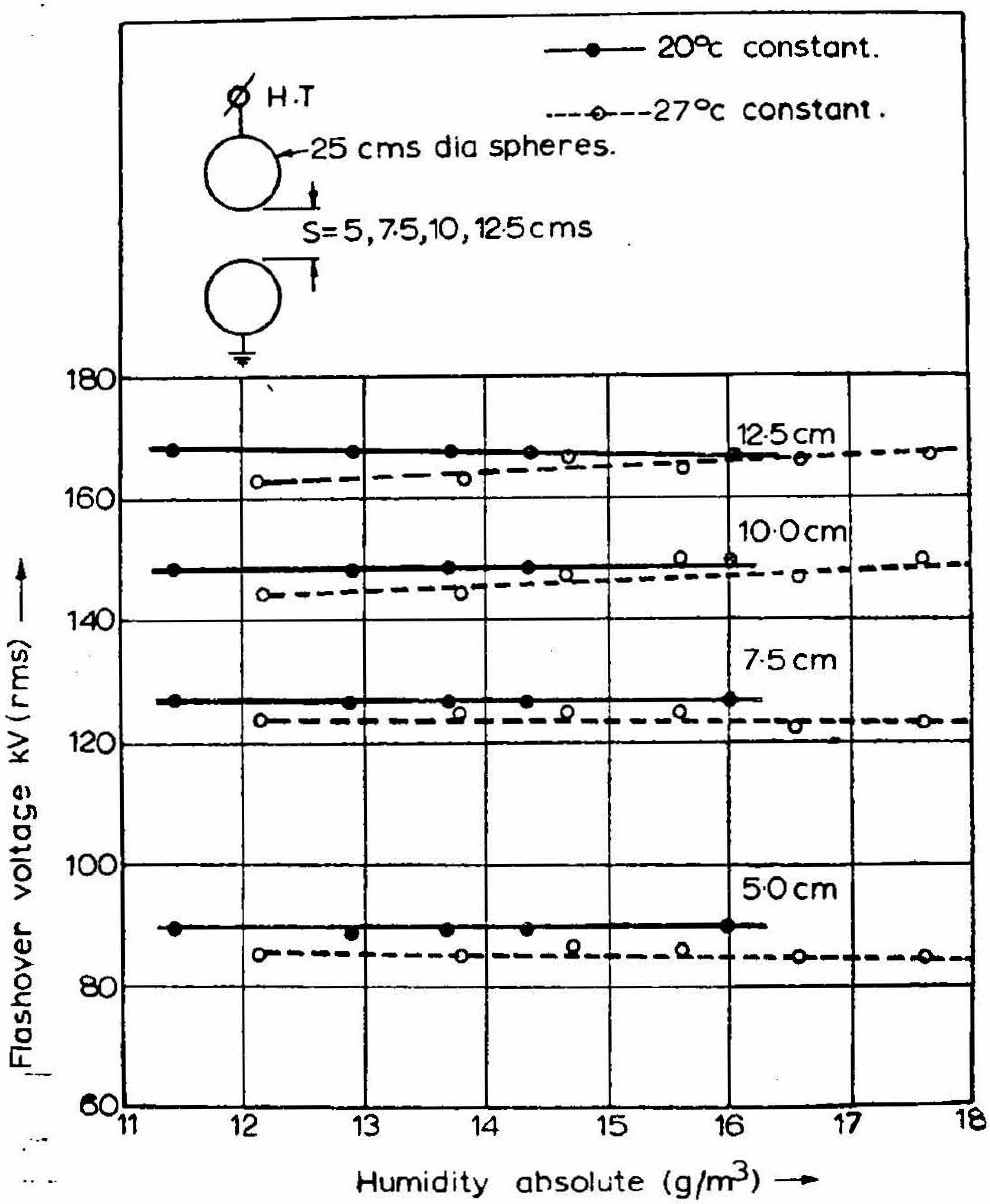

FIG. 2. Effect of humidity on breakdown voltage of sphere gap.

3.1. *Humidity effect on sphere-gap breakdown voltage.*—The breakdown voltages obtained as an average of twenty readings for various humidities at 20° C and at 27° C are plotted in Fig. 2. The mean value of the breakdown voltage has got a maximum standard deviation of 2·2 kV. The scatter is more at high humidities. It is observed that the breakdown voltage does not vary significantly and thus, it may be concluded that variation in humidity does not affect the breakdown voltage of sphere gaps.

3.2. *Humidity effect on rod-gap breakdown voltage.*—The breakdown voltage variation with varying humidities for 250, 400, 500, 600 and 700 mm rod-

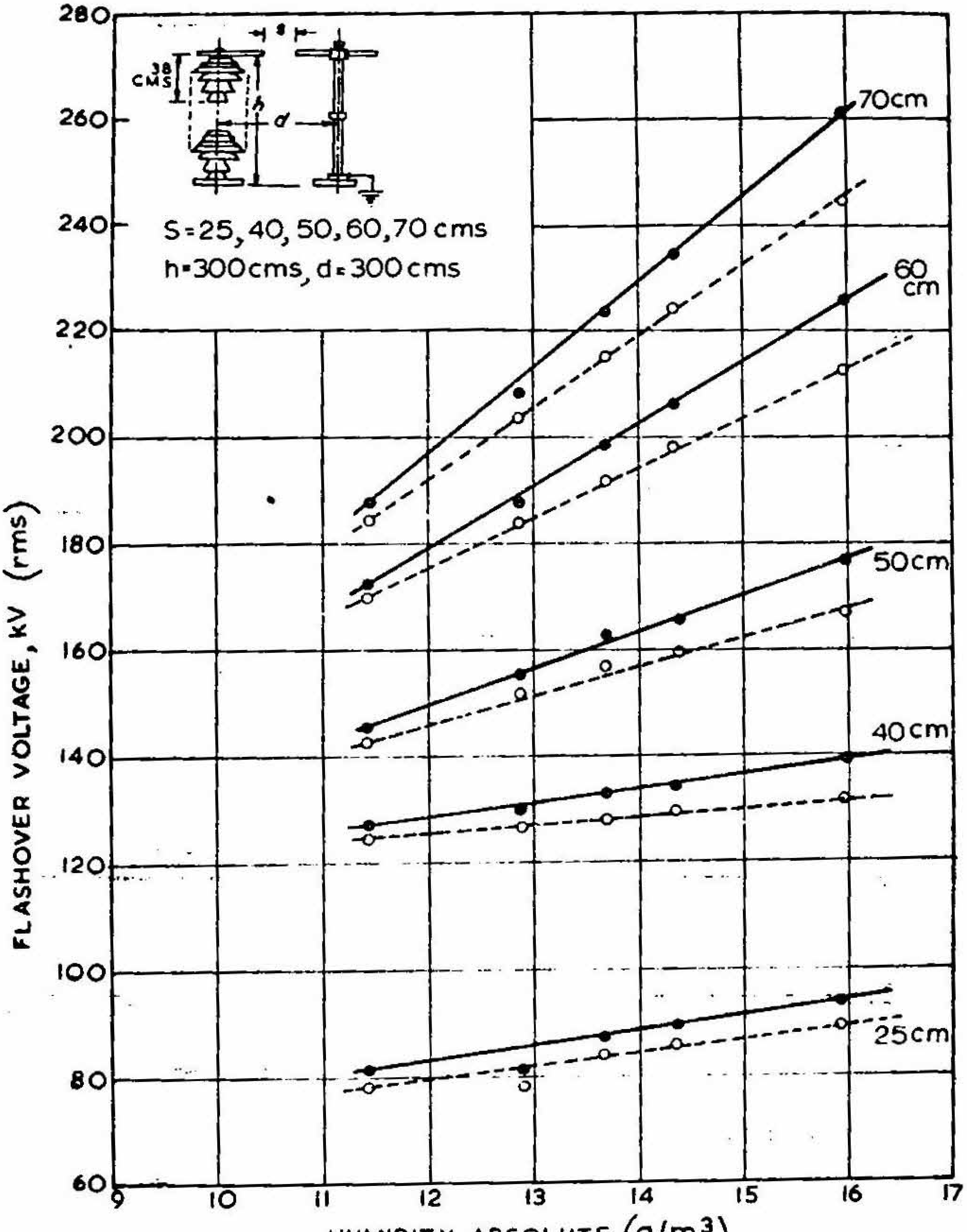

FIG. 3. Effect of humidity on breakdown voltage of rod gaps at 20° C.
—●— experimentally obtained data; ···○··· data corrected by applying standard humidity correction.

gap spacings at the two temperatures 20° C and 27° C are shown plotted in Fig. 3 and Fig. 4. Mean values were calculated after taking twenty readings at each spacing and the standard deviation was found to be between 0·66–2·98 kV.

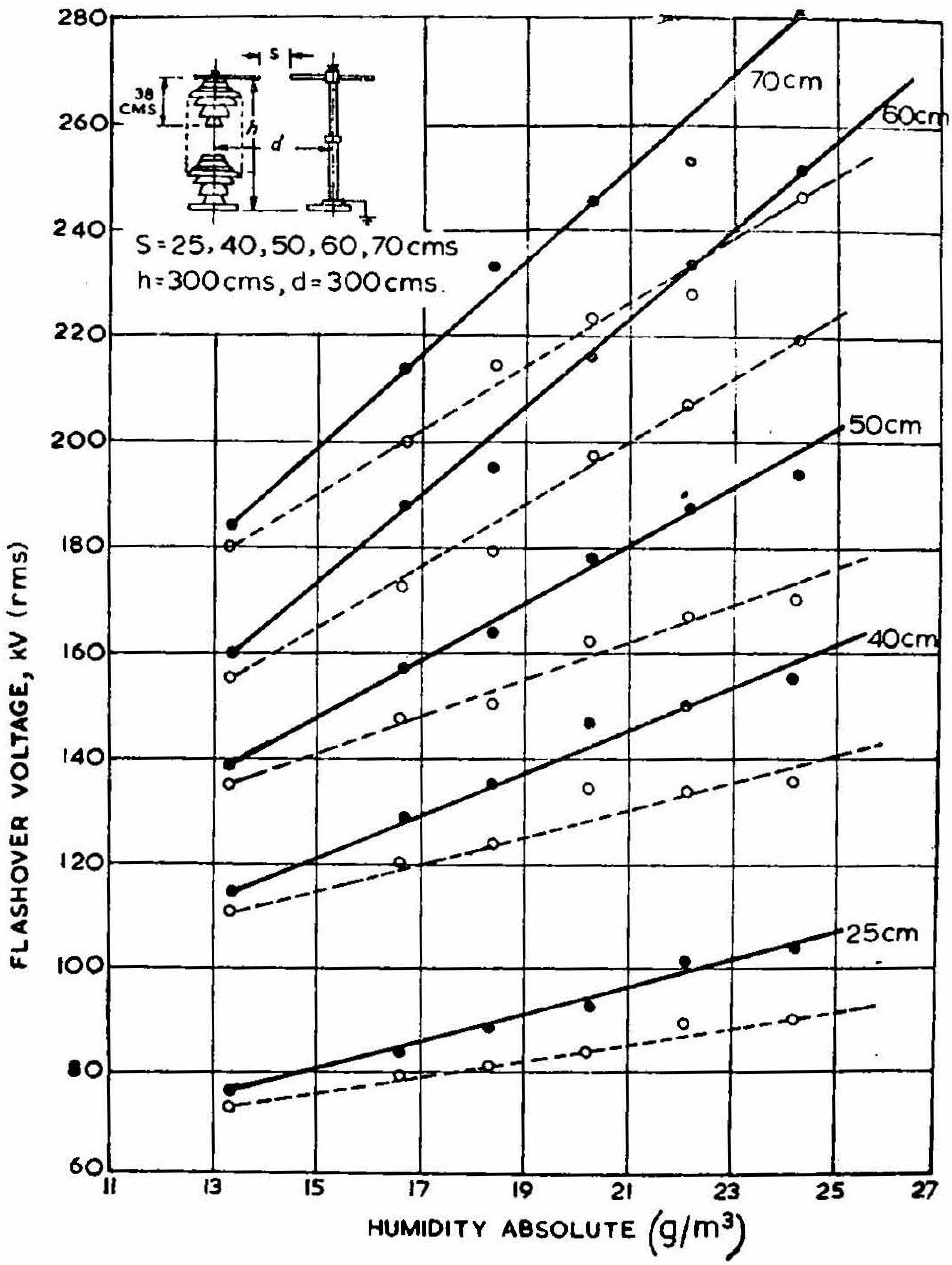

FIG. 4. Effect of humidity on breakdown voltage of rod gaps at 27° C.
—●— experimentally obtained data. ···○··· data corrected by applying standard humdidity correction.

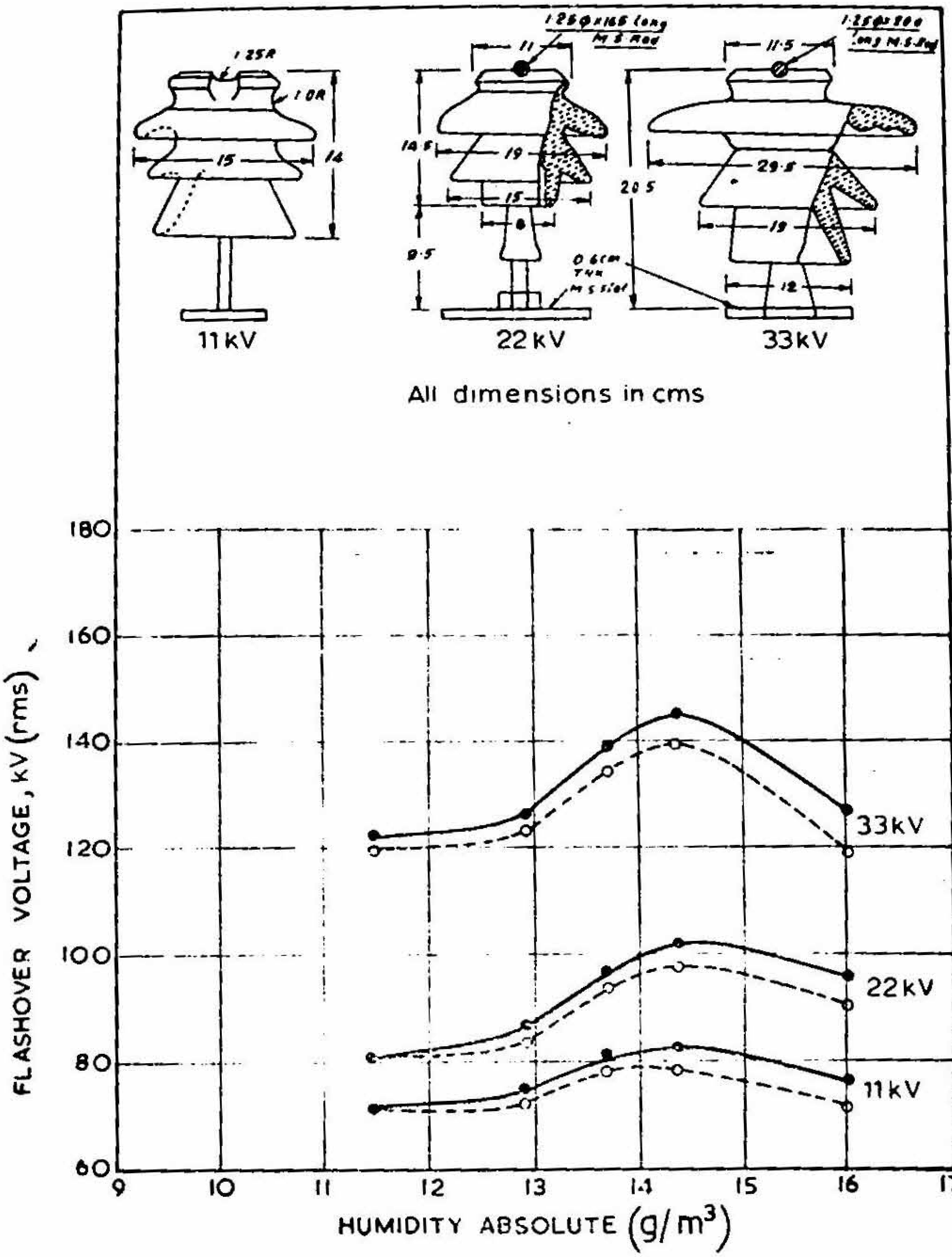

FIG. 5. Effect of humidity on flashover voltage of pin insulators at 20° C; —●— experimentally obtained data; ···○··· data corrected by applying standard humidity correction.

The results indicate that the breakdown voltage rises almost linearly with the rise in humidity and the effect is more pronounced at larger spacings.

(i) The effect of humidity on the breakdown voltage of rod-gaps is much dependent on the gap length. Larger the spacing, higher is the variation.

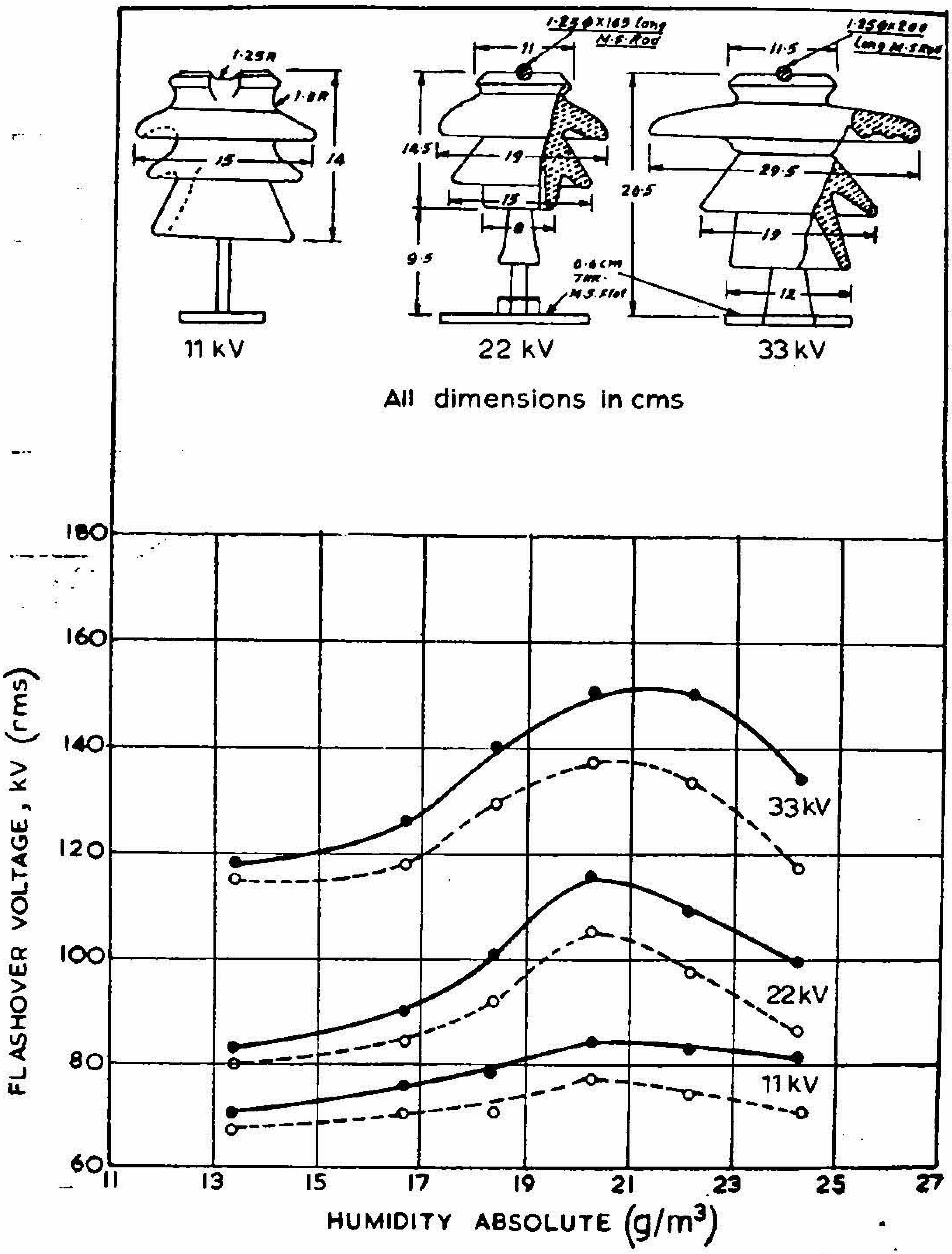

FIG. 6. Effect of humidity on flashover voltage of pin insulators at 27° C. —●— experimentally obtained data; ··○··· data corrected by applying standard humidity correction.

(ii) The effect of humidity is different at different temperatures and thus if 27° C has to be adopted as the standard temperature, the humidity correction curve, as given in the standards to refer the breakdown voltage to 20° C, cannot be used. This can also be concluded from the corrected lines shown dotted in Fig. 3 and Fig. 4.

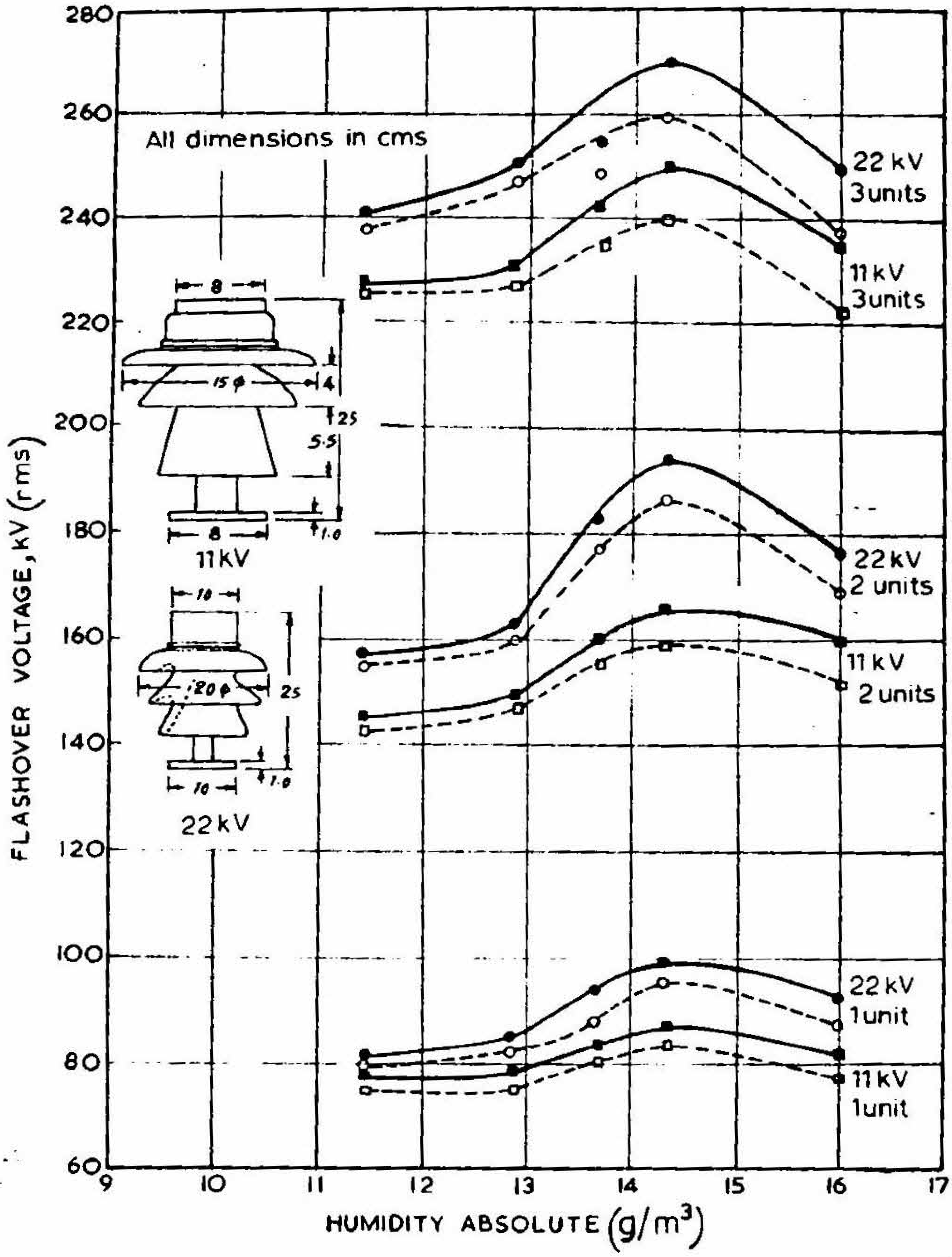

FIG. 7. Flashover voltage variation with humidity for post insulators at 20° C.
—●— experimental curve; ···○··· corrected curve.

3.3. *Effect of humidity on flashover voltages of line and station insulators.*— The mean flashover voltages of pin insulators obtained at different humidities are shown in Fig. 5 and Fig. 6. The maximum standard deviation is 1·75 kV. From the results, it can be concluded that the rate of rise of flashover voltage with humidity is less between the relative humidity range

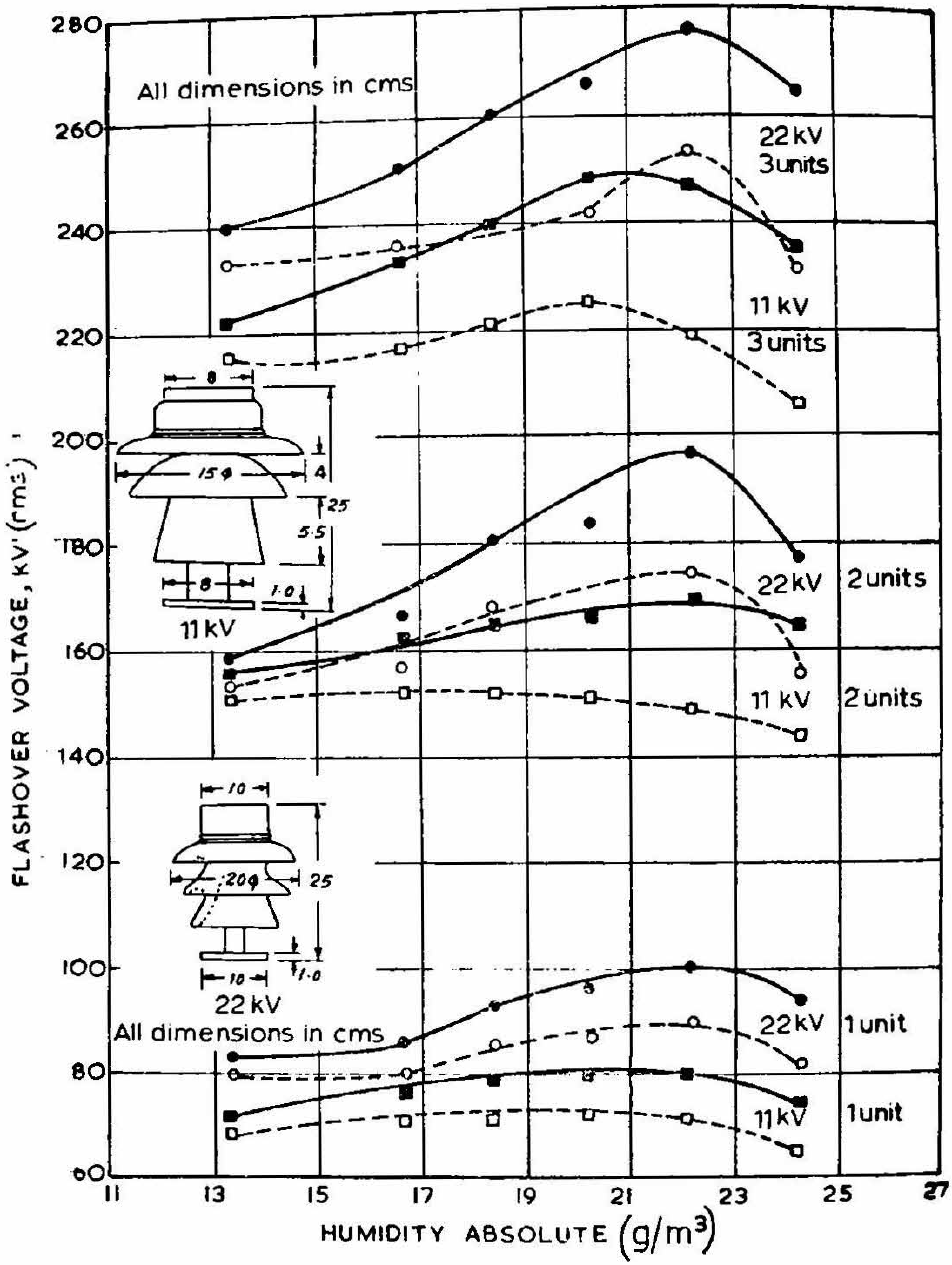

FIG. 8. Flashover voltage of variation with humidity for post insulators at 27° C. —●— experimental curve; ···○··· corrected curve.

of 65 to 70 per cent at 20° C and 50 to 65 per cent at 27° C. There is a steep increase of the flashover voltage in the range 70 to 80 per cent relative humidity or 13 to 15 g/m³ absolute humidity at 20° C and 17 to 21 g/m³ at 27° C.

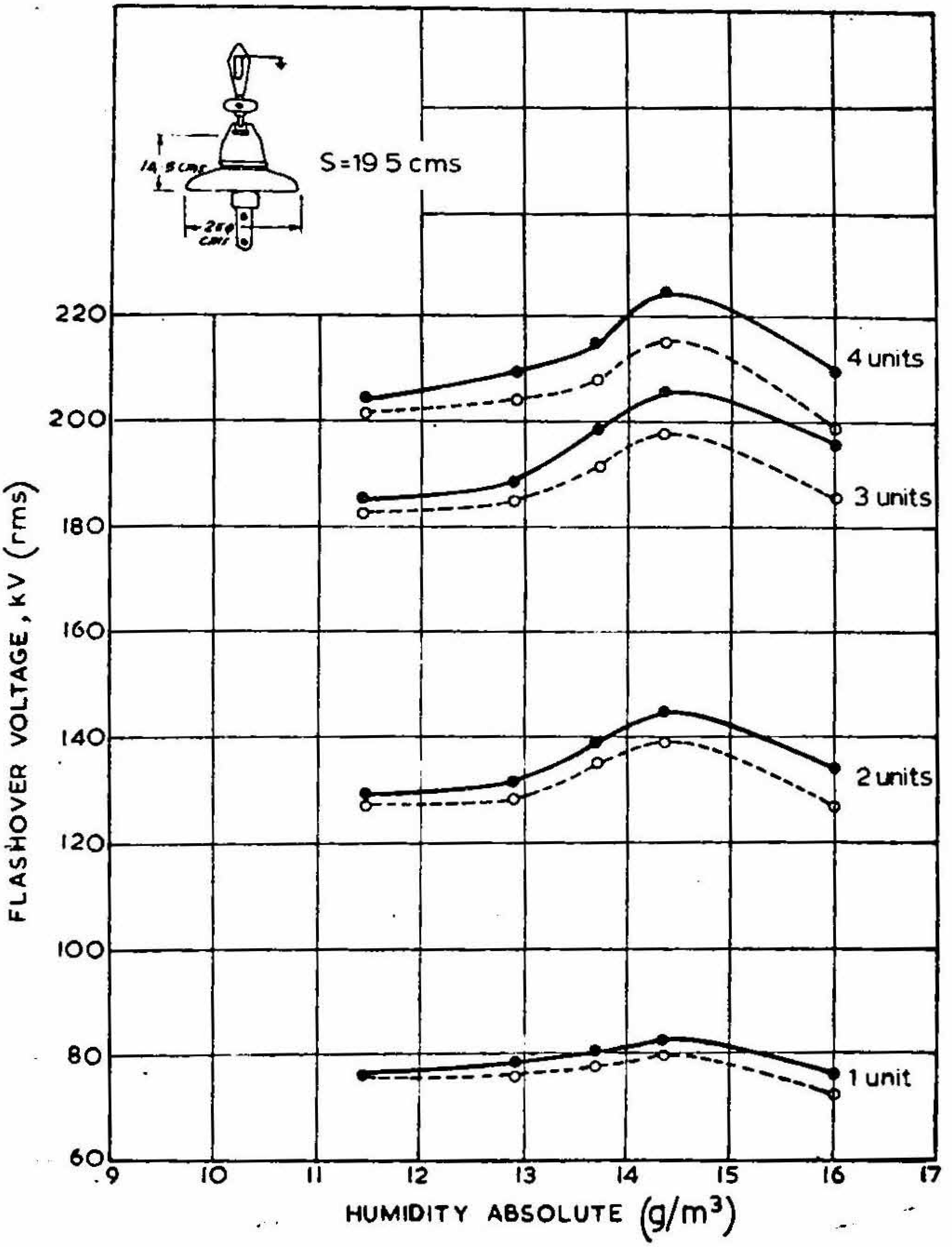

FIG. 9. Variation of flashover voltage of suspension disc insulator with humidity at 20° C. —●— experimental data; ···O··· corrected curve.

The results obtained for post insultaors are shown in Fig. 7 and Fig. 8. Those for standard suspension disc insulators are shown in Fig. 9 and Fig. 10. The trend of these curves are similar to those of pin insulators.

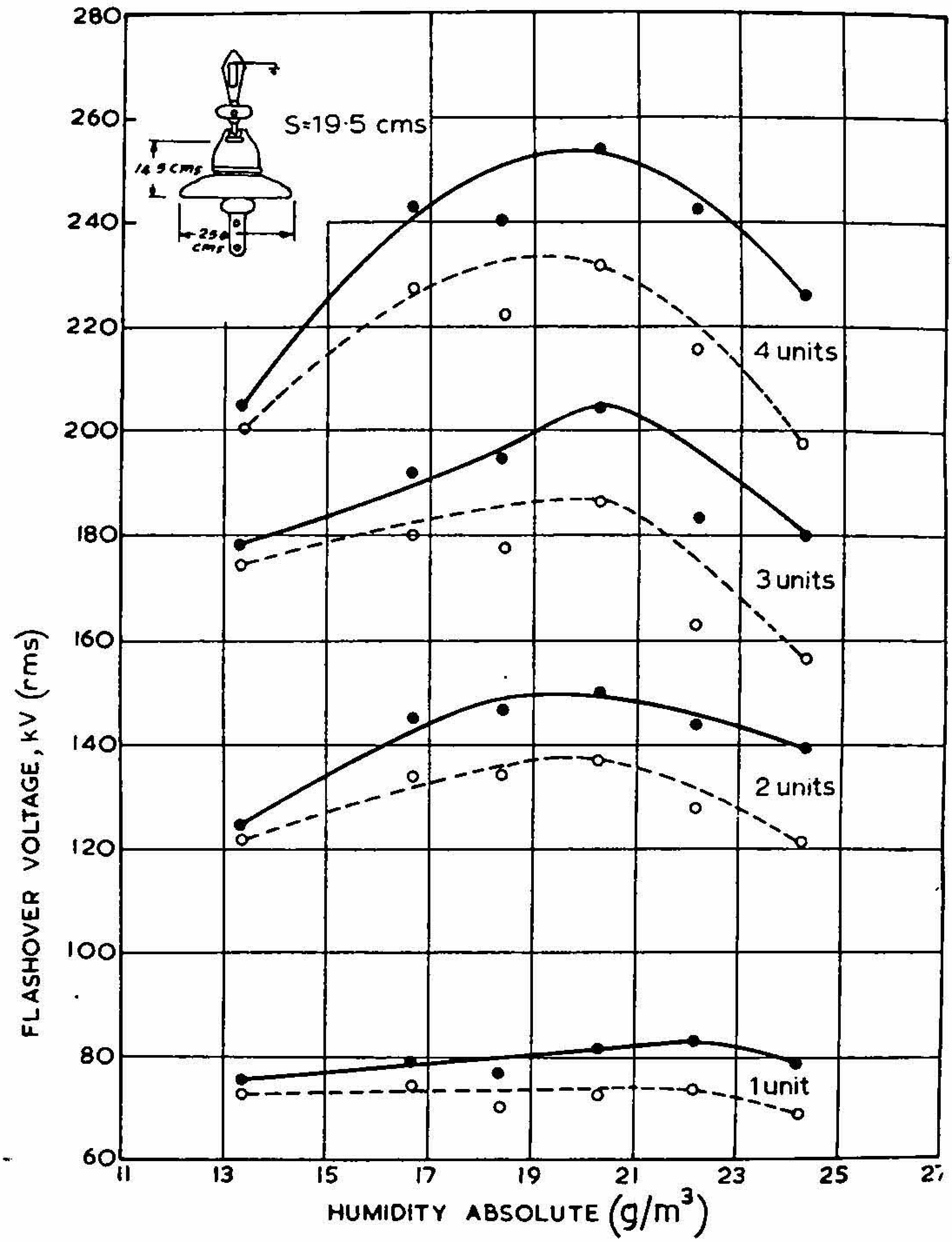

FIG. 10. Variation of flashover voltage of suspension disc insulator with humidity at 27° C. —●— experimental data; ···○··· corrected curve.

With the almost similar results obtained for different types of insulators, it is possible to conclude generally that the variation in the flashover voltage of insulators with variation in humidity has significantly three regions. The first region corresponds to a humidity range of upto 65 per cent. In this range, the characteristics show a constant slope, and are similar to those of the rod-gap. Between 65 per cent and 75 per cent elative humidity range, the flashover voltage characteristics have larger slope. Insulator shape has significant effect on the characteristics in this range. At these humidities, there is better voltage distribution on the surface of the insulators contributing to the increased flashover voltage. After reaching a maximum between 70–80 per cent, the third region corresponds to the falling characteristics. Condensation of moisture on the surface is the main cause for the drop in the flashover voltage.

4·0. Conclusions

Some general conclusions that can be drawn from this study are as follows:

(i) The effect of humidity on the breakdown voltage of sphere gap is not significant.

(ii) Rod-gap breakdown voltage increases linearly with the increase in the humidity.

(iii) Insulator flashover voltages show three different zones—one corresponding to the lower humidity range in which the flashover voltage increases slowly with the increase in humidity, the second, a small region, showing a rapid increase, and the third, at very high humidities, showing a fall in flashover voltages.

(iv) The humidity correction factors proposed in the standards are neither sufficient nor appropriate as seen by the dotted curves after applying corrections. They need a thorough revision in view of the flashover voltage of insulators showing different trends in different humidity ranges. Further work is envisaged at higher temperatures.

References

[1] Fielder, F. D. .. Humidity effect on flashover of high voltage apparatus. *The Electric Journal*, 1935, 32, 543–547.

[2] Gerber, O. .. Effect of air humidity on flashover voltage of insulators. *The Brown Boveri Review*, 1948, pp. 296–305.

[3] Fischer, A. .. Influence of humidity on dc and ac breakdown voltage of air gaps. *Electra*, 1969, pp. 65–77.

[4] Prabhakar, B. R., Nandagopal, M. R. and Gopalakrishna, H. V. Effect of humidity and temperature on impulse flashover voltage of air gaps. *Proc. IEE (GB)* 1971, **118** (6), 823–824.

[5] Allibone, T. E. and Dring, D. Influence of humidity on the breakdown of sphere and rod-gaps underi mpulse voltages of short and long wave fronts. *Proc. IEE (GB)*, 1972, 119(9), 1417–1422.

[6] *High Voltage Test Techniques*, International Electrotechnical Commission, Publication, 60, 1962

[7] British Standard Specification: 'Specifications for porcelain and toughened glass insulators for overhead power lines,' B.S. 137: 1960.

[8] Indian Standard Specification: 'Specifications for porcelain post insulators,' IS: 2544: 1963.

[9] Smee, J. F., and Edwards, F. S. Effect of humidity on the dry flashover voltage of air gaps and insulators. *J. IEE*, 1959, p. 594.

[10] Standring, W. G., Browning, D. H., Hughes, R. C., and Roberts, W. J. Effect of humidity on flashover voltage of air gaps and insulators under alternating and impulse voltages. *Proc. IEE (GB)*, 1963, 110(6), 1077–1081.