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Effect of Absolute Humidity on Flashover Voltage of Insulators

KAZUHIRO HIDAKA, YUKIO MIZUNO
Engineering Physics, Electronics and Mechanics
Nagoya Institute of Technology
Showa, Nagoya 466-8555
JAPAN

KATSUHIKO NAITO
Research Institute
Meijo University
Tempaku, Nagoya 468-8502
JAPAN

OSAMU FUJII
NGK High Voltage Laboratory
NGK Insulators, Ltd.
Mizuho, Nagoya 467-8530
JAPAN

Abstract: - Effect of humidity on flashover voltage of four kinds of porcelain and one polymer insulators was studied experimentally for several years under natural humidity condition in Japan. It was found that the existing IEC humidity correction seems to be proper for most insulators regardless of the kind of applied voltage but that change may be necessary for pin type insulator under positive lightning impulse voltage application and for unit suspension disk and station post insulators under AC voltage application.

Key-Words: Insulators, Flashover voltage, Absolute humidity, Humidity correction

1 Introduction

Humidity correction prescribed in the existing IEC Standard [1] is based on the experimental results reported in 1950's: that is, flashover voltage of insulators increases with absolute humidity [2]. However, at least a paper reported recently a tendency different from the past data [3]. A possibility is also pointed out that the existing correction is not adequate because it occasionally results in excessive correction and causes problems in commercial tests. Under such circumstances, revision of the existing IEC standard is under progress, where some modification of humidity correction seems to be taking into account [4].

Proper humidity correction on test voltage becomes more important for accurate evaluation of the insulator performance. For example, in a puncture test of the insulators for overhead lines specified in the IEC Technical Report [5], the test voltage is calculated based on 50 % negative lightning impulse flashover voltage of the insulator unit at standard atmospheric condition. Therefore, if humidity correction on the 50 % flashover voltage for conversion to standard atmospheric condition is not proper, accurate evaluation of the insulator performance can not be done.

The authors have carried out a series of flashover tests in natural humidity conditions in order to examine the validity of the existing humidity correction in high absolute humidity region above 15 g/cm^3. This paper reports the results of the experiments.

2 Experimental Procedure

Four kinds of porcelain and one polymer insulators were used as specimens. Shapes and technical specifications of the specimens are shown in Table 1. Specimens and electrodes were arranged as prescribed in the IEC Standard [1] on high voltage test.

Table 1 Technical Specifications of specimens

Insulator	H[mm]	D[mm]	LD[mm]	NS
Pin type	138	100	325	--
Suspension disk	146	254	292	--
Long rod	585	160	1020	10
Station post	620	170	1070	10
Polymer long rod	620	125	980	7

H: height, D: diameter, LD: leakage distance, NS: number of shed

AC voltage was supplied by the 300kV transformer. The sources were stiff enough to cause no voltage drop practically [6]. Maximum charging voltage was 600kV for lightning impulse voltage and its waveform was $\pm$1.2/50 μs.

AC flashover voltages were measured by increasing the voltage till flashover occurred. The arithmetic mean of 10 measurements at a given condition was adopted as flashover voltage. 50% lightning impulse flashover voltages were obtained by the up-and-down method [7] with 40-time voltage application at a given condition. Experiments were carried out in a room of 18 x 18 x 12 m height considering the size of a specimen.

All experiments were performed under natural humidity condition for several years since different result may be obtained in artificially controlled humidity conditions because of invisible water condensation on an insulator surface [8]. The dates of experiments were selected according to the change of absolute humidity over three years shown in Fig. 1, which was recorded at the test site. Variation of absolute humidity recorded at a weather observatory station in Bangkok, Thailand, is also shown in Fig. 1 for reference. Another experiment is going on in one of the Thai universities by using the same insulators and following the same experimental procedures. At our test site, the absolute humidity varies in a very wide range from 4.0 to 20.5 mg/m^3, which is suitable for purpose of the present experiment. Bangkok is more preferable place to carry out experiments in high humidity region.

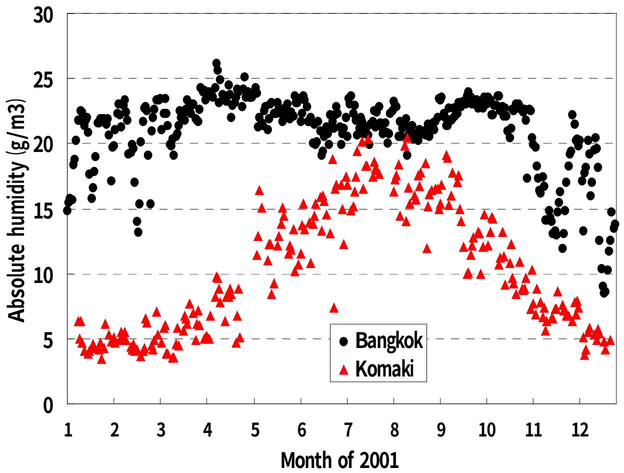

Fig. 1 Temporal changes of absolute humidity at the test site in Japan and at weather observatory station in Bangkok.

3 Test Results and Discussion

According to the IEC Standard [1], flashover voltage measured at a given condition is to be converted by using the atmospheric correction factor to the voltage which would be obtained under the standard condition; temperature of 20 degree C, pressure of 1013 hPa and absolute humidity of 11g/m^3. The atmospheric correction factor Kt is the product of two correction factors and is expressed by

$$Kt = k_1 \text{ x } k_2.$$

k_1 is the air density correction factor expressed by $k_1 = \delta^m$, which is a function of the relative air density δ. k_2 is the humidity correction factor given by $k_2 = k^w$. k is a parameter which depends on the type of applied voltage and is given as functions of absolute humidity and δ. Values of m and w are obtained from a figure in the Publication.

Two kinds of corrections were made to the raw data obtained. One is the correction to the standard relative air density (RAD). The other is to the standard RAD and absolute humidity of 11g/m^3. Both are shown in each figure in this chapter.

3.1 Pin type insulator

Figures 2, 3 and 4 show absolute humidity dependence of flashover voltage of pin type insulator under AC, positive and negative lightning impulse voltage application, respectively. All the data are normalized as the flashover voltage under the conditions of standard RAD and the absolute humidity of 11g/m^3. The curve in each figure denotes the correction factor in the existing IEC Standard [1]. It is extrapolated to high humidity region above 15 mg/cm^3, the upper limit of the present standard. Lines of 1±0.3 % are also drawn in figures.

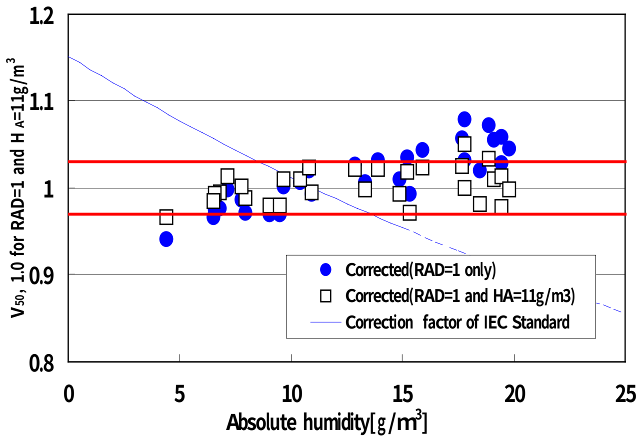

Fig.2 Absolute humidity dependence of AC flashover voltage of pin insulator.

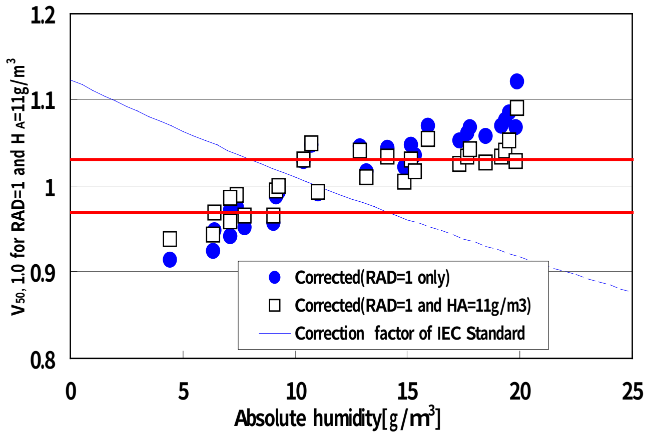

Fig.3 Absolute humidity dependence of 50% positive lightning impulse flashover voltage of pin insulator.

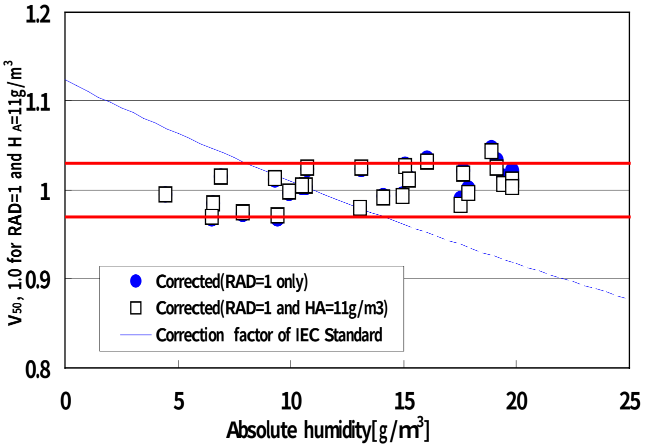

Fig. 4 Absolute humidity dependence of 50% negative lightning impulse flashover voltage of pin insulator.

The existing IEC humidity correction method seems proper for AC and negative lightning impulse flashover voltages. In the case of positive polarity, the existing correction is not proper since normalized flashover voltages do not lie in the 1±0.3 % area in both low and high humidity regions.

3.2 Unit suspension disk insulator

Absolute humidity dependence is shown in Fig. 5 of AC flashover voltage of the unit suspension disk insulator. Figures 6 and 7 show the results obtained by applying positive and negative lightning impulse voltages, respectively.

The existing IEC humidity correction method seems proper for both positive and negative lightning impulse flashover voltages. For AC voltage, the existing correction is not proper since normalized flashover voltages do not lie in the 1±0.3 % area in

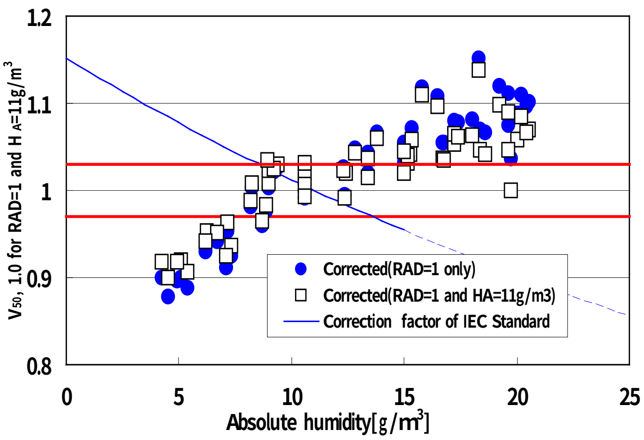

Fig.5 Absolute humidity dependence of AC flashover voltage of unit suspension disk insulator.

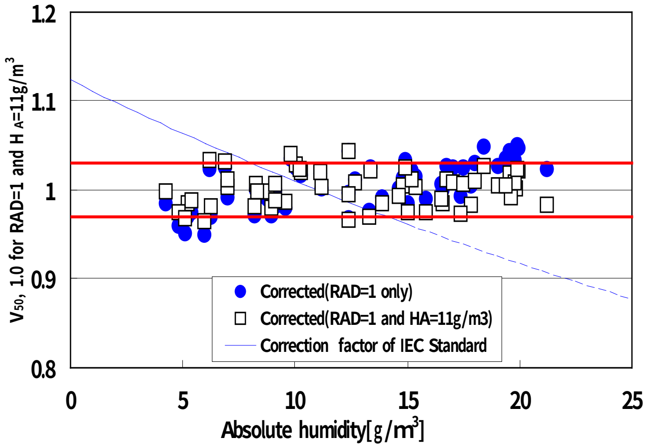

Fig.6 Absolute humidity dependence of 50% positive lightning impulse flashover voltage of unit suspension disk insulator.

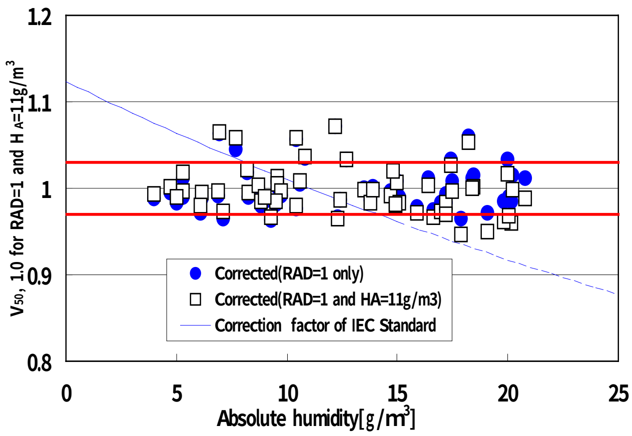

Fig.7 Absolute humidity dependence of 50% negative lightning impulse flashover voltage of unit suspension disk insulator.

both low and high humidity regions.

3.3 Station post insulators

Figure 8 shows absolute humidity dependence of AC flashover voltage of station post insulator. Change of the existing correction method seems necessary all over the humidity region.

The results for positive lightning impulse voltages are shown in Fig. 9, suggesting that the existing correction method seems proper. Examination of correction method for negative lightning impulse voltage was not available this time because of the limitation of the capability of the transformer used.

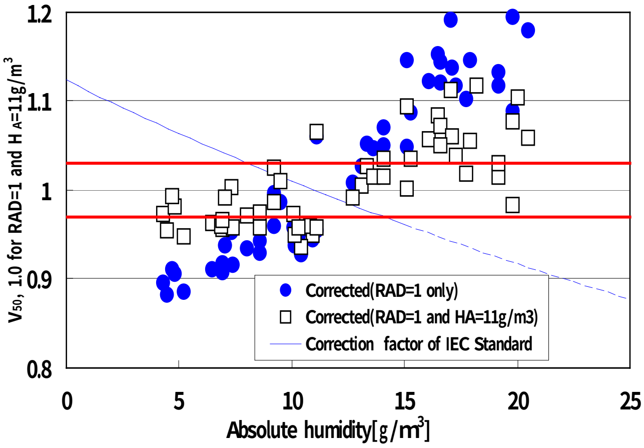

Fig.8 Absolute humidity dependence of AC flashover voltage of station post insulator.

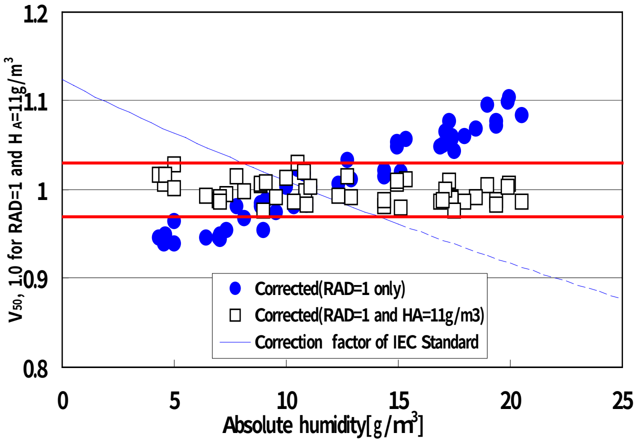

Fig.9 Absolute humidity dependence of 50% positive lightning impulse flashover voltage of station post insulator.

3.4 Long rod insulators

Results obtained for the porcelain long rod insulator are shown in Figs. 10, 11 and 12 for AC, positive and negative lightning impulse voltages, respectively.

Characteristics of the polymer long rod insulators are shown in Figs. 13, 14 and 15 as a function of absolute humidity for AC, positive and negative lightning impulse voltages, respectively.

For long rod insulators, regardless of its material, flashover voltage increases with absolute humidity and the existing correction seems proper.

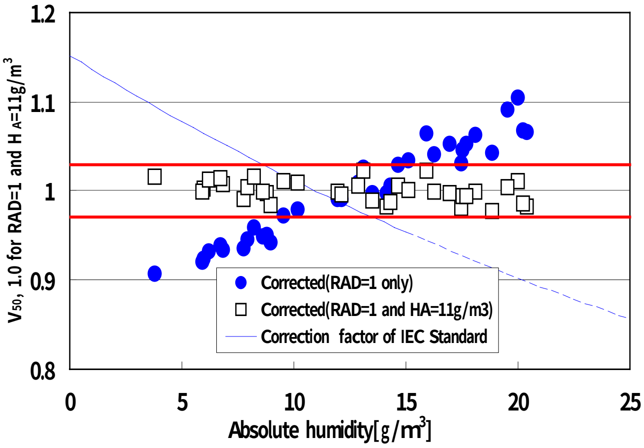

Fig.10 Absolute humidity dependence of AC flashover voltage of long rod insulator.

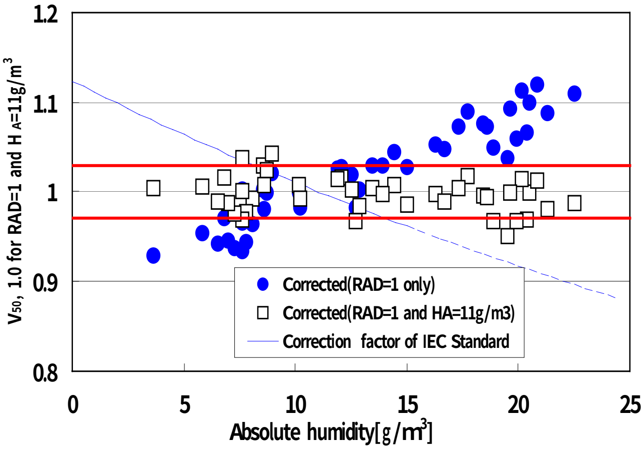

Fig.11 Absolute humidity dependence of 50% positive lightning impulse flashover voltage of long rod insulator.

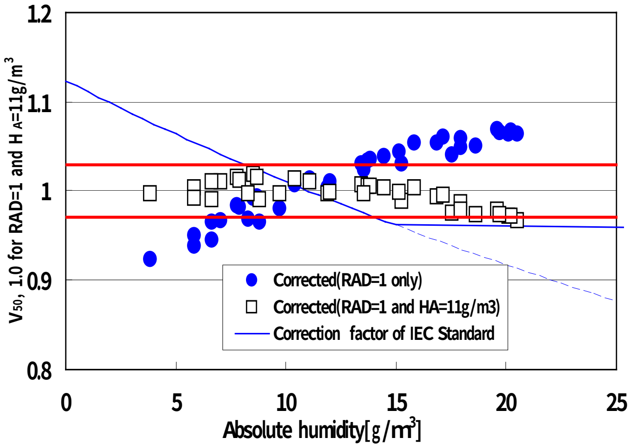

Fig.12 Absolute humidity dependence of 50% negative lightning impulse flashover voltage of long rod insulator.

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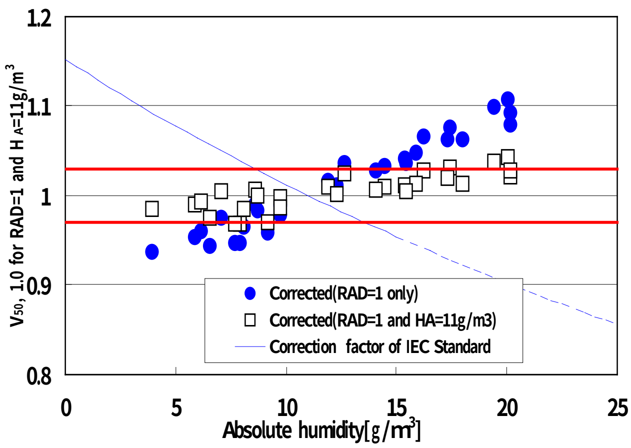

Fig.13 Absolute humidity dependence of AC flashover voltage of polymer long rod insulator.

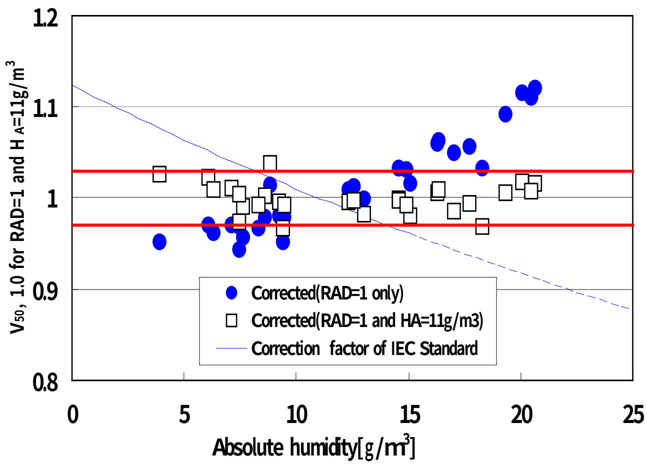

Fig.14 Absolute humidity dependence of 50% positive lightning impulse flashover voltage of polymer long rod insulator.

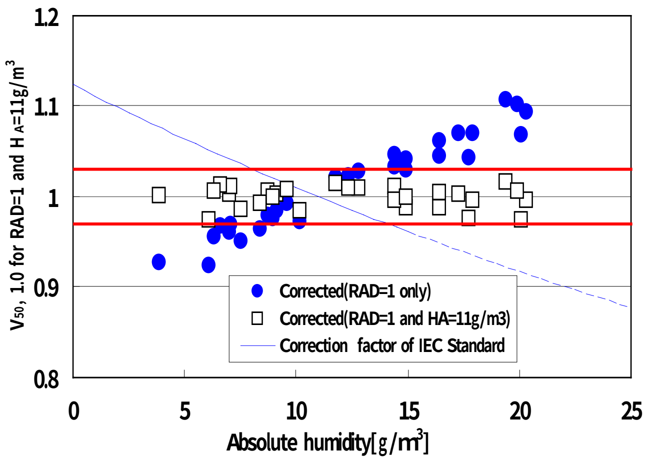

Fig.15 Absolute humidity dependence of 50% negative lightning impulse flashover voltage of polymer long rod insulator.

3.5 Summary and possible modification of humidity correction method

The results obtained so far are summarized in Table 2. For most of the cases, the existing correction method seems proper but modification of correction factor seems needed in three cases.

Table 2 Summary of experimental results.

Insulator	AC	positive LI	negative LI
Pin type	○	×	○
Suspension disk	×	○	○
Long rod	○	○	○
Station post	×	○	N/A
Polymer long rod	○	○	○

○: existing correction seems proper up to 20mg/cm^3
×: change of existing correction seems necessary

A possible change of the existing correction is discussed for the case indicated by the mark "×" in Table 2. Since the humidity correction k_2 is not considered enough, there are two ways to increase the value of k_2; one is to increase the value of k and the other is to increase the value of the exponent w.

k is given by $k = 1 + 0.012\ (h/\delta - 11)$ in the existing humidity correction method for AC voltage, where h is absolute humidity. In the case of AC flashover voltage of station post insulator, if 0.012 is replaced by 0.018, the improvement is confirmed by comparing Fig. 16 with Fig. 8.

In the cases of positive lightning impulse flashover

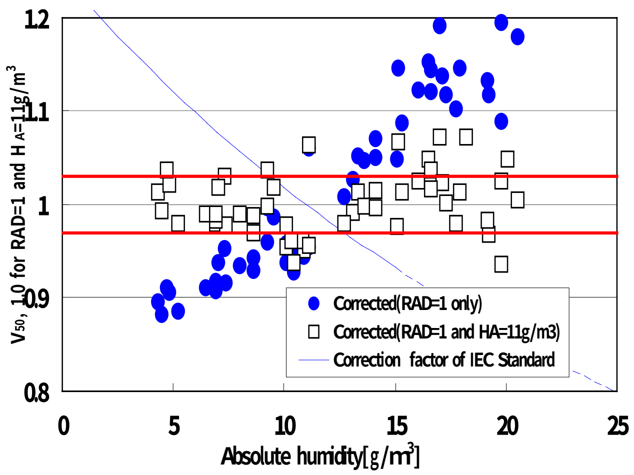

Fig.16 Absolute humidity dependence of AC flashover voltage of station post insulator when the factor of 0.012 is replaced by 0.018.

voltage of pin insulator and AC flashover voltage of unit suspension insulator, little improvement was confirmed by changing the factor of 0.012. Thus, w=1 was assumed for the two cases. The results are shown in figs. 17 and 18. Comparing Figs. 4 and 5, obtained by the existing correction method, the proposed correction method seems a possible modification of the existing correction method.

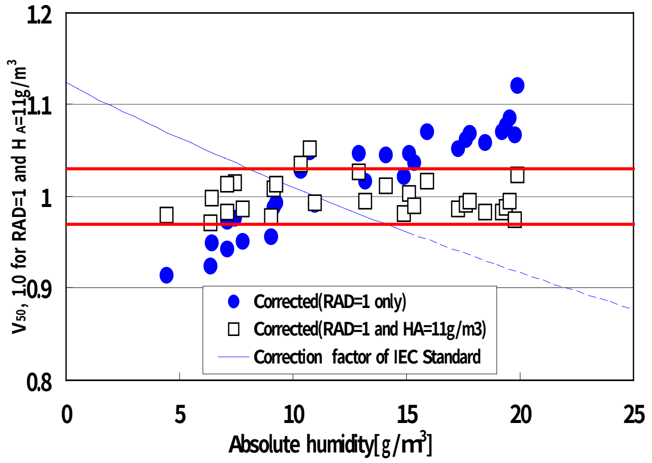

Fig.17 Absolute humidity dependence of 50% positive lightning impulse flashover voltage of pin type insulator when w=1 is assumed.

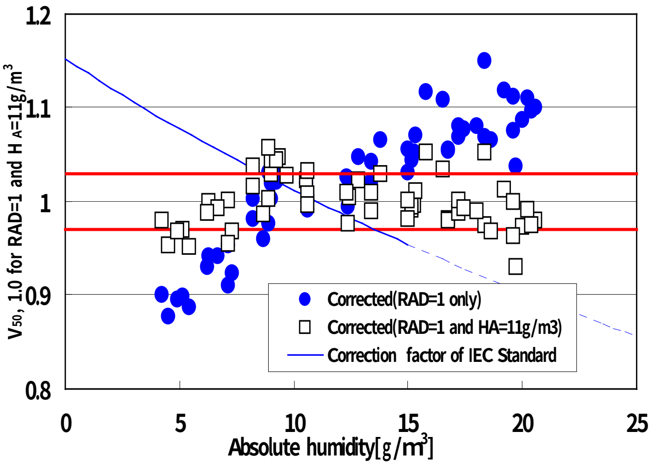

Fig.18 Absolute humidity dependence of AC flashover voltage of unit suspension disk insulator when w=1 is assumed.

4 Conclusion

Effect of absolute humidity on flashover voltage of various insulators was studied under natural conditions by applying AC or lightning voltage. The main results obtained are as follows:

(1) For most of insulators, the existing humidity correction seems to be proper regardless of kinds of applied voltage.
(2) Modification of humidity correction seems necessary for unit suspension disk and station post insulators under AC voltage application and for pin type insulator under positive lightning impulse voltage application.
(3) A possible modification method of humidity correction was proposed for the three cases described in (2). Further investigation is necessary to check the validity of the proposal.

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