

Research on Standardized Maintenance Technology and Quality Control of Flameproof Motors and Electromagnetic Starters

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Abstract

Flameproof motors and electromagnetic starters are core electrical equipment in industrial production, especially in special operating scenarios such as underground coal mines. Their operational reliability is directly related to production efficiency and operational safety. Currently, equipment maintenance faces challenges including inconsistent technical standards, inadequate quality control systems, and insufficient intelligent monitoring methods, which are prone to inducing equipment failures and even safety accidents. Based on relevant national and industry standards, combined with advanced concepts such as lean management and intelligent monitoring, this paper systematically sorts out the standardized maintenance technical requirements for motors and electromagnetic starters, and constructs a full-process quality control system covering pre-maintenance, in-maintenance, and post-maintenance stages. By integrating technical means such as equipment full-life cycle management and intelligent monitoring and early warning, this study provides more comprehensive theoretical and practical support for improving equipment maintenance quality and ensuring stable equipment operation.

Keywords

Flameproof Motor; Electromagnetic Starter; Standardized Maintenance; Quality Control; Lean Management; Explosion-proof Performance.

1. Introduction

As the core power output device, flameproof motors and electromagnetic starters-key equipment for electrical control and protection-are widely used in complex operating environments such as underground coal mines [1,2]. Such equipment operates long-term under high-load, high-corrosion, flammable, and explosive working conditions, making them prone to failures such as deterioration of insulation performance, component wear and aging, and failure of flameproof structures [3,4]. Without unified maintenance standards, strict quality control, and intelligent monitoring methods, the maintenance process will not only shorten the service life of equipment and increase operation and maintenance costs but also may trigger major safety accidents such as electrical short circuits and gas explosions [5].

At present, China has issued a series of standards to regulate equipment maintenance, such as the Coal Mine Safety Regulations and Explosive Atmospheres - Part 1: Equipment - General Requirements (GB/T 3836-2021) [6,7]. However, practical operation and maintenance still face problems including non-standard technical implementation, inadequate quality acceptance, and insufficient fault prediction capabilities. Against the background of the transformation and upgrading of the coal industry, the promotion of concepts and technologies such as lean management and smart

mine construction has provided new ideas for equipment maintenance and control [8]. Based on this, this paper combines lean management theory, intelligent monitoring technology, and multi-parameter collaborative monitoring experience to conduct research from the perspectives of standardized maintenance processes, full-process quality control, and integrated intelligent technologies, aiming to build a solid technical defense line for the safe and stable operation of equipment.

2. Standardized Maintenance Technical Requirements for Flameproof Motors

The maintenance of flameproof motors must balance insulation performance, mechanical performance, and explosion-proof performance, strictly comply with national and industry-specific standards, and integrate lean maintenance concepts to ensure that the maintained equipment meets the requirements of operating conditions.



Figure 1. Physical picture of explosion-proof motor

2.1 Insulation Performance Testing and Repair

Insulation performance is the foundation for the safe operation of flameproof motors. Precise testing and targeted repair must be carried out using professional instruments, with clear testing standards and repair processes formulated.

- a. A megohmmeter and a turn-to-turn tester are used to conduct a comprehensive inspection of the stator insulation performance of the flameproof motor, focusing on checking the coil insulation resistance and setting a qualified threshold for insulation resistance (balanced three-phase insulation resistance without zero resistance). If the coil insulation resistance is zero or the three-phase insulation is unbalanced, the faulty coil must be rewound. After rewinding, varnishing and drying treatment are required to restore the coil insulation performance;
- b. Uniformly replace aging insulation seats and terminal posts of the flameproof motor. After replacement, a retest of the overall insulation performance of the flameproof motor must be conducted to ensure compliance with the Coal Mine Safety Regulations and relevant electrical safety standards, eliminating potential leakage hazards;
- c. Establish an insulation performance testing file to record each test data, maintenance measures, and retest results, forming a full-life cycle traceability system.

2.2 Disassembly and Inspection of Core Components

The state of the core mechanical components of flameproof motors directly affects operational stability. Comprehensive disassembly and refined inspection must be carried out, and operating specifications must be formulated with reference to lean maintenance standards.



Figure 2. Partial disassembly drawing of explosion-proof motor

- a. Disassemble components such as the front and rear bearing end caps and rotor of the flameproof motor in accordance with standard procedures. Conduct a dynamic balance test on the rotor, and simultaneously detect the radial runout of the rotor shaft (not exceeding 50% of the design threshold), the welding firmness of the squirrel cage bars, and the lamination tightness of the silicon steel sheets. For damaged components found during inspection, such as deformation, fracture, and corrosion, timely repair or replacement is required. Bearings and seals must be completely replaced with new ones to avoid equipment vibration or seal failure caused by old components;
- b. The purchased components used for the assembly of flameproof motors must be consistent with the original design model to ensure component compatibility. If components need to be replaced due to model obsolescence, at least three compliant brands must be provided for selection, and a component compatibility test report must be issued to ensure that the performance of the equipment is not affected after replacement;
- c. Formulate operating guidelines for the inspection and repair of core components, specifying the disassembly sequence, inspection methods, quality judgment standards, and assembly requirements to reduce differences caused by human operations.

2.3 Inspection and Replacement of Auxiliary Components

The integrity of auxiliary components is an important guarantee for the continuous and stable operation of flameproof motors. Functional testing must be carried out one by one, and an inspection checklist system must be established.

- a. Detect the contact performance and shell integrity of the cable socket of the flameproof motor. Timely replace unqualified sockets with poor contact or damaged shells with new ones. If there are missing components, they must be supplemented according to specifications to ensure stable power supply connection;
- b. Check the blade integrity and rotation smoothness of the motor fan. If the fan fails to meet usage requirements, such as blade deformation or bearing jamming, it must be replaced with a new one to ensure the heat dissipation effect during motor operation and avoid failures caused by overheating;
- c. Implement a "spot inspection system" for auxiliary components, specifying the inspection frequency (daily inspection once a day for daily maintenance, once a week for regular maintenance), responsible personnel, and recording requirements to ensure no omissions in inspections.

2.4 Explosion-proof Performance Guarantee

In explosive environments such as underground coal mines, the explosion-proof performance of flameproof motors is the core bottom line for safe operation, and strict explosion-proof testing standards must be implemented.

- a. During maintenance, comprehensively inspect all threaded holes and flameproof surfaces of the flameproof motor to ensure no defects such as collisions, scratches, or corrosion, and the flameproof gap must comply with the requirements specified in GB/T 3836-2021;
- b. After maintenance, the equipment must pass professional explosion-proof testing and fully meet the explosion-proof standards specified in Explosive Atmospheres - Part 1: Equipment - General Requirements (GB/T 3836-2021), eliminating safety accidents caused by the infiltration of explosive gases;
- c. Establish a special inspection file for explosion-proof performance, recording test data, inspectors, and test dates. Equipment that fails the inspection is strictly prohibited from being put into use.

2.5 Testing and Label Supplement

The inspection and repair of flameproof motors must strictly follow multiple standard specifications to ensure the compliance of maintenance processes and technical parameters, and strengthen traceability management after maintenance.

- a. The inspection and repair process must be carried out in accordance with standards such as Test Methods for Three-Phase Asynchronous Motors (GB/T 1032-2004) and General Technical Conditions for Electrical Equipment Used in Underground Coal Mines (MT/T 551-1996) [9,10], and process records must be kept for each procedure;
- b. After the completion of inspection and repair, a special test report including key data such as insulation resistance, rotor dynamic balance accuracy, and flameproof gap must be issued, specifying the maintenance parts and results. At the same time, clean the oil and dust on the motor surface, and supplement labels such as indicator plates, nameplates, explosion-proof marks, and safety warnings to ensure that the labels are complete and clear.

3. Standardized Maintenance Technical Requirements for Electromagnetic Starters

The maintenance of electromagnetic starters must focus on flameproof protection, the reliability of the electrical system, and the integrity of electronic control functions, integrating intelligent sensing technology to achieve dual guarantees of equipment control performance and safety performance.



Figure 3. Physical picture of electromagnetic starter

3.1 Maintenance of Flameproof Shells and Components

The flameproof shell is the core protective structure for the operation of the starter in explosive environments, and strict usage judgment and professional renovation standards must be implemented.

- a. Usage judgment and replacement: Flameproof shells and components can continue to be used only if they meet two conditions: first, the flameproof joint surface complies with the requirements of Explosive Atmospheres - Part 2: Equipment Protected by Flameproof Enclosures "d" (GB 3836.2-2010) and the shell has no damage such as deformation or cracks [11]; second, the terminal posts (including grounding terminals) comply with the requirements of GB 3836.1-2010, GB 3836.2-2010, and the equipment technical manual. If the components are damaged or do not meet the requirements of a series of standards such as GB/T 3836-2021, they must be replaced with new ones;
- b. Treatment of flameproof joint surfaces: Professionally renovate the finish, flatness, width, and fastening threaded holes of the flameproof joint surface. The renovation parameters must comply with the relevant provisions of GB/T 3836-2021. After renovation, the flameproof joint surface must be phosphated or anti-corrosion treated, and the flameproof cavity must be anti-corrosion treated and sprayed with insulating arc-resistant paint;
- c. Machine vision measurement technology is used to detect the dimensional accuracy of the flameproof joint surface, improving detection accuracy and reducing manual measurement errors.

3.2 Maintenance of Electrical Components and Conductors

The reliability of electrical components and conductors directly determines the control accuracy of the starter. Systematic inspection and standardized maintenance must be carried out, and an account of component replacement must be established.

- a. Conduct a one-by-one inspection of the electrical components inside the starter cabinet and the connecting conductors outside the cabinet (including cables, busbars, control conductors, and connecting connectors). Perform partial or complete replacement according to the damage status such

as contact ablation and insulation layer damage. The specifications and colors of the replaced conductors (cables) must be consistent with the original design to ensure circuit matching;

b. After rewiring, clearly number the lines according to the original design drawings to ensure correct and firm connection and good contact. The purchased components used for starter assembly must be the same as the original design model. If components need to be replaced, at least three filed brands must also be provided for selection;

c. Introduce infrared temperature measurement technology to monitor the temperature of the contact points of electrical components, predicting potential faults such as poor contact in advance.

3.3 Testing of Sensors and Electronic Control Systems

Sensors and electronic control systems are the "neural center" of the starter. Comprehensive performance testing must be carried out to ensure operational stability, integrating the concept of intelligent collaborative control.

a. Calibrate the electrical parameters of all sensors of the starter to ensure they comply with electrical standards. Timely supplement new sensors for damaged or missing ones to ensure the accuracy of signal collection;

b. Conduct a power-on test on the electronic control system to verify the reliability of the display function, key sensitivity, and various control functions of the electronic control cabinet. Record key parameters such as voltage, current, and protection action threshold during the test;

c. After the completion of maintenance, a full operating condition performance test must be conducted. Combine rough neural network technology to analyze the test data, optimize the control parameters of the electronic control system, and the test report must be delivered together with the starter.

3.4 Label Supplement

After the completion of starter maintenance, thoroughly clean the dust and oil on the equipment surface, and supplement complete labels such as indicator plates, nameplates, explosion-proof marks, and safety warnings to ensure that the labels are firmly attached and the content is clear. At the same time, supplement the maintenance date, maintenance personnel, and suggested next inspection time in the labels to provide clear guidance for subsequent operation and maintenance.

4. Maintenance Quality Control System for Motors and Electromagnetic Starters

To ensure the effective implementation of standardized maintenance technology, combined with lean management theory and full-life cycle management concepts, a full-process quality control system covering "pre-maintenance, in-maintenance, and post-maintenance" is constructed.

4.1 Pre-maintenance Control

a. Equipment fault diagnosis: Adopt the "interview method + on-site observation method + statistical analysis method" to conduct a comprehensive fault diagnosis of the equipment, clarify the fault type and maintenance scope, and formulate a targeted maintenance plan with reference to the historical fault data of the equipment;

b. Spare parts screening: Strictly screen spare parts to ensure that purchased components have compliant certifications and model matching. Test reports must be retained for key spare parts, and an inventory early warning mechanism for spare parts should be established to avoid delayed maintenance due to lack of spare parts;

c. Personnel preparation: Conduct special training for maintenance personnel, including maintenance standards, explosion-proof requirements, and the use of intelligent testing equipment. Only those who pass the assessment can take up their posts. Clarify the division of responsibilities among maintenance personnel (set A and B roles to ensure seamless connection of responsibilities).

4.2 In-maintenance Control

- a. Process acceptance mechanism: Establish a three-level acceptance system of "self-inspection, mutual inspection, and special inspection". After the completion of each maintenance procedure, conduct quality verification against standards, keep process records, and ensure that maintenance operations comply with technical specifications;
- b. Supervision of key procedures: Arrange professional personnel to conduct on-site supervision for key procedures such as explosion-proof performance and insulation performance. Retain process data by means of video recording to eliminate irregular operations;
- c. Schedule control: Adopt a flexible maintenance schedule mode, reasonably allocate time according to the complexity of maintenance tasks (4 hours for daily maintenance, 6 hours for medium maintenance, and 8-12 hours for major maintenance) to improve maintenance efficiency.

4.3 Post-maintenance Control

- a. Comprehensive performance acceptance: After the completion of maintenance, conduct a comprehensive performance acceptance, verify equipment parameters one by one against the test report, and comprehensively evaluate the equipment operation status using multi-parameter collaborative monitoring technology to ensure compliance with standards;
- b. File establishment: Establish an equipment maintenance file to record information such as maintenance parts, replaced components, test data, and maintenance personnel, realizing traceability of maintenance quality and providing data support for equipment full-life cycle management;
- c. Operation tracking: Regularly track the equipment operation status, adopt a combination of online spot inspection and manual spot inspection (detect key parameters every 2 hours), and promptly detect and handle potential subsequent faults;
- d. Assessment and incentive: Incorporate maintenance quality into performance appraisal, formulate reward and punishment standards, reward personnel with excellent maintenance quality, and hold accountable for unqualified maintenance to strengthen the sense of responsibility of maintenance personnel.

5. Conclusion and Prospects

Standardized maintenance of flameproof motors and electromagnetic starters is a key measure to ensure the safe and stable operation of equipment, and a sound quality control system is an important support for the implementation of standardized maintenance. The maintenance technical requirements sorted out in this paper are fully aligned with national and industry standards, integrated with advanced concepts such as lean management and intelligent monitoring, covering the full-dimensional maintenance of core components and auxiliary systems of equipment. The constructed full-process quality control system realizes quality control throughout the maintenance cycle and improves the standardization and reliability of maintenance work.

In the future, we can further combine technologies such as the Internet of Things (IoT) and big data to build an equipment maintenance and operation status monitoring platform, realizing equipment fault early warning and maintenance demand prediction; deepen the application of technologies such as machine vision and radio frequency explosion-proof testing in maintenance to improve the intelligence and accuracy of maintenance; improve the inter-enterprise maintenance standard sharing mechanism, promote advanced maintenance experience, and provide stronger guarantees for the safe operation of equipment in industrial production and special operating scenarios.

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