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Discussion on Practical Strategies of Quality Control Technology for Energy Efficiency Testing of Electronic and Electrical Products

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Abstract: In the current social environment, the importance of energy conservation and emission reduction is increasing day by day for both the country and its people. Electronic and electrical products, as important items for people's production and life, require high attention from industry insiders in terms of their energy efficiency testing. Relying on energy efficiency testing can achieve the goal of energy conservation and emission reduction, and related quality control technologies will also inject new momentum into the green development of the industry. This article will discuss the practical strategies of quality control technology for energy efficiency testing of electronic and electrical products based on the significance of such testing, hoping to provide some help.

Keywords: Electronics and electrical appliances; Product energy efficiency testing; Testing significance; Quality control technology; Practical strategies

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1. Introduction

With the global increasing emphasis on energy, the dual-carbon strategy has become a key strategy to promote the development of various countries. Electronic and electrical products are not only the top priority for improving people's living standards, but may also bring huge energy consumption. Along with the development of information technology and the continuous launch of smart electronic and electrical products, the issue of energy consumption is becoming increasingly severe. This has also increased the industry's emphasis on energy efficiency testing. However, focusing on the actual situation, the energy efficiency test results of many electronic and electrical products are not satisfactory, and there are many influencing factors, including data management errors, personnel operations not following process requirements, and equipment accuracy not meeting standards, which can affect the accuracy of test results and weaken the credibility and authority of testing [1]. This also prompts relevant monitoring units to pay attention to the construction of quality control systems, strengthen the integration of equipment calibration, improve the intelligent level of data monitoring, and enhance the quality of testing to promote the green development of the industry.

2. Significance of energy efficiency testing for electronic and electrical products

Energy efficiency testing for electronic and electrical products can assist in evaluating energy utilization efficiency and demonstrate its value in multiple aspects: (1) Energy conservation and environmental protection to achieve dual-carbon goals. Energy efficiency testing can identify the characteristics of energy-intensive products through testing methods, guiding enterprises to optimize design, production, and other links to reduce product standby and operating energy consumption. For example, compared to ordinary air conditioners, energy-saving air conditioners can save more than 30% of electricity. Promoting energy-saving air conditioners across society can achieve even more significant energy-saving effects. At the same time, the energy consumption of electronic and electrical products affects carbon emissions, and improving energy efficiency can help reduce pollutant emissions, achieve carbon neutrality development goals, and enhance ecological environmental protection. (2) Policy regulation and strengthened energy efficiency management. There are currently numerous policies related to energy efficiency standards in our country. Based on market access mechanisms and regulatory spot checks, enterprise behavior can be constrained. At the same time, it can quantify energy conservation target assessments, ensure the proper completion of energy conservation targets, and help promote low-energy products, achieving dual-track development of energy-saving products and renewable energy [2]. (3) Technological innovation to promote industrial upgrading. Energy efficiency testing, as an important task for enterprises to follow certification systems and meet testing standards, can promote increased investment in research and development and make progress through technologies such as intelligent control, frequency conversion technology, and energy-saving chips. In the long run, products with higher energy consumption will tend to be eliminated, and the industry will also transition to intelligent and green directions, achieving overall optimization of the industrial structure.

3. Practical strategies for quality control techniques in energy efficiency testing of electronic and electrical products

3.1. Environmental and testing equipment control

Environmental conditions need to be precisely controlled. A stable laboratory environment should be established with a temperature of approximately 23°C (with an upper and lower error not exceeding 0.5°C) and a humidity of approximately 50% (with an upper and lower error not exceeding 5%). The laboratory should be equipped with an environmental monitoring system to monitor the environmental status at any time. The sensors should complete the collection of laboratory environment data every few minutes to ensure that the testing environment meets the standard requirements. If the laboratory needs to test electromagnetic compatibility, shielding effectiveness verification should be completed beforehand. An electric field strength tester should be used to detect the intensity of external electromagnetic interference, and background noise should be controlled below the standard limit. To ensure that the environment meets the requirements, it is necessary to ascertain whether there are various interference factors in the laboratory, such as voltage fluctuations and mechanical vibrations. If they exist, active isolation measures should be taken. In practice, a stabilized voltage source with voltage fluctuations not exceeding 1% can be used to avoid affecting the test results [3].

Regarding equipment, all testing equipment should have accuracy compatible with international standards and be calibrated at regular intervals, such as thermocouples, electricity meters, and power meters. Measurement errors should be controlled to less than 0.5%. Standard reference sources such as high-precision power sources can also be equipped. After properly verifying the equipment's functionality, relevant testing can be completed. Equipment should be inspected every three months, and the stability of repeatedly measured equipment should meet the requirements. Additionally, equipment drift trends should be monitored.

Taking the energy efficiency testing of new distribution transformers in Jiangsu Electric Power as an example, conventional distribution transformer energy efficiency testing requires the cooperation of testers and instruments. Not only does the testing work need to be fixed, but the testing phase also requires frequent replacement of wiring and equipment based on testing requirements, which cannot achieve ideal testing efficiency. The company has introduced energy efficiency testing equipment that can establish a multi-channel isolated measurement module. It can control the circuit through simple operations, achieve different functions such as insulation isolation and output wiring switching, and has a fast upload speed. It can also generate test reports synchronously, significantly saving time. Moreover, parameters such as power, current, and voltage can be controlled within an error of five ten-thousandths [4].

3.2. Management of detection data and methods

Data should meet the requirements of full lifecycle management, utilizing an automated data collection system that simultaneously generates original data records. This minimizes manual data transcription, thereby reducing errors caused by human factors. The data management platform should also feature an alert system to promptly notify of any abnormal data patterns. Statistical methods, such as control charts, can be employed to monitor data trends. Pre-set standby power detection results and upper and lower control limits should be established. If more than three consecutive data points fall outside these limits, an alarm will be triggered, requiring staff to re-test. Additionally, the data should be encrypted and backed up, with test reports generated in PDF format. Original data should be stored on physically isolated servers, where it can be traced back for several years, provided the necessary permissions are granted [5].

The primary detection method typically involves multi-condition segmented detection, allowing for specific detection techniques based on complex products. Taking air conditioners as an example, different load conditions and rated heating or cooling capacities can be tested according to various scenarios. It is advisable to test under multiple conditions to prevent deviations in results caused by relatively singular testing scenarios. Additionally, uncertainty analysis techniques can be adopted to quantify the contributions of various influencing factors, including operator error, environmental factors, and equipment inaccuracies, to the detection results (usually requiring the establishment of a mathematical model). This ensures that the results fall within a confidence interval, avoiding unreliable outcomes. Method comparison experiments can also be conducted. For instance, in microwave testing, both direct measurement and indirect calculation methods can be used, controlling the difference between the two methods to less than 5% to ensure accurate test results [6].

In the case of energy efficiency testing conducted by a certain laboratory, it was found that equipment, testing personnel, and technology can all affect the testing results to some extent, leading to fluctuations and potentially compromising accuracy. The laboratory adopted data analysis methods, including robust statistical analysis and relative deviation analysis, to precisely analyze the data and assist in identifying electronic and electrical faults. For example, during air conditioning energy efficiency testing, testers noticed a significant relative deviation in the data and traced it back to equipment sensor aging and performance issues. Before laboratory calibration, factors such as detection accuracy, measurement points, and detection range should be clarified. Detection instruments should be selected based on these considerations to ensure they meet the detection requirements. Calibrate the power meter and confirm the air conditioning power accuracy according to the calibration certificate requirements. These methods enable timely identification of factors influencing test results, facilitating targeted handling of these factors and enhancing the reliability and accuracy of the test results [7].

3.3. Management of standard samples and materials

The selected test samples should have uniformity and representativeness. For practical testing extremes, techniques such as systematic sampling or stratified sampling should be used to ensure that the samples cover various models, batches, and production lines, enhancing the persuasiveness of the test results. The samples need to be pretreated and verified beforehand. Before testing, a comprehensive inspection of the outer packaging and accessories of electronic and electrical products should be conducted to prevent damage to the samples, reducing deviations between test results and actual usage requirements. If the electrical and electronic products belong to the same model but there are many samples, repetitive testing needs to be carried out, and the calculation of the relative standard deviation of energy efficiency indicators should be completed. This value should not exceed 3% [8].

The selection of standard materials should comply with relevant national requirements, such as standard power sources and standard resistors. The uncertainty of the set value should be controlled within 1/3 of the allowable error of the detection method. During the period, the verification of standard materials should be emphasized. Every six months, it is necessary to compare the existing working standard materials with higher-grade standard materials. According to the higher-grade standard materials, the working standard materials should be selected to avoid errors in quantity transmission. If there is no ready-made standard material for the testing project, it can also be self-made. Generally, multiple laboratories will jointly determine the characteristic value through joint calibration [9].

3.4. Operational norms and quality of inspection personnel

Operational procedures need to meet standardization requirements. The testing unit should formulate and improve visual operational procedures. In practice, key parameter setting tables, wiring diagrams, etc., can be posted near the testing equipment to inform inspectors of the parameter setting requirements of electronic and electrical equipment, maximizing the accuracy of personnel operations. The test results should be double-checked by two people to verify the detection data such as voltage, current, and operating time of the electronic and electrical equipment. In practice, one person can record the data, and another person can verify the authenticity of the data based on historical records. A targeted processing flow should be constructed for any abnormalities arising from the detection. If inspectors find abnormalities in the winding equipment, or if there is a large error between the data and historical data, they should stop the inspection work immediately, retest the sample, record all data, and filter out useless data to prevent it from mixing in [10].

The management of inspection personnel should follow the requirements of employment with a certificate system. Training and assessment of inspection personnel should be organized beforehand to ensure that their comprehensive quality meets the requirements of laboratory testing. Inspection personnel need to be familiar with energy efficiency standards and understand equipment testing methods. The assessment can adopt the blind sample assessment method, conducting energy efficiency testing for the same electronic and electrical products. The deviation of the results measured by two inspectors should be controlled at 2% or less. If this standard is not met, the reasons should be analyzed, and training should be conducted again. Regularly participate in proficiency testing programs and evaluate the operational level of personnel based on the comparison of laboratory results.

3.5. Continuous improvement and quality control

Testing organizations should establish and improve databases to assist in quality control, statistically analyze historical monitoring data, and accurately identify error items with higher risks to optimize equipment parameters and testing techniques. They can also introduce AI technology based on the advantages of machine learning algorithms to analyze the correlation between energy efficiency results and testing parameters, automatically optimize testing conditions and environments, and improve testing accuracy and efficiency [11].

Testing techniques need to be certified by relevant authorities, and all quality systems should be documented, including operation instructions, procedure documents, and quality manuals. Employees in various positions should fulfill their respective duties to ensure the quality system meets workload requirements. Testing organizations should conduct management reviews and internal audits annually. Through simulating the entire testing process, they can identify whether the quality management system has loopholes such as expired equipment calibration labels or missing original record signatures, develop targeted corrective measures, and continuously track the results of these corrections [12].

4. Conclusion

In summary, quality control of energy efficiency testing for electronic and electrical products is crucial to improving their quality. Testing organizations should focus on controlling the environment and testing equipment, managing testing data and methods, standardizing samples and materials management, standardizing operations and enhancing the quality of testing personnel, and continuously improving quality control. These efforts will ensure the accuracy and persuasiveness of test results, providing technical support for the green development of electronic and electrical products and injecting new momentum into the industry.

Disclosure statement

The author declares no conflict of interest.

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