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Study on Calibration Method for Emergency Lighting and Evacuation Indicating System

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Abstract
The quality inspection department regularly conducts spot checks on the quality issues of the fire emergency lighting and evacuation indication system, and detects the internal power supply voltage, emergency time, charging and discharging voltage, charging and discharging current, and other metrological characteristics of the system to ensure that the metrological characteristics of the system meet the requirements of national standards. However, there is a lack of reliable calibration methods and devices in China. In order to solve the problem of quantity traceability of detection devices for fire emergency lighting and evacuation indication systems, a calibration method for detection devices for fire emergency lighting and evacuation indication systems is studied.

Keyword
Evacuation indicating system
Emergency time
Metrological characteristics
Calibration method
Quantity traceability.

I. INTRODUCTION

With the rapid development of China's social economy and the acceleration of urbanization, there are more and more large-scale urban complex buildings, and the attendant fire safety management issues cannot be ignored.
In accordance with the detection requirements of GB 17945-2010 "Fire Emergency Lighting and Evacuation Indication System" and GB 51309-2018"Fire emergency lighting and evacuation indication system technical standards"[1]. In fire-fighting facilities, the fire emergency lighting and evacuation indication system is a very important part, which can not only provide lighting during fire-fighting operations, but also provide assistance for evacuating people [2].

The design of fire emergency lighting and evacuation indication system products need to meet the technical requirements of currently implemented fire protection standards and design specifications to ensure the stability and reliability of the operation of the fire emergency lighting and evacuation indication system [3]. In the system of fire emergency lighting and evacuation instruction, the metrological characteristics of fire emergency lighting products are checked to see if they meet the requirements, test items include emergency time, charge and discharge voltage, charge and discharge current, power supply, etc.

In recent years, with the continuous innovation of lighting and evacuation indication systems. The accuracy of the detection device of the fire emergency lighting and evacuation indication system is also improved. At present, there is a lack of reliable calibration methods and devices in China. In order to solve the problem of traceability of the measurement value of the detection device of the fire emergency lighting and evacuation indication system in the quality inspection department[4]. After investigation and research in the field of fire-related emergency lighting products and measuring devices. A calibration method of fire emergency lighting and evacuation indication system is studied. Develop a comprehensive fire emergency lighting and evacuation indication calibration device.

II. CALIBRATION METHOD

According to the testing requirements of GB 17945-2010 "Fire Emergency Lighting and Evacuation Indication System", the technical indicators of the fire emergency lighting lamp detector should meet the requirements of Table 1.

The main metering characteristics include emergency conversion time, emergency working time, DC charging voltage, DC discharge voltage, DC charging current, DC discharge current, test temperature and test humidity.

Table 1. Technical specifications of the detector

Parameter	Technical specification
Emergency switch time (general area)	MPE: ± 0.5 s
Emergency switch time (high risk area)	MPE: ±0.025 s
Emergency working hours	MPE: ±0.1 s the emergency time is not less than 90 min
DC charging voltage	MPE: ±0.1%
DC discharge voltage	MPE: ±0.1%
DC charging current	MPE: ±0.2%
DC discharge current	MPE: ±0.2%
AC voltage output	MPE: ±1%
Test temperature	MPE: ±2 °C
Test humidity	MPE: ±5 %RH

A. Delay time test system

The calibration of the delay time test system can directly calibrate the delay time of emergency switching time .The calibration of emergency switching time is shown in Figure 1. The working principle of the fire emergency lighting fixture detector for emergency switching time detection , one end is connected to a start switch (solid state relay).

It utilizes the fast response characteristics of the solid-state relay. When a sudden power failure occurs, it switches from charging mode to discharging mode, and the charging current circuit is zero, triggering a timing start circuit to turn on the start signal[5].The other end is connected to a photoelectric sensor. When the emergency light comes on momentarily, the circuit is in the discharge mode, triggering the timing end circuit and starting the stop signal.

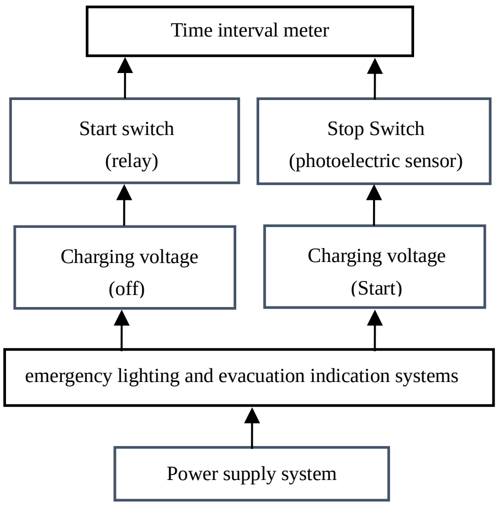

Fig.1. emergency switching time

The calibration of emergency working time is shown in Figure 2.The detection principle of the emergency working time of the fire emergency lighting lamp detector is as follows, one end connect a photoelectric sensor at one end, and when the emergency lamp is momentarily lit, the circuit is in the discharge mode, triggering a timing start circuit to turn on the start signal. The other end is connected to a solid-state relay. When the set time is reached, the charging circuit voltage is turned on, and the circuit is in charging mode. When the charging current reaches a constant value, the timing end circuit is triggered to start the stop signal.

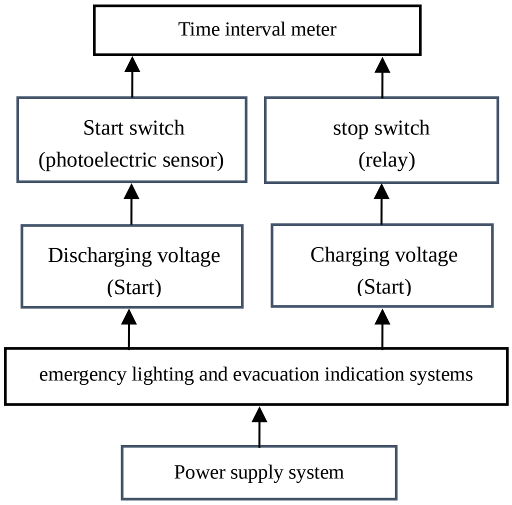

Fig.2. emergency working time

B. Calibration of AC output voltage

The fire emergency lighting lamp detector controls the output of AC stabilized power supply. It controls the output of AC voltage X_1. The AC digital voltmeter measures the output voltage X_0 at both ends. After the output is stable, the output value is recorded and the measurement result is calculated.

C. Calibration of DC charging and discharging voltage

For DC charging voltage calibration, using the DC standard voltmeter method, it sets the constant voltage charging mode, connects the DC digital voltmeter in parallel to both ends of the detector's output voltage, compares the voltage value X_1 displayed by the DC digital voltmeter X_0 and the calibrated fire emergency lighting fixture detector, and calculates the measurement results.

For DC discharging voltage calibration, using the DC standard voltmeter method. It sets the constant current discharge mode, connects a DC digital voltmeter in parallel to both ends of the output voltage of the tester, compares the voltage value X_1 displayed by the DC digital voltmeter X_0 and the calibrated fire emergency lighting fixture detector, where U is the DC digital voltmeter, and calculates the measurement results[6].

D. Calibration of DC charging and discharging current

For DC discharging current calibration, using the DC digital ammeter method, as shown in Figure 3. It sets the DC electronic load to the constant resistance mode. The electronic load is connected first, and then starting the calibrated fire emergency lighting fixture detector to output the current. After the current stabilizes, recording the DC digital ammeter reading and the current indication of the calibrated fire emergency lighting fixture detector, and calculating the measurement results.

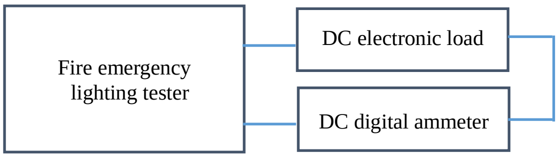

Fig.3. DC discharging current

For DC charging current calibration, using the DC digital ammeter method, as shown in Figure 4. It sets the calibrated fire emergency lighting detector to constant current charging mode. It sets the DC stabilized voltage to the constant voltage mode. The DC stabilized power supply output first, and then starting the calibrated tester. After the current output is stable, recording the current readings of the DC digital ammeter and the calibrated tester, and calculating the measurement results.

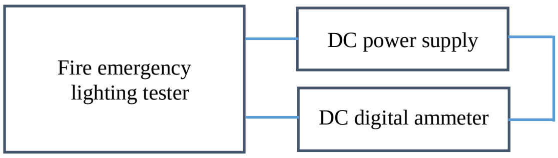

Fig.4. DC charging current

E. Calibration of ambient temperature and humidity

As the test system requires emergency time testing in a sealed environment, the box of the test system is an environmental temperature and humidity box. Refer to the test point layout method in the JJF1101-2019 Environmental Test Equipment Temperature and Humidity Calibration Specification.The location of the test points is shown in Figure 5.

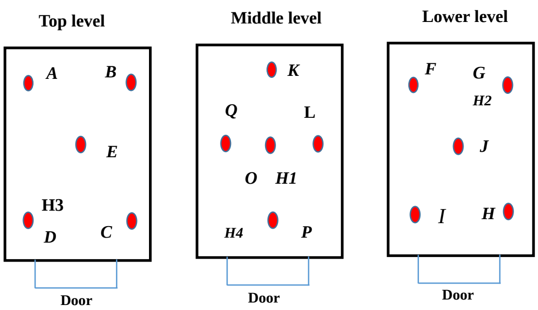

Fig.5. Layout measurement points

Test point N=15, (O, A, B, C, D, F, G, H,I,J,K,L,Q,P), where in test point O is arranged at the geometric center of the working space of the test box, and other test points are arranged in layers at the eight corners of the upper and lower layers of the test box. The distance from the test point to the box wall is 1/8 of the length of the opposite side of the inner wall of the test box. Refer to the temperature wiring diagram and place the humidity sensor in a suitable location. After stabilization, calibrate the humidity in the test box. Humidity test points with H1,H2,H3,H4 characters.

III. DESIGN OF CALIBRATION DEVICE

A. Measuring principle

As shown in Figure 6, the fire emergency lighting lamp detector is mainly composed of a microcomputer control system, a DC unit (DC regulated output), a discharge unit (DC electronic load), a charge and discharge control unit, and a measurement unit to achieve the detection of fire emergency lighting lamps. The main detection parameters include emergency conversion time, emergency working time, DC charging voltage, DC discharge voltage, and DC charging current DC discharge current, environmental test temperature, and environmental test humidity [7].

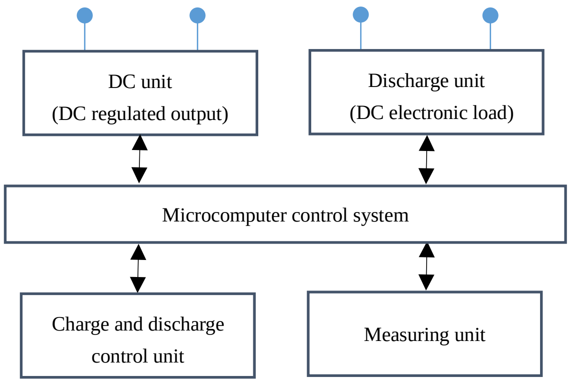

Fig.6. Measuring principle

B. Design of emergency time

The system timing control CPU circuit uses the STM32F405RGT6 chip, as shown in Figure 7.It completes the timing measurement of time, control of display, key input, control of DC voltage source, control of output AC source, and other functions. The clock uses a 10MHz thermostatic crystal oscillator.

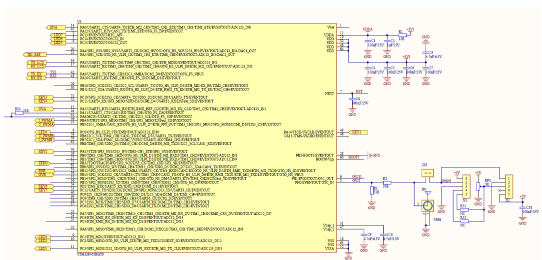

Fig.7. Timing control circuit

C.Design of AC programmable power supply

A self-developed control program using a MEGA48PA control chip as shown in Figure 8. Adopting unipolar SPWM modulation method, where H_ A、H_ B is high-frequency drive (40kHz), H_ C、H_ D is a low frequency drive (50Hz). CURR is the H-bridge overcurrent signal input, and EN is the input enable. After receiving a valid signal, an AC output voltage is established.

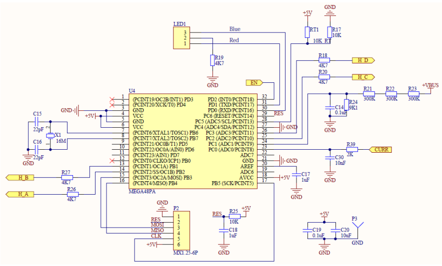

Fig.8. AC output voltage *circuit*

The design of the isolation drive circuit is shown in Figure 9. The SI8235 is based on a magnetic isolation gate driver, with an isolation voltage greater than 1500 V, and an output of a totem pole structure, with an output current of up to 4 A.

The VDDA adopts a bootstrap power supply mode. When the lower tube is turned on, a voltage of +12 V charges C9 and C10 through R14 and D14, a set of isolated drive circuits is saved.

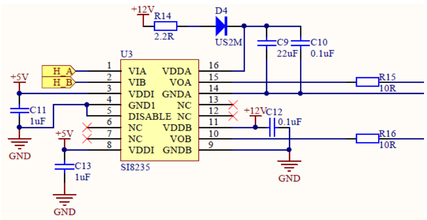

Fig.9. Isolated drive circuits

D. Design of program controlled

DC output power supply Q11 (27N80) is used to adjust the MOS transistor as shown in Figure 10.

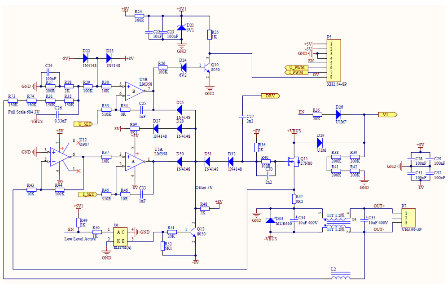

Fig.10. Linear adjustable power supply circuit

The basic principle is to change the voltage of the gate electrode, thereby changing the equivalent resistance of the MOS to complete the voltage adjustment. A part of U5 is an output current regulator, and the B part of U5 is an output voltage regulator. Both are PI regulators, and C25 and C33 are integral capacitors to ensure no steady-state error in the output voltage (current). U_ PWM，I_ PWM is a given signal for output voltage and output current, respectively.The design of the adjustable power fast switch for the emergency time measurement device is shown in Figure11.

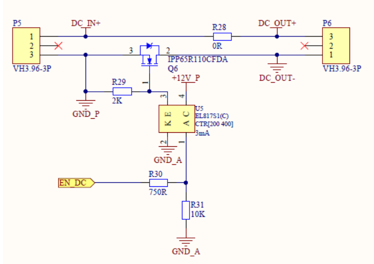

Fig.11. Fast switching circuit of adjustable power

The output voltage adjustment speed of the existing programmable DC power supply is relatively slow (generally using a time of 100 ms), and it is not possible to quickly establish the set voltage. This device adds MOS switch control output on the basis of existing programmed DC voltage, and can quickly establish a set voltage (using time of 100 μs) And can meet the requirements for fast setting of the power supply voltage of the time relay measurement system.

Adopting a composite mechanism of soft switching resonant switching power supply and linear power supply, utilizing the advantages of high efficiency of switching power supply, as well as the advantages of small ripple coefficient, high accuracy, and fast response of linear regulated power supply, the output of 10 V to 400 V DC regulated power supply is realized, with accuracy of 0.01% and stability of 0.005%.

IV. UNCERTAINTY ANALYSIS

Using this calibration method, a fire emergency lighting detector is calibrated. The fire emergency lighting detector models are XFDJ-2 and YDJ-1.

Table 2. Test data

Model	Parameter	Display value	Actual value	Uncertainty （*k* =2)
XFDJ-2	switch time	261 ms	260.8 ms	1.2 ms
YDJ-1	switch time	258 ms	257.4 ms	1.2 ms
XFDJ-2	Working time	10 min	10 min 0.1 s	0.2 s
YDJ-1	Working time	10 min	10 min 0.1 s	0.2 s
XFDJ-2	DC charging voltage	12.00 V	12.00 V	0.01 V
YDJ-1	DC charging voltage	12.00 V	12.01 V	0.01 V
XFDJ-2	DC charging current	76.22 mA	76.19 mA	0.08 mA
YDJ-1	DC charging current	76.20 mA	76.18 mA	0.08 mA
XFDJ-2	Temperature	20.1 ℃	20.1 ℃	0.1 ℃
YDJ-1	Temperature	20.1 ℃	20.1 ℃	0.1 ℃
XFDJ-2	Humidity	50.3 %RH	50.2 %RH	2.0 %RH
YDJ-1	Humidity	50.2 %RH	50.4 %RH	2.0 %RH

The emergency conversion time, emergency working time, DC charging voltage, DC discharge voltage, DC charging current, DC discharge current, and AC power output voltage are shown in Table 2. Compared with other calibration devices, the calibration device can meet the technical requirements for calibration of fire emergency lighting tester, and can carry out the calibration of fire emergency lighting tester.

Taking emergency switching time as an example, the sources of measurement uncertainty for calibration devices are analyzed, mainly including standard uncertainties introduced by factors such as the maximum allowable error of time interval meters, measurement repeatability, allowable error of photoelectric sensors, and solid-state relay contact switches. Within the measurement range 1 μs to 100 s, the fire emergency lighting lamp detectors are evaluated to have the same source.

A.Uncertainty component introduced by allowable error limit of time interval measuring instrument

According to the technical indicators of time interval measuring instrument, the maximum allowable error of the time interval: ± 0.1 μs , which is qualified after verification and evaluated according to class B. Assuming uniform distribution and inclusion factor *k* be equal to $\sqrt{3}$, uncertainty is equal to 0.06 μs.

B.Uncertainty component introduced by measurement repeatability

Under the specified conditions, use the time interval measuring instrument to make six repeated measurements on the calibration device, with the data being:260.8 ms, 261.2 ms, 261.4 ms, 261.5 ms, 260.9 ms, 261.3 ms and 269.2 ms. According to class a evaluation, the standard uncertainty introduced is calculated by Bessel formula, uncertainty is equal to 0.28 ms.

C.Uncertainty component introduced by the photoelectric sensor sensitivity

The standard uncertainty introduced by photoelectric sensor sensitivity which is based on the response time of the photosensitive transistor, the maximum allowable error introduced by photoelectric sensor shall not exceed 5 μs. Assuming uniform distribution and inclusion factor *k* be equal to $\sqrt{3}$, uncertainty is equal to 2.9 μs .

D.Uncertainty component introduced by asynchronous switching relay

The standard uncertainty introduced by asynchronous switching relay, the maximum allowable error introduced by asynchronous switching relay shall not exceed 1 ms. Assuming uniform distribution and inclusion factor *k* be equal to $\sqrt{3}$, uncertainty is equal to 0.58 ms .

E.Synthetic standard uncertainty

The above standard uncertainty components are not related to each other, so the synthetic standard uncertainty is equal to 0.6 ms.

F.Extended uncertainty

Take *k* be equal to 2 , Extended uncertainty be equal to 1.2 ms.

V. CONCLUSION

In order to solve the problem of quantity traceability of detection devices for fire emergency lighting and evacuation indication systems, this article analyzes the detection requirements of GB17945-2010 "Fire Emergency Lighting and Evacuation Indication System", and GB51309-2018 "Fire Emergency Lighting and Evacuation Indication System Technology", investigates the technical parameters of fire emergency lamp detectors on the market, studies a calibration method for fire emergency lighting lamp detectors, and designs a set of calibration devices[8], field test and measurement comparison show that this calibration device can meet the traceability requirements of the fire emergency lighting lamp detector and can be used as a measurement standard.

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