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THE INFLUENCE OF CHEMICAL AGENTS ON THE TECHNICAL CHARACTERISTICS AND SAFETY OF PROTECTIVE EQUIPMENT AGAINST ELECTRIC SHOCK

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Abstract

The research project's primary goals were to develop occupational risk management protocols for people who perform maintenance tasks on electrical installations and, in turn, to develop new work tools designed to protect workers in those installations. The research project's findings are presented in this paper. In order to check the behaviour of the safety characteristics of the protective equipment material under certain influence of professional risk factors, protective equipment materials were subject to tests. The components of in use or new electro-insulating equipment, were evaluated through sampling. Electro-insulating materials underwent dielectric, mechanical, attrition testing, and chemical agent application. The findings revealed the weakness of some electrical insulating materials whose declared duration of use exceeded five years after commissioning, necessitating the assessment of new technical standards for health and safety workplace.

Keywords: *electro-insulating material, chemical agent, prototype.*

Introduction

The main objective of manufacturers is to bring high-performance work and protection equipment to the market that is competitive in terms of quality and price, while also ensuring an appropriate level of safety.

The paper presents part of the results of the project: "Research for the development of procedures for the management of occupational risks for persons carrying out activities in electrical installations and for the development of work equipment for their protection in electrical installations necessary for the prevention of occupational risks."

In the first part of the project, the electrical systems, the components' work equipment and the devices and protective equipment used during operation and maintenance work were assessed.

The evaluation was carried out from a technical and occupational health and safety point of view and aimed to establish and develop a structure of risk-causes-consequences and preventive measures. At the same time, the evaluation also aimed to analyse the use of the equipment and protective means used, the definition and development of test procedures and assessment and testing methods [1].

During the assessment, the way the equipment and protective means are used, maintained, and stored, including the way they are transported and regularly inspected, was analysed on the

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basis of the technical documentation and SSM documents/procedures issued by the manufacturers and the internal working documents/procedures [2, 3].

Nonconformities have been identified due to the way they were designed and manufactured, as well as incorrect actions and omissions by workers when used in the production process.

Conception and development of experimentation procedures and evaluation and testing methods

The analysis of the risks of injury and illness and the non-conformities identified in the electrical installations brought to light a series of events whose causes were generated by the users and the work environment. In addition to electrical, mechanical, and thermal risk factors, chemical risk factors generated by chemical agents used during maintenance activities were highlighted [1-3].

From the analysis of the workload of the workers who carry out activities in electrical installations and the weight of the chemical risk factors generated by the chemical agents used during the maintenance work, it was found that the most significant weight in use is held by electrical insulating oils and lubricating substances, followed by sulfuric acid and degreasing substances - isopropyl alcohol.

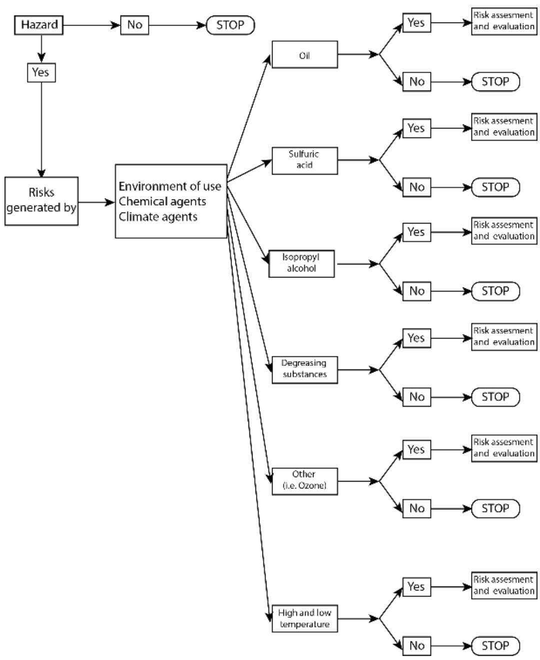


Fig. 1. The overall structure of chemical risks [1]

Thus, the protective equipment components' materials can suffer chemical damage during use [1]. Accidental releases of toxic/flammable/explosive substances can have severe consequences for workers or the neighbouring population. However, the need to identify and evaluate risks of a chemical nature must be considered in terms of the impact on the safety characteristics of the prototype product [4-6].

The chemical risk assessment was carried out based on two criteria: the categorisation of the substance in terms of hazard and the quantitative threshold above which the presence of the substance can lead to accidents or to the weakening/damage of protective equipment [7].

In fig.1, the overall structure of chemical risks is presented, a structure developed within the project that will represent an essential criterion in evaluating and testing the security quality of work equipment and means of protection against the influence of chemical agents.

The modular structure can also be expanded at a later date with little effort. Block modules can be modified or new modules added to fulfil other additional requirements that are necessary for the assessment and testing of the safety quality of work equipment and means of protection against the effects of chemical substances [8].

The overall structure of chemical risks was the basis of the evaluations and testing of the prototypes developed within the project.

When establishing the overall structure of chemical risks, the types of equipment and means of protection were considered, namely technical and constructive characteristics, the way of use, the conditions in which they are used as well as the categories of material from which they are made, materials that differ in composition and properties.

Based on the evaluations, risks and technical non-conformities identified in the protective equipment in use, combined with the analysis of the technical, ergonomic, and functional aspects reported by the users within the project, five types of protective equipment [1]:

- three phase portable equipment for earthing or earthing and short-circuiting for medium-voltage overhead power lines (OPL), equipped with electro-insulating elements
- two models of modular electrical insulating rods, with multiple uses for electrical installations, with a nominal voltage above 1 kV
- bipolar phase correspondence indicator, for use in electrical installations with nominal voltage 6 -3 5 kV
- portable electric field detector for use in low and medium voltage electrical installations.

Experimental procedures and evaluation and testing methods were designed and developed for the prototypes of products designed and developed to prevent occupational risks and ensure the protection of people who carry out activities in electrical installations.

The product prototypes developed within the project were tested and validated (documentation and product) according to the logical scheme in the experimentation procedure and presented in fig. 2.

Experimental procedures

The product prototypes were tested in three stages. In the first stage, the prototypes were evaluated, functionally tested, and requested for endurance (repeated operation). Fig. 3 shows the principle diagram of the first stage of validation and testing of a prototype.

In the second stage, their component materials were subjected to a combination of electrical, mechanical, and chemical stresses. Fig. 4 shows the principle diagram of the second stage of validation and testing, in which specific samples are established depending on the prototype's component materials.

A chemical risk analysis is necessary because electrical insulating materials can release toxic vapours and/or corrosive by-products in the event of a short circuit, which can irritate the eyes and respiratory system [9].

Also, insulation resistance measurement is one of the main tests performed to ensure the safety of workers and the safety of electrical installations. The reason these tests are performed is to prevent accidents caused by electric shock and equipment damage [10].

In the third stage, shown in fig. 5, the prototypes were also tested for electrical, mechanical, thermal and climatic demands, ensuring compliance with the requirements established through functional, technical, and security procedures.

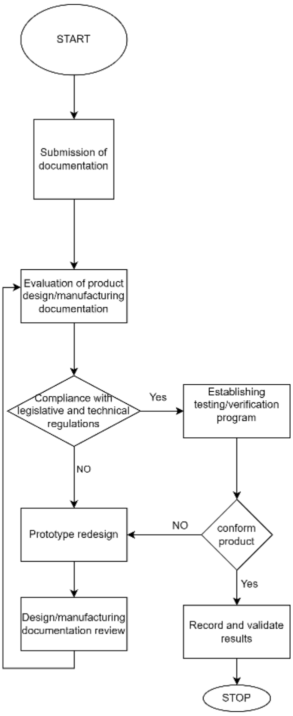


Fig. 2. Logical diagram of the prototype experimentation and validation stages (documentation and product) [1]

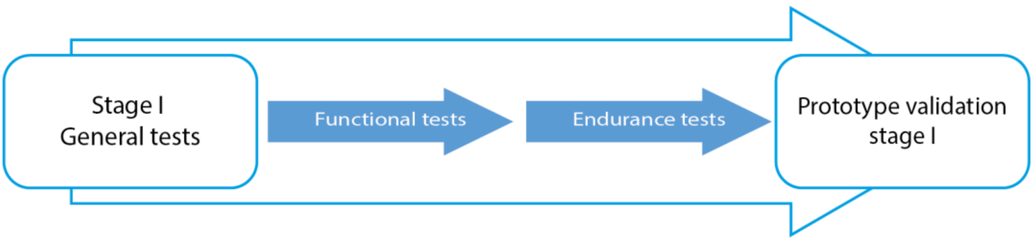


Fig. 3. Stage I - validation and testing [1]

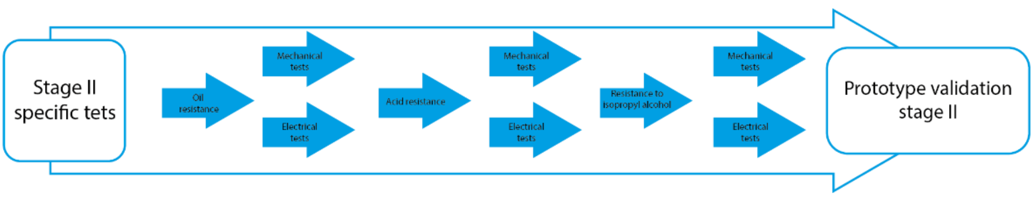


Fig. 4. Stage II - validation and testing

Microclimate conditions can also decisively influence the safety of the produced prototype, and the degradation of the insulation, which leads to a high risk for workers [11].

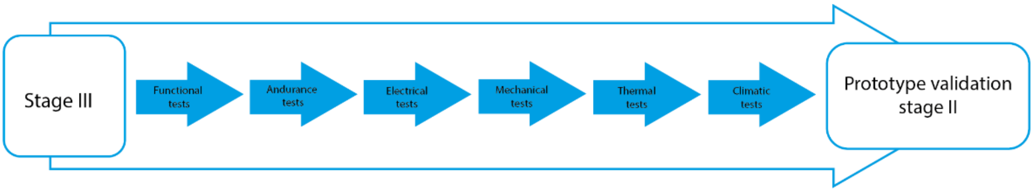


Fig. 5. Stage III - validation and testing

The tests were carried out according to the assessment and testing methods established and developed within sub-activity A2 of the project, within the “Electrical and Mechanical Risks” (REM) testing laboratory and the ICSPM - CS certification body.

A group of materials intensively used in the electrical field are electro-insulating and continuously developed with better characteristics than their predecessors [12]. Thus, in the study, they were sampled for experimentation:

- flexible electrical insulating materials, yellow in colour, which have elastomer in composition and are made by casting (coded RE 0920);
- flexible electrical insulating materials, black in colour, which have elastomer in composition and are made by casting (coded RE 0921);
- rigid electro-insulating materials, black/dark grey, executed by casting from PVC granules (coded RE 0922);
- rigid electro-insulating materials, yellow-coloured PVC granules with glass fibre insert (coded RE 0923).

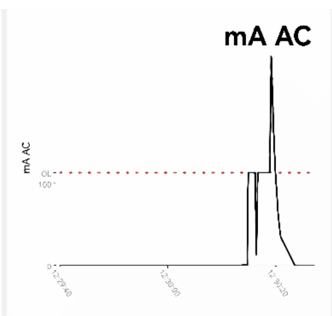
Three samples from each type of material coded RE 0920, RE 0921, RE 0922, and RE 0923 were preconditioned for three hours under environmental conditions in the laboratory. They were then conditioned by immersion in oil at a temperature of (70^0C ± 5^0C) for 24 hours.

The oil in which the tests were performed is of mineral oil type, having the characteristics of aniline point - 124°C ± 1; kinematic viscosity - 20 x10-6 m^2/s; flash point - minimum 243°C [1].

After conditioning, the oil on the samples was removed with a cloth, and they were left to dry for 45-60 min; then, the mechanical and electrical tests were performed.

The test voltage was applied for 1 minute. For the specimens used in low-voltage installations, the test voltage was 5250 Vac, and for those used in medium-voltage installations, the test voltage was 50 kVac [1, 5].

The dielectric samples were considered appropriate for samples coded RE 0920-1, RE 0920-2, RE 0921 -1, RE 0921 -2, RE 0921 -3, RE 0922-1, RE 0922-2, RE 0922-2, RE 0923-1, RE 0923-2, RE 0923-3. Leakage current values above one mA was not recorded. No audible or visible phenomenon occurred, and neither puncture nor flashover occurred.



a)

b)

Fig. 6. Leakage current values - after the oil immersion test, at a temperature of 70°C: a) sample RE 0920-3; b) sample RE 0920-1

In fig. 6a and 6b graphically presented the results of the dielectric strength test after being subjected to immersion in oil for 24 hours for the coded samples RE 0920-1 and RE 0920-3.

The dielectric test for the coded sample RE 0920-3 needed to be considered inadequate. The test tube was pierced. The prototype composed of the coded material RE 0920 was considered inadequate and needed to be validated, and the evaluation procedure was completed.

Based on the test results, the material and accompanying technical documents were analyzed, and it was found that it was from a manufacturing batch older than five years.

Following the analysis of the composition/recipe of the material, slight differences were identified between the technical design data of the material for the prototype housing and the characteristics of the material used. The material recipe was modified, and the new samples were subjected to a new experimental procedure.

After checking the resistance to oil, the materials were tested for resistance to sulfuric acid. This test applies only to protective equipment made of elastomer or having elastomer components.

Three samples from each type of material were conditioned by immersion in a sulfuric acid solution of 32 °Be at a temperature of (23 ± 2) °C for (8 ± 0.5) hours. After conditioning with sulfuric acid, the specimens were rinsed with water and left to dry for (2 ± 0.5) hours at 70 °C in the climatic chamber. The mechanical elongation test was performed sixteen hours after they were removed from the climatic chamber. An increase in the residual elongation of the specimens after traction was recorded, but it did not exceed 15% of the initial value [1]. Then, the electrical test was performed with a test voltage of 5250 Vac for the samples used in low-voltage installations and 50 kV ac for the samples used in medium-voltage installations [1, 5]. Fig. 7 presents the results of the dielectric strength test after the sulfuric acid immersion test for the RE 0920-2 coded sample. Short discharges were registered on the surface of the sample. Dielectric tests were considered adequate.

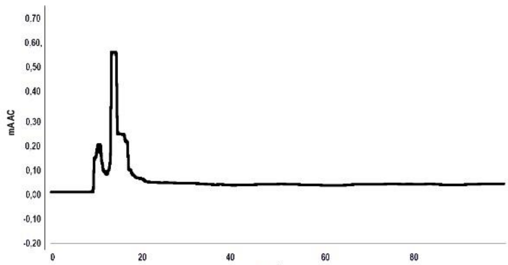


Fig. 7. Leakage current values – after the application to sulfuric acid (test piece RE 0920-2)

The material's resistance to isopropyl alcohol was performed by immersing the samples for one hour. The samples were tested for the mechanical resistance to elongation. Fig. no. 8 graphically presents the results of the dielectric strength test after the isopropyl alcohol resistance tests combined with the elongation test for the coded sample RE 0920-2 [1].

Analyzing the sample graph, areas where the lacquer was damaged were identified on its surface.

Results and Discussions

The results highlighted the low protection quality of some electro-insulating materials whose technical life span was more than five years from manufacture, which required the establishment of new technical conditions for safety and health at work regarding the design and realization of some product prototypes intended for the prevention of occupational risks in order to ensure the protection of people who carry out activities in electrical installations.

The vulnerability of varnished electro-insulating materials to chemical and mechanical stresses was found, and varnishing was carried out to meet the electrical protection requirements so that in the event of an event (defect in the electrical installation), neither puncture nor flashover takes place, and neither audible nor visible phenomenon occurs.

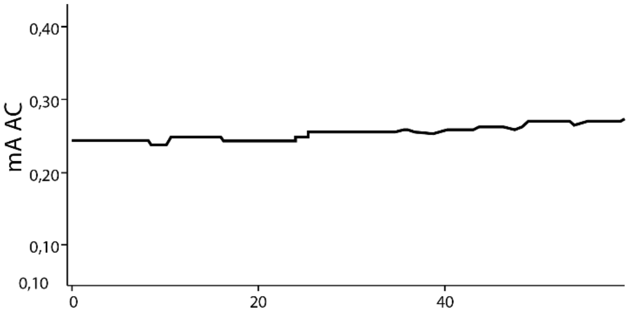


Fig. 8. Leakage current values - after application to isopropyl alcohol (sample RE 0923 - 1)

Analysing the risks and test results, the manufacturers of protective equipment can adopt technical solutions (for example, the choice of another material, another design, or other components) that consider the requirements of safety and health at work, all the technical criteria, such as durability, ergonomics [13].

Implementing the assessment technique validates that the technical functions' requirements are met while keeping the operational indicators' values within the prescribed limitations [14].

Their implementation's opportunity, aim and necessity resulted from the present occupational safety and health (OSH) law requirements [15].

Conclusions

Research studies were conducted to create decision management tools that would assist manufacturers in creating new goods that would reduce occupational risks and guarantee the safety of those engaged in industrial activities.

As a result of the research, new decision-making instruments for the design, evaluation, and verification of product prototypes have been developed. They are meant to help protective equipment manufacturers implement the best technical solutions that consider the working environment, safety, and health regulations, as well as the impact of risk factors caused by chemical agents used in intervention, repair, and overhaul activities. These factors can lower the dielectric safety quality of the materials used in protective equipment components.

After experimenting and testing various product prototypes, the authors conducted for the project intended to establish and develop decision support tools that manufacturers could use to develop new products to prevent occupational risks in the industry.

New techniques and protocols were created in response to the research studies conducted for the project to assess and mitigate professional hazards that have the potential to cause catastrophic outcomes.

The authors suggest that more research be done in collaboration with the industry's producers to create new managerial tools that will be made available to them to boost their competitiveness in the market and guarantee a high standard of safety for individuals engaged in industrial activities - primarily those who have a high “accidentogenic” degree at work.

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