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A Fire Protection System with Thermo-Sensitive Tube by One Cylinder for Two Switchboards

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Abstract: The purpose of this research is to increase economic efficiency by adapting a selector valve to a switchboard to protect two switchboards with one cylinder. As a result of the detection tube's operating temperature test, it was confirmed that the thermo-sensitive tube operates within ±5%. In the dispersion performance test, the switchboard fire protection system using selector valve detected fire within 5 sec on average and dispersed fire-extinguishing agent immediately. The fire-extinguishing agent's dispersion time was about 47 sec and was suitable for the dispersion performance test's acceptance criteria of the dispersion within 60 sec. Through this experiment, it was found that the thermo-sensitive tube used in the experiment was suitable for the acceptance criteria. It was also found that it was effective to protect two switchboards with one cylinder unlike the conventional case.

Key words: Thermo-sensitive tube, switchboard, cylinder, selector valve, fire protection

INTRODUCTION

Electrical equipment has been getting bigger with the increase of electric energy usage. Therefore, if there is a fire in the switchboard which is a convenient electrical installation and consists of power supply in a building as the drive system a large collection of protective equipment for an electrical equipment, a lot of main equipment that is connected to a switch board will stop and it can bring a huge damage from stop of production line in the factory in the worst case (Kyung, 2013).

Existing studies on fire protection in switchboards were analyzed such as the study of Choo and Yew (2015) in regard to "design of arc fault temperature detector in low voltage switchboard". This study presents an arc fault temperature detector used for the detection of overheating in a low voltage switchboard before an arc occurs. The simulation test results showed that the proposed arc fault temperature detector can detect the overheating in the switchboard and reduce the possibility of fire due to arcing (Choo and Yew, 2015).

Accprding to Land and Gammon (2014) tested the historical validity of the arc fault protection systems for naval vessels in their study on "addressing arc-flash problems in low-voltage switchboards: a case study in arc fault protection". They examined various approaches to the detection of the arc and the prevention of the arc fault. Marine switchboards are manufactured according to the specifications similar to the specifications of those used in industrial field but arcing occurs more frequently. According to the US Navy data, wiring errors are the main cause of arc faults in the shipboard switchboard. This study aimed at helping to build an arc fault prevention system for the switchboards of the industrial field by studying the arc fault protection system in the poor marine environment (Land and Gammon, 2014).

In the study on "Design of arc fault pressure and temperature detectors in low voltage switchboard", presented a design of an arc fault pressure and temperature detector capable of detecting over-pressure and over-heating in a low voltage switchboard before an arc fault occurs. The simulation test results showed that the arc fault pressure and temperature detector sent a trip signal to the circuit breaker if only it detected pressure and temperature levels higher than the reference values. This prevented unnecessary power interruption due to no fault tripping signal being sent to the circuit breaker.

The fire extinguishing performance of the condensed aerosol extinguisher on the b or c class fire in a small cabinet such as switchboards or distribution boards was experimentally analyzed and the suitability of the condensed aerosol extinguisher for fire in a small cabinet were examined by Park *et al.* (2009, 2006) with the theme of "Fire extinguishing performance of condensed aerosol extinguisher on the B, C class fire in a small cabinet". In the oxygen concentration measurement experiment, the

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fire was completely suppressed after the elapse of 5 sec from the start of the fire-extinguishing agent's dispersion. In the case of oil fires, the flame propagated faster than in the case of electric fire because the flame propagation speed reached to the detection line of the fire extinguisher was faster and it was completely suppressed after the elapse of 5 sec from the start of the of the fire extinguishing agent's dispersion. In addition, the temperature measurement experiment and radiation efficiency measurement were carried out and it was confirmed that the condensed aerosol extinguisher complied with KFIS (Korea Fire Institute Standard) 026 and KFIS 023 (Park *et al*., 2009).

Presented the structure and the design criteria of the fixed aerosol auto fire-extinguishing systems developed in their study on "characteristics of fixed aerosol auto fire-extinguishing systems" and described the method of manufacturing fire extinguishing agents. In addition, the digestion ability of the fixed aerosol auto fire-extinguishing systems was evaluated. The fixed aerosol has an average particle size of 0.195 μm and the maximum concentration particle size of 0.217 μm. In addition, the fixed aerosol auto fire-extinguishing systems were verified as conforming to the acceptance criteria of the ministry of public safety and security by carrying out the electrical conductivity measurement, the maximum height test and the oil and polymeric fire test according to the technical standards officially announced by the ministry of public safety and security for the type approval and product test of fixed aerosol auto fire-extinguishing systems.

In the study of Lee (2015) on "auto fire extinguishing system for distributing board", it was claimed that the introduction of the auto fire extinguishing system in a small cabinet such as incoming panels and switchboards could prevent the spread of fire in case of electric fire in panels such as incoming panels, switchboards and distributing boards and reduce the damage. In addition, he claimed that the auto fire extinguishing system could make it easy to acquire evidence of fire caused by electricity in the fire investigation and make it possible to prevent an attempt of arson faking an electric fire by preventing incoming panels, switchboards and distributing boards from being completely burned (Lee, 2015).

Analyzed NFPA 2001 and NFSC 107A for the amount of the HFC-227ea clean fire extinguishing agent used in an automatic fire extinguishing system for incoming panels, switchboards and distributing boards in their study, "a study to determine the quantity of clean agent in an automatic fire extinguisher for switchgear". In addition, they derived the estimation method. The amount of the clean fire extinguishing agent used in an automatic fire extinguishing system for incoming panels and switchboards is first calculated by the volume of the protection zone (m^3)×the required gas amount per volume (kg m^{-3}). Then, the formula can be applied after multiplying this value by the atmospheric pressure correction factor according to the automatic fire extinguishing system's installation height allowing for its installation location. This is the minimum fire extinguishing agent quantity calculation formula applying the atmospheric pressure correction factor according to the height, preventing the excessive design due to the addition for incoming panel/switchboard openings and the application of the 120% safety factor to the calculated amount.

In the study, "implementation of an inference based intelligent distribution panel system for prevention and fast detection of fire caused by electricity", Park *et al*. (2006) proposed the method using the JESS inference mechanism for the implementation of an inference-based intelligent distribution panel system for detection of fire. In addition, they performed the inference through the virtual model implementation of the incoming panel and switchboard system and the expression and execution of the rules (Park *et al*., 2006).

In a similar study, "A study on the development of fire extinguishing system for machinery spaces of a small craft", Lee *et al*. (2006) developed a fire extinguishing system that can be practically used for machinery spaces of a small craft. In addition, they tested the developed fire extinguishing system. The experimental results showed that the prototype of the automatic powder fire-extinguishing system installed in the upper part of the miniature model's spaces had higher fire-extinguishing effect than when it was installed in the lower part of the miniature model's spaces. The results also showed that the method to maximize the fire-extinguishing effect was fire-extinguishment by smothering. This method was to smother the fire by spraying the fire-extinguishing agent all at the same time with a quick release time for the fire-extinguishing agent. In the case of the manually-operated powder fire-extinguishing system, the diameter of the copper pipe was limited according to the capacity of the fire extinguisher to be injected. In addition, it was confirmed that in terms of the copper pipe length of about 7 m under the condition of bending the copper pipe 5 times, the condition of making about 20% of the allowance for the copper pipe was a useful restrictive condition (Lee *et al*., 2006).

Thus, the conventional researches tested the fire extinguishment using an automatic fire extinguishing system with a single switchboard. Unlike previous ones, the purpose of this research is to increase economic efficiency by add a selector valve to switchboard to protect two switchboards with one cylinder.

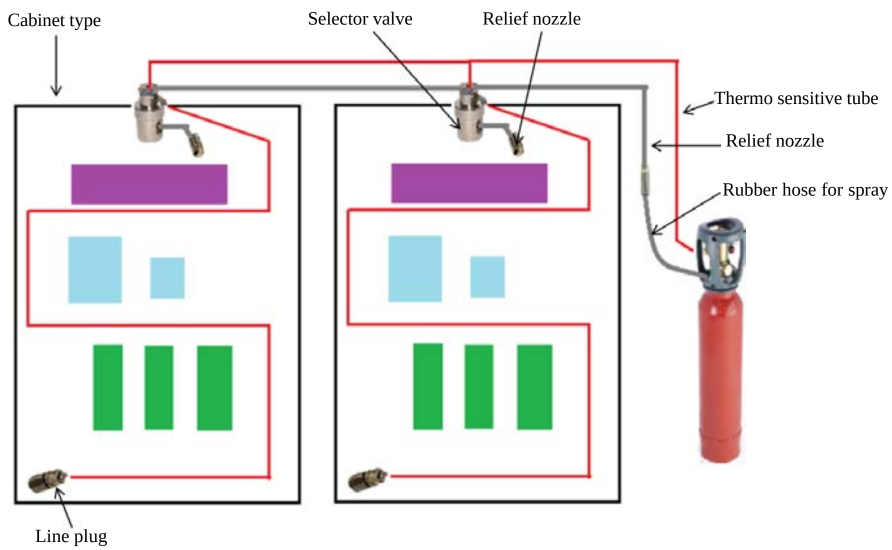

Fig. 1: The switchboard fire protection system using selector valves

MATERIALS AND METHODS

Paper preparation: The experimental apparatus which could protect two switchboards as a single cylinder by using selector valves was constructed by equipping the switchboard model with the relief nozzle, the selector valves, the thermo-sensitive tube, the relief tube, the line gauge, the line plug, the rubber hose for spray as shown in Fig. 1.

RESULTS AND DISCUSSION

Experimental standards and experimental results

Experimental standards: In Table 1, the actuators using thermo-sensitive tubes shall be free from malfunction and stable at nominal operating temperatures. The operating temperature test for the thermo-sensitive tube shall be within ±5% of its nominal operating temperature.

In terms of the dispersion performance test, the fire-extinguishing agent shall be released immediately after the activator is activated. The fire-extinguishing agent used for this experiment was carbon dioxide. When the carbon dioxide fire-extinguishing agent was used in the automatic fire-extinguishing system, the dispersion time shall be determined by the technical standards for gas and powder automatic fire-extinguishing systems according to VDS 2093 and CEA 4007 of Europe and the type approval and product test of Korea which provides that the maximum dispersion time shall not exceed 60 sec. NFPA 12 of the US also requires that the carbon dioxide fire-extinguishing agent be dispersed within 1 min in case of surface fires and within 7 min for deep-seated fires (Table 1).

Table 1: Standards for the operating temperature test and dispersion performance test

Test type	Technical standards
Operating temprature test	If the thermo-sensitive tube is heated with the rate of 1°C min^{-1} or less from the temperature 10% lower than the nominal operating temperature (10% lower than the nominal operating temperature if the nominal operating temperature is above 100°C), the temperature at which the thermo-sensitive tube operates shall be within ±5% of the nominal operating temperature
Dispersion performance test	The fire extinguishing agent shall be effectively dispersed immediately after the activator is activated The design value of the dispersion time at 20°C shall be within 60 sec in the case of the carbon dioxide and inert gas fire-extinguishing systems

Operating temperature test: The thermo-sensitive tube used in this study has the nominal operating temperature of 125°C. Table 2 showed that the thermo-sensitive tube operated within ±5% of the test result according to the operating temperature test standards.

Dispersion performance test: As shown in Fig. 2, the dispersion performance test was carried out in order to confirm whether the two switchboards could be protected by one cylinder when using the selector valve. The test results showed that the fire extinguishing agent was immediately released and that no residue was found.

As a result of the experiment shown in Table 3 which was carried out in accordance with the technical

Fig. 2: Process of the test for the switchboard fire protection system using selector valves: a) Combustion; b) Fire-extinguishment and c) Flame-check

Table 2: Operating temperature test

Times	Operating temperature (°C)
1	124.0
2	123.0
3	123.0
4	124.0
5	125.0
Average	123.8

Table 3: Dispersion performance test

Times	Operating temperature (°C) (sec)
1	46
2	48
3	46
4	47
5	47
Average	47

standards of the dispersion performance, the average time of the fire-extinguishing agent's release was 47 sec and all fire extinguishing agent was dispersed within 60 sec.

CONCLUSION

The purpose of this study is to protect two switchboards with one cylinder by using a selector valve considering economic efficiency because only one switchboard has been protected by one cylinder in the past. Firstly, the experimental results of the thermo-sensitive tube's temperature test confirmed that the operating time of the thermo-sensitive tube used in the experiment was 125°C ±5% which was suitable for the regulation. In the dispersion performance test carried out next, the switch board fire protection system with the thermo-sensitive tube on the switchboard detected fire within 5 sec on average and released the fire-extinguishing agent immediately.

The fire-extinguishing agent's dispersion time was about 47 sec and was suitable for the dispersion performance test's acceptance criteria of the dispersion within 60 sec. Through this experiment, it was confirmed to be effective to protect two switchboards with one cylinder. Therefore, it is desirable to design the fire protection system of the switchboard, so as to protect two switchboards with one cylinder considering the economic efficiency.

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