

Report 2

Evaluation Method for Ion Migration Using Dew Cycle Test (Part 2)

Yuuichi Aoki*1/Hirokazu Tanaka*1/Shigeharu Yamamoto*1/Osamu Obata*2/Yoshiki Saito*2

Dew condensation has become a nemesis of the electronics field. It causes a number of problems, from ion migration to malfunction and breakdown of electronic equipment. Because of this, evaluation through dew cycle test has become indispensable for parts and products.

In the Part 1, we reported on stability and reproducibility in dew condensing test with the dew cycle test chamber. In this report (Part 2), we shall discuss how the test chamber has made possible abruptly raising the temperature from a normal temperature range (hereafter called low temperature) to a higher range of temperature and humidity (hereafter called high temperature). The test chamber has also made possible greater fidelity in reproducing the market environment in tests.

In addition, we have confirmed the relationship between the speed at which ion migration forms and the quantity of dew condensation forming in the test chamber when temperature and humidity conditions are changed.

1. Introduction

Currently no standardized testing method exists for dew cycle test. Different companies use a variety of testing methods. The lone exception to this lack of standardization are the JASO vehicle standards, which establish that the temperature and humidity conditions in which a vehicle is operated be considered in dew condensing test. Temperature and humidity conditions need to be set in accordance with the temperature and humidity encountered in each specific field for the specimen being evaluated.

Measurement can be made using one of two methods. In one, current is passed through the specimen, then the electricity is shut off and the specimen checked for evidence of ion migration. In the other, an external signal terminal is used to send current to operate the specimen while continuously monitoring and recording consumption of electricity. Continuous measurement during the test period is required because intermittent defective operation caused by dew condensation cannot be confirmed by a measurement that requires interrupting the test.

Dew cycle test can be carried out under a wide range of temperature and humidity conditions, depending on the type of equipment and the variety of environmental conditions in which the equipment is being used. Because of this, we shall report on testing performed to determine dew condensing quantity under a variety of temperature and humidity conditions.



Photo 1 Dew cycle test chamber

*1 Environmental Test Technology Center

*2 Product Design Department

2. Determining Dew Condensing Quantity Through Differences in Temperature and Humidity Conditions

The transition over time of the quantity of dew condensation forming, as we announced in the report part 1, can be postulated as in Fig. 1. We defined total dew condensing quantity as the integral value of the dew condensing time and quantity forming at rate time, then we measured quantity and duration of dew condensation. The equipment used in testing is as follows.

Test equipment:

Dew cycle test chamber DCTH-70, made by Tabai Espec

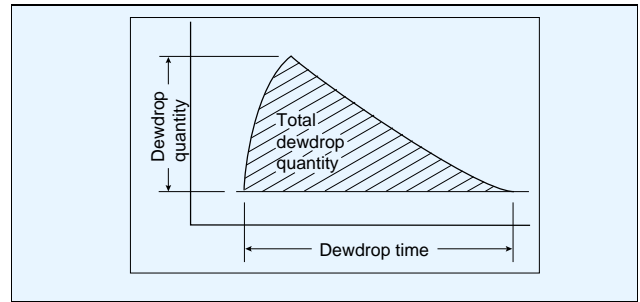


Fig. 1 Change in dew condensing quantity

2-1 Measuring Dew Condensing Quantity

2-1-1 Method of Evaluating Dew Condensing Quantity

We measured dew condensing quantity relatively from current leakage during dew formation. We used teflon to prevent the substrate board from absorbing humidity and plated the electrodes with gold to make it as difficult as possible for migration to form.

Then we applied alternating current. The resulting waveform of current leakage is not stable, but the peak value of current leakage showed the conditions to be reproducible. Taking this peak value as a representative characteristic of dew condensing quantity, we investigated the relationship between the peak value and each of the conditions, which we shall define. The method of measuring and the specifications of the substrate board are given in Table 1.

Table 1 Specimen specifications, prior processing, and method of measuring current leakage

Substrate board specifications	Board material: teflon. Tandem compound gold-plated electrodes corresponding to JIS type 2
Prior processing	First clean in alcohol (IPA) with ultrasonic wave, then hand wash in alcohol.
Measurement method	Apply 5V AC and measure the average peak value of current leakage.

2-1-2 Analysis of the Effect of the Temperature Difference (ΔT)

Because we felt that the quantity of dew condensation would change in relation to the temperature difference (ΔT), we examined the dew condensing quantity from the perspective of the temperature difference. We set the low temperature at a uniform $+5^{\circ}\text{C}$ and progressively changed the high temperature settings for humidity and temperature. Results are shown in Fig. 2.

The results show a temporary relationship between the temperature difference and the peak current leakage.

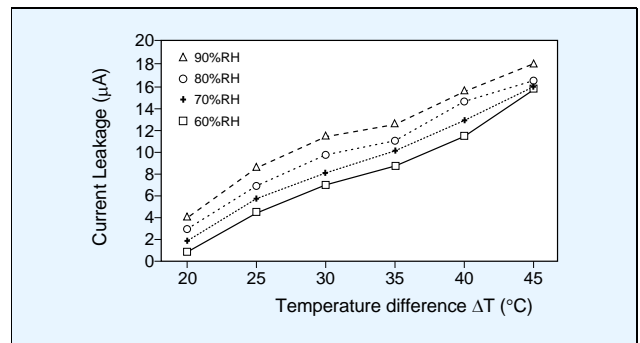


Fig. 2 Temperature difference (Δ) vs current leakage characteristics

2-1-3 Analysis of the Effect of the Difference in Temperature Settings

With the temperature difference (ΔT) between low temperature and high temperature set to a uniform 20°C , we looked for changes in dew condensing quantity when the temperature settings were changed. In addition, we set the high temperature relative humidity to a uniform 90%RH. Fig. 3 shows the results. The quantity of dew condensation varies in response to the temperature setting range. We were able to confirm that the higher the temperature range, the greater the quantity of dew condensation. This can be postulated as due to the higher the temperature range, the greater the saturation quantity of steam in the air, even when the temperature difference remains the same. (Refer to Fig. 2 and 3.)

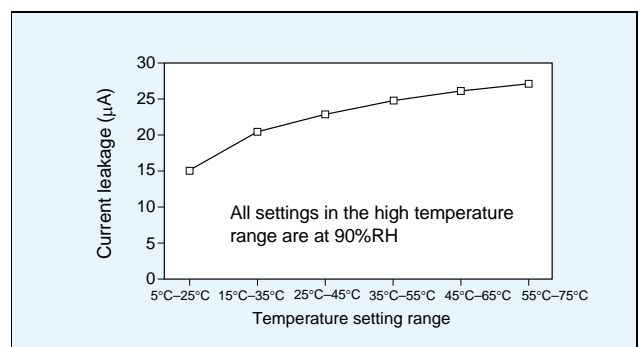


Fig. 3 Temperature setting range vs current leakage characteristics

2-2 Measuring Dew Condensing Time

Fig. 4 shows changes in specimen temperature occurring in the dew cycle test. The range ($t_0 \rightarrow t_1$) of temperature equilibrium at which dew condensation forms on the specimen shows wet-bulb temperature. In the next range ($t_1 \rightarrow t_2$), that of transition from wet-bulb temperature to dry-bulb temperature, the surface of the specimen can be assumed to be drying regionally. Because of this, we measured the time ($t_0 \rightarrow t_1$) charted for wet-bulb temperature of the specimen and used it to represent dew condensing time. Because this time varies according to the thermal capacity of the specimen, we used a 10 mm diameter steel ball as the standard specimen for this series of tests. The ball has dew condensation for at least half the high temperature exposure and dries within the time period.

Dew condensing time can be postulated as $t_0 \rightarrow t_2$, but since the condition is uncertain in $t_1 \rightarrow t_2$, we measured $t_0 \rightarrow t_1$ during which time the dew formation on the specimen can be assumed to be uniform.

2-2-1 Method of Measuring

First, we measured the surface temperature of the steel ball. Next, through reciprocal comparison between the steel ball surface temperature and the time charted for the wet-bulb temperature in the chamber, we examined the changes in dew condensing time caused by humidity, temperature, and wind speed.

Table 2 shows test conditions. We set the temperature difference (ΔT) to a uniform 20°C for the temperature and humidity conditions, which we changed by 10°C at a time.

2-2-2 Test Results

Fig. 5 shows test results. When a uniform temperature difference was maintained, the higher the temperature setting, the shorter the dew condensing time. In addition, the higher the wind speed, the shorter the dew condensing time. Both these results and the dew condensing quantity results in item 2-1-3 show that the dew condensing quantity increases at the high temperature conditions, and drying can also be assumed to be faster. We can also assume that the higher the wind speed, the faster the drying time.

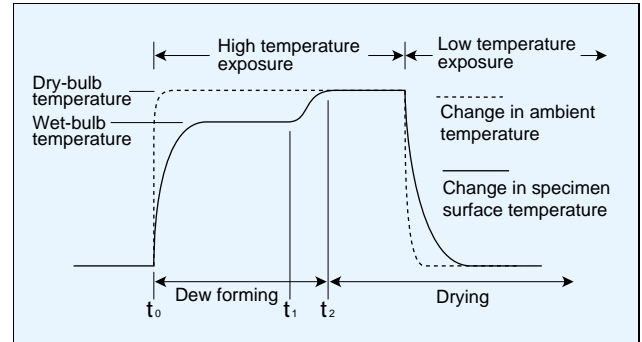


Fig. 4 Specimen temperature change in the dew cycle test

Table 2 Temperature and humidity conditions and wind speed for measuring dew condensing time (○ : indicates condition enforced)

Temperature and humidity conditions	Wind speed		
	MIN. (0.9m/s)	MID. (1.4m/s)	MAX. (1.9m/s)
5°C 90%RH ↔ 25°C 90%RH (20 minutes each)	○	○	○
15°C 90%RH ↔ 35°C 90%RH (20 minutes each)	○	○	○
25°C 90%RH ↔ 45°C 90%RH (20 minutes each)	○	○	○

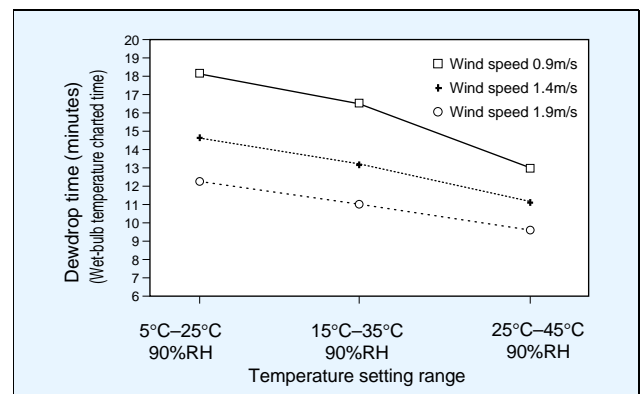


Fig. 5 Steel ball dew condensing time characteristics

3. The Relationship Between Temperature/Humidity Conditions and Migration

3-1 Test Method

The main conditions influencing the speed at which migration occurs are temperature, humidity, and electrical field. We can also report that for dew condensation, ion shift time varies according to the way drops of water adhere. However, the relationship between migration and temperature and humidity conditions in the dew cycle test is not well understood, so we examined migration occurring in response to each of the temperature and humidity conditions.

Table 3 shows test conditions.

Table 3 Dew cycle test conditions for confirming migration

Temperature and humidity conditions	(1) 5°C↔25°C 90%RH (20 minutes each) (2) 15°C↔35°C 90%RH (20 minutes each) (3) 25°C↔45°C 90%RH (20 minutes each)	
Test cycles	80 cycles	
Specimen	Material	Glass epoxy substrate board
	Pattern	Tandem compound electrodes corresponding to JIS type 2 (spacing 0.318 mm)
	Sample number	n = 15
	Substrate board dimensions	50 mm x 120 mm
Prior processing	No coatings such as flux or resist Ultrasonic cleaning in alcohol (IPA)	
Bias	DC 5V applied	
Measuring method	External observation by intermittent removal each 10 cycles	
Judgment method	Even one occurrence of migration in pattern results in failure	

3-2 Test Results

Fig. 6 shows test results. Photo 2 shows the migration that formed. The higher the range of the temperature setting, the more quickly migration formed and the less time elapsed before failure. The results, as seen in Fig. 7, indicate that the speed at which migration forms is more strongly related to dew condensing quantity than to dew condensing time.

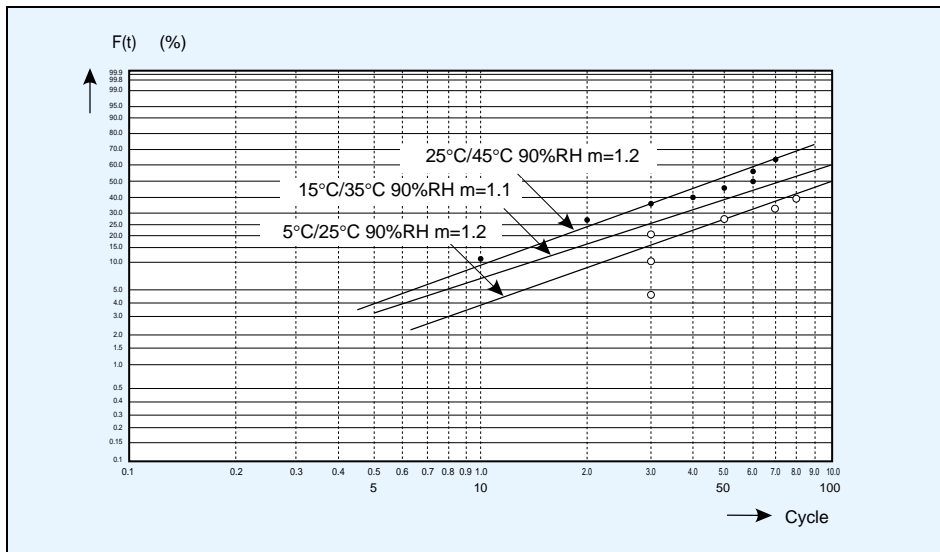


Fig. 6 Weibull probability plot data on dew cycle test results for migration

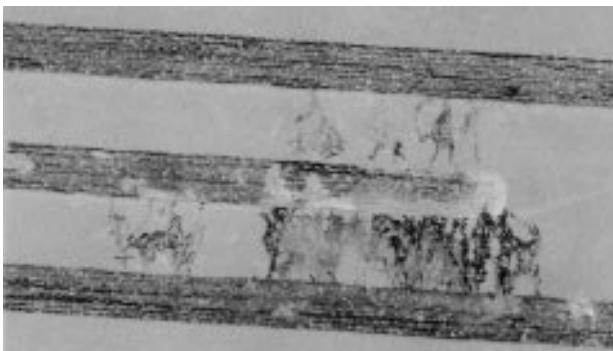


Photo 2 Migration formed in the dew cycle test

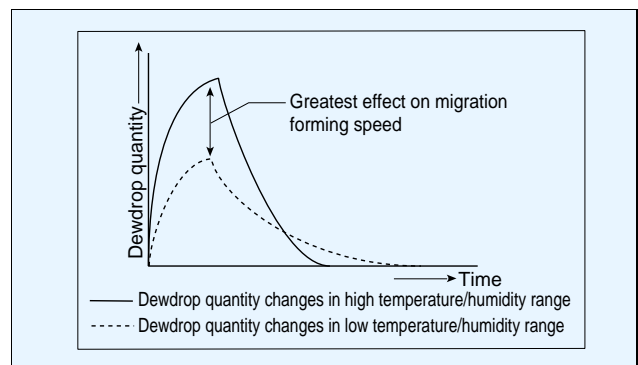


Fig. 7 The relationship between dew condensing time and quantity

3-3 Examining migration caused by dew condensation

At temperature and humidity conditions with a uniform temperature difference, the profile parameters all resulted in similar values ($m = 1.2$) regardless of conditions set. Failure caused by ion migration can be postulated to be the same at the various temperature and humidity conditions at which these tests were performed. The average life was approximately proportional to the temperature range set. We surmise that this is due to the strong influence of the different saturation level of steam in each temperature range.

In this type of dew cycle test with changes in conditions set, the difference in dew condensing quantity due to the different saturation level of steam for each temperature can be postulated to increase the speed at which migration forms. However, when evaluating marketplace products, we must keep in mind that materials come in a variety of shapes for both high temperature and low temperature use, making the causes more complex. Therefore, we must consider more than the dew condensation. We need to create tests that account for changes in materials. Accordingly, we must take great care to examine and select the characteristics of the test specimen.

4. Summary

These tests revealed the following points.

1. The greater the temperature difference (ΔT) in the dew cycle test, the greater the quantity of dew condensation.
2. When the temperature difference (ΔT) is uniform in the dew cycle test, higher temperature also produced more dew condensation, but duration is shorter.
3. The greater the wind speed, the shorter the dew condensing time.
4. Migration forming speed is strongly related to the peak time of dew condensing quantity and is influenced by the saturation steam quantity of the setting temperature.

The next tests that need to be carried out are an examination of the relationship between cycle acceleration characteristics and failure reproducibility in market products.

In addition, recently cases involving the use of specialized insulation resistance measurement systems have been increasing. This type of measurement method makes it possible to continuously monitor changes in insulation resistance. This seems as if it would be an effective method for collecting data for the dew cycle test.

5. Acknowledgments

We would like to take this opportunity to express our gratitude for the advice in putting together this report that we received from everyone in the Quality Assurance Group, Quality Management Department at Matsushita Communication Industrial Co., Ltd.

[Reference Bibliography]

- 1) Tsuneo Ajiki:
"Reliability Technology of Semiconductor Devices" Union of Japanese Scientists and Engineers (1988)
- 2) Kiyoshige Echikawa:
"Reliability Test of Electronics Components" Union of Japanese Scientists and Engineers (1985)
- 3) Yuko Kanai/Shizuhiko Okiyama/Hideo Yamada/Satoshi Kobayashi/Ikuo Watarai:
"A Study on a Method of Testing Ion Migration" Proceedings of the 24th. Union of Japanese Scientists and Engineers Symposium on Reliability and Maintainability (1994)
- 4) Yuuichi Aoki/Hirokazu Tanaka/Shigeharu Yamamoto/Osamu Obata:
"Evaluation Methods of Ion Migration by Dew Condensation Cycle Test" Proceedings of the 24th. Union of Japanese Scientists and Engineers Symposium on Reliability and Maintainability (1994)
- 5) Yuuichi Aoki/Hirokazu Tanaka/Shigeharu Yamamoto:
"Evaluation Method Using Condensation Cyclic Test Chamber" Seminar Text of Japan Institute for Interconnecting and Packaging Electronic Circuits Japan Institute for Interconnecting and Packaging Electronic Circuits (1995)
- 6) Hirokazu Tanaka/Yuuichi Aoki/Shigeharu Yamamoto/Kunikazu Ishii:
"A Study on Reliability Evaluation of Electronic Parts" Proceedings of the 25th. Union of Japanese Scientists and Engineers Symposium on Reliability and Maintainability (1995)
- 7) Yuuichi Aoki/Hirokazu Tanaka/Shigeharu Yamamoto/Osamu Obata/Yoshiki Saito:
"Evaluation Methods of Ion Migration by Dew Condensation Cycle Test, Part 2" Proceedings of the 25th. Union of Japanese Scientists and Engineers Symposium on Reliability and Maintainability (1995)