Application of T-Test Method in The High Temperature Test of Air Traffic Control Monitoring Equipment in Civil Aviation

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Abstract. Civil aviation ATC equipment needs to fully consider whether it meets environmental requirements before being put into operation. This article introduces the classification of air traffic control equipment and the different harsh environments to which various types of equipment will be subjected. It also introduces the details of the various effects of high temperature on the equipment. Then, taking the high temperature test of the secondary surveillance radar of the civil aviation ATC as an example, this article details introduces the test steps according to GB2423.2 for carrying out the high temperature test of this type of equipment. The receiver’s dynamic range was tested during the test. After the test, the test results were calculated using the t-test method. Then, the calculated results are compared with the t-distribution critical value table to judge whether the equipment has passed the high temperature test.

1. Introduction

In order to ensure the flight safety and strengthen the management of civil aviation air traffic communication, navigation and surveillance equipment (hereinafter referred to as CNS equipment, and equipment classification is shown in Table 1), Civil Aviation Administration of China (CAAC) CIVIL AVIATION CNS EQUIPMENT CERTIFICATION RULES (CCAR-87) stipulates that all manufacturers of civil aviation air traffic CNS equipment must apply for the provisional certificate of approval and the certificate of approval of civil aviation air traffic CNS equipment. It also stipulates that after receiving the application from the manufacturer, the verification and testing work must be completed based on relevant standards and requirements, which includes the testing of the equipment's requirements for environmental reliability[1].

Table 1. Classification of civil aviation air traffic CNS equipment

| Communication equipment                      | Navigation equipment                  |
|---------------------------------------------|---------------------------------------|
| HF Air-Ground Communication System (HF)     | Instrument Landing System (ILS)       |
| VHF Air-Ground Communication System (VHF)   | Marker Beacon (MB)                    |
| Voice Communication Switch System (VCS)    |                                       |
| AFTN Communication System (AFTN-MS)        |                                       |
| Data Recorder (DR)                         |                                       |
| VHF Data Link Remote Ground Station (VDL RGS)|                                      |
In order to ensure that there is no obstruction by other objects in the surveillance range, most surveillance equipment is installed at high altitudes, usually the highest point in the local area, such as the top of a mountain. And higher altitude usually leads to lower temperature.

2. The Necessity of Environmental Reliability Testing for Civil Aviation Air Traffic Control Equipment

2.1 Analysis of environmental impact on CNS equipment

CNS equipment is usually installed at airports, mountain tops, coastal areas and other areas, and will inevitably be affected by a variety of complex and harsh environmental factors such as temperature, humidity, air pressure, salt spray, wind, snow, sand and dust. In order to protect the air-ground communication from obstructions, the antenna of civil aviation communication equipment is usually installed at a high place, so it will be affected by environmental factors such as temperature, humidity, air pressure, wind and snow. If the airport is a plateau airport or a high plateau airport, the navigation equipment will be affected by highland environmental factors. In order to ensure the coverage of surveillance, the installation location of surveillance equipment needs to be at the highest point around, so it will be affected by highland environmental factors as well. In addition, the equipment installed at coastal areas should consider the impact of salt fog, vibration during transportation before the equipment is installed and used, etc. At the same time, in order to ensure flight safety, all equipment must be kept working all year round.

2.2 High temperature

The high temperature environmental conditions experienced by all equipment come from the atmospheric conditions of where they are located. Usually, when the average temperature of the day is greater than or equal to +35℃, it is defined as high-temperature weather. On July 31, 2015, extremely rare high-temperature weather occurred in Iran since meteorological records, and its daily average temperature reached +74℃. In China, the highest daily average temperature has reached +50.6℃ as well. As shown in Table 2, the average annual high temperature day can reach 50 to 70 days in the following areas [2].
Table 2. Extreme temperature records in China

| No. | Area               | Temperature | No.  | Area                        | Temperature |
|-----|--------------------|-------------|------|-----------------------------|-------------|
| 1   | Lake Eding in Turpan | +50.6°C     | 2    | Turpan Civil Aviation Airport | +49.6°C     |
| 3   | Turpan             | +47.7°C     | 4    | Chongqing                   | +44°C       |
| 5   | Luoyang            | +44°C       | 6    | Jiangxi                     | +44°C       |
| 7   | Nanjing            | +43°C       | 8    | Changsha                    | +43°C       |
| 9   | Wuhan              | +41.3°C     | 10   | Nanchang                    | +41°C       |

In unventilated spaces, such as the interior of closed cars, aircraft surface sections exposed to sunlight, tents, the internal temperature is often much higher than the external temperature. As shown in Table 3, in high-temperature weather, there is also a significant temperature difference between inside and outside the cabin after the aircraft is docked at the airport.

Table 3. Comparison of temperature inside and outside the cabin at the same time

| No. | Parking location             | Cabin temperature | Atmospheric temperature at the same time |
|-----|------------------------------|-------------------|------------------------------------------|
| 1   | Xinjiang Turpan Civil Aviation Airport | +64.7°C          | +47.6°C                                 |
| 2   | Nanchang Xiangtang Airport   | +60.7°C          | +41°C                                   |
| 3   | Changsha Datoupu Airport     | +57.1°C          | +43°C                                   |

2.3 Analysis of the impact of high temperature on equipment

High temperature can cause changes in the structure, physical characteristics, and electrical properties of the different materials that make up the equipment, which may cause permanent and irreversible damage or changes to the equipment. According to the classic Arrhenius equation, each time the temperature rises by 10°C, the failure rate of the product doubles and the reliability decreases by half. For example, when the operating temperature is increased from +35°C to +50°C, the reliability index may drop about 95%. Therefore, high temperature may cause the performance of the equipment to be significantly reduced, and it may also cause the life of the equipment to be significantly shortened. The high temperature environment will have harmful effects on the equipment, including the following failure modes:

1) Because the expansion coefficients of the different materials that make up the equipment are not the same, different expansions will occur between the materials, which will cause the parts are stuck and misaligned with each other;

2) Due to the change in the viscosity of the lubricant, the leakage of the lubricant caused the lubrication capacity of the joints of various components to be greatly reduced, which in turn caused the equipment to be inflexible;

3) The cover or seal is damaged and permanently deformed;

4) The resistance of the fixed resistor changes, which causes the transformer and electromechanical components to overheat, and the pull-in / release range of the relay (the magnetic or thermal device) to change;

5) Equipment performance has degraded;

6) Working life has reduced.

3. High-temperature Test Method for Civil Aviation ATC Surveillance Equipment

3.1 Testing requirements

This article takes air traffic secondary surveillance radar as an example to carry out environmental reliability tests. According to MH/T 4010-2016 "Technical Specifications for Air Traffic Control
Secondary Surveillance Radar System"[3] 4.3.6, the environmental requirements of the secondary surveillance radar system are as follows:

A) Indoor equipment should be able to operate normally in the following environments:
   1) Working temperature: 0℃~+40℃;
   2) Relative humidity: 5%~90%);

B) Indoor equipment should be stored in the following environments:
   1) Storage temperature: -10℃~+50℃;
   2) Relative humidity: 5%~90%);

C) The environmental conditions required for outdoor equipment are as follows:
   1) Working temperature: -55℃~+70℃;
   2) Relative humidity: 5%~100%;

D) The indoor and outdoor equipment should work normally in areas where the altitude does not exceed 3500m.

3.2 Test preparation
This test requires equipment such as temperature sensors, high-temperature test chambers, radar field analyzers (RFA), radar video interconnectors (RVI), and radar video recorders (RVR). To ensure the validity and reliability of the test results, all equipment must be within the calibration validity period.

3.3 Test steps
3.3.1. According to GB/T2423.2-2008 "Environmental Tests for Electrical and Electronic Products-Part 2: Test Methods Test B: High Temperature"[4], it carries out a high temperature test on the main part of the secondary surveillance radar. First, it's necessary to confirm that the equipment under test is a non-radiating test equipment or a thermal test equipment. Distribute the temperature sensor around the equipment, especially near the heat dissipation point, and record the highest temperature as $T_1$. At the same time, place 1-2 sensors away from the equipment and record the temperature as $T_2$ for testing room temperature. After the equipment is turned on for normal operation, compare the temperature difference between $T_1$ and $T_2$. In this process, if $T_2$ changes greatly, it should be considered whether it is caused by the surrounding environment or the sensor itself not meeting the test requirements. At this time, adjust the sensor placement position or increase the number of sensors, and then compare the value of $T_2$ until they are relatively stable. If the temperature difference between $T_1$ and $T_2$ is greater than 5℃, the equipment shall be a thermal test sample. Considering that the equipment is powered on for functional performance testing during the test, this test is a Be test.

3.3.2. Pre-treat the equipment. In order to eliminate the possible effects of other tests on this test as the equipment may have been used for other tests in the previous period, functions that may affect the detection should be reset according to the technical requirements of the equipment before starting the high temperature test.

3.3.3. Put the equipment into the high temperature test chamber noted that the distance between the device and the inner wall of the chamber should be at least 150mm.

![Diagram](image)

Figure 1. Dynamic range connection diagram of secondary surveillance radar receiver

3.3.4. Test the dynamic range of the radar receiver. The A channel sum beam test result is $A_1$ (unit: dB, the same below);
3.3.5 Set up test steps on the high temperature test chamber controller (see Figure 2). The steps include:

1) Make the temperature inside the chamber to reach normal temperature, usually around +25℃, and keep it for 10 minutes;
2) $T_0$-$T_1$: increase the temperature to +40℃, according to the standard requirements, the temperature change rate should not be greater than 1℃/min;
3) $T_1$-$T_2$: According to GB/T2423.2-2008 6.5.3, set the time to keep the current temperature. If only high-temperature storage tests are required, the hold time should be as long as possible. If only high-temperature working tests are required, the hold time meets the test function performance test is sufficient.
4) $T_2$-$T_3$: test the A channel sum beam again, and the test result is $A_2$;
5) $T_3$-$T_4$: reduce the temperature to +25℃, and the temperature change rate not be greater than 1℃/min;
6) Test the A channel sum beam again, and the test result is $A_3$;
7) Repeat the whole process 3 to 7 times, and record the test results as $A_4$, $A_5$, $A_6$ .. $A_n$ (n≤21);

![Figure 2. Illustration of test steps](image)

3.3.6 Issues to be noted during testing

1) After the temperature in the chamber reaches +40℃, it should be kept for at least 2 hours to ensure that the overall temperature of the equipment can reach +40℃ before starting the functional performance test. This means that $T_1$-$T_2$ should be at least 2 hours.
2) During the test, high-temperature-resistant materials should be selected for the connection equipment such as power line feeders.

3.3.7 Result analysis [5]

1) Compare: Compare $A_1$, $A_2$...$A_n$ with the data required by the standard. If one of the test results does not meet this requirement, it is necessary to analyze the cause of the test result;
2) If $A_1$, $A_2$...$A_n$ meet the requirements of the standard, the T-test method can be used for statistical analysis of the result. The method is as follows:

   Calculate the overall arithmetic mean: $\bar{A} = \frac{A_1 + A_2 + A_3 + ... + A_n}{n}$.
   Calculate the sample arithmetic mean: $\mu = \frac{A_1 + A_2 + A_3 + ... + A_m}{m} \quad (m \leq n)$.
   Calculate the standard deviation: $s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (A_i - \bar{A})^2}$.
   Calculate the value of t: $t = \frac{\mu - \bar{A}}{s / \sqrt{m-1}}$.
3) Judge: Assume the significant level is 0.05, $df = m - 1 = 19$, check the t-distribution critical value table, the critical value is $t(19)_{0.05} = 2.093$. Then compare the calculated t with 2.093.
If $t$ is less than 2.093, the test passes. If $t$ is greater than or equal to 2.093, the equipment fails the high temperature test, and it is necessary to analyze the cause of the test result.

3.3.8. Cause Analysis
If the test does not meet the requirements, corresponding measures should be formulated. Re-test after changing test equipment, inspectors etc. Increase the number of cycles to increase the number of samples collected if necessary.

4. Conclusion
Any equipment must be in a certain environment and needs to be used under certain environmental conditions, so it cannot get rid of the environmental impact. Especially the civil aviation management equipment, although the installation conditions are relatively harsh, the safety requirements are much higher, and as a result more attention should be put into the entire process of product design, development, production, testing and use. Therefore, the equipment must be tested for environmental reliability before it is put into operation, which is also a very important link.

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References
[1] Order No. 111 of the General Administration of civil aviation of China. Civil aviation air traffic communication navigation monitoring equipment use license management issued
[2] Wang, S.R., Ji, F.Y. (2016) Environmental test technology. Publishing House of Electronics Industry. Beijing
[3] MH/T 4010-2016 Technical Specifications for Air Traffic Control Secondary Surveillance Radar System
[4] GB/T 2423.2-2008 Environmental testing for electric and electronic products-Part 2:Test methods-Tests B:Dry heat
[5] Li, Z.P. (2018) Application of statistics in laboratory quality control. Research and Exploration in Laboratory, 37(09): 300-304+310.