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Review of the Research on the Identification of Electrical Fire Trace Evidence

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Abstract

In this paper, we review the research results about the identification of the electrical fire trace evidence and the fire reason recognition. We point out the existing problems and put forward the corresponding suggestions to promote the development of the cause of the fire investigation and make it better to serve for the work of fire investigation.

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Keywords: electrical fire, trace evidence, fire investigation

1. Introdution

With the development of science and technology, the application of electric power is more and more extensive. It doesn't only provide a convenient and comfortable living environment for people, but also become the main energy of power, lighting, heating, control, signal and communication. However, everything has its dual attributes. Fire accidents caused by the electrical hazards and illegal use show a rising trend. According to statistics, from 1993 to 2007, about 373700 electrical fires occurred nationwide. It occupied 24.5% of the total fires on average. From 1997 to 2007, 1324 catastrophic electrical fires occurred nationwide. The direct property losses were about 1.56 billion. They accounted for 31.5% and 44.3% of all major fires respectively. Electrical fires occupied the first place of all types of fires. Electric lines are the main fire sources (almost 50%) in the electrical fires. Secondly, the use of electrical appliances, electrical equipment and electrical facilities is also an important cause of electrical fires. In addition, the lighting apparatus is also very prominent. The main cause of electrical fires is the short circuit fault (about 51%). In the face of severe electrical fire situation, the focus of fire investigation and fire-prevention work is to identify the failure modes and the cause of the fire, to take measures to prevent similar incidents from happening again, to protect people's lives and safety, to reduce the loss of social property [1].

In the remaining traces of the fire scenes, besides the residues produced directly by electrical reasons, in the process of occurrence and spread of fire caused by non-electrical reasons, electrical facilities are in high flame temperature effect, electrical insulation is destroyed, induced electrical accidents such as short circuits continue to occur on the live lines which will leave corresponding residue traces. Therefore, in the process of scene investigation, to find and extract these traces accurately and correctly, to distinguish and identify these traces are very important to determine the cause of fire. This paper mainly summarizes the research results of the cause identification of electrical fire trace evidence in recent years. Some advices are also proposed in this paper in order to promote the development of the actual fire investigation work to some extent.

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2. Research on the trace evidence identification

2.1. Short circuit trace

In fire investigation, we separate short circuit into two types: first short circuit and second short circuit. First short circuit is also called short circuit before fire. It means a short circuit caused by wire due to its own fault before the fire. Second short circuit is also called short circuit during the fire. It means a short circuit caused by electric wire insulation fault under the effect of external flame or high temperature. After a short circuit, all kinds of traces will appear at the short circuit point and around the short circuit point. These traces are called short circuit traces. The common traces include short circuit bead, pit like fuse trace, splash bead, tip fuse trace and fusing trace. Wang Liantie and others produced metallographic samples through simulation test method, and conducted analysis and summarization by means of macroscopic analysis and metallographic analysis. They concluded the trace characteristic rules when short circuit fault happened.

Through the research on the fault mode of the AC (Alternating Current) and DC (Direct Current) power supply line, it is found that the trace characteristic distinction between AC and DC is very obvious: The metallographic structure of first short circuit on the direct current line is mainly based on the fine columnar crystal which has fewer holes. There are two transition regions between the matrix and the end of the fuse trace on the metallographic structure of the circular fuse trace. They exist between the matrix and the fine columnar crystal and between the fine columnar crystal and the coarse columnar crystal. This kind of feature is seldom seen in the structure of first short circuit fuse trace of the AC line. Another obvious distinction is that the metallographic structure of first short circuit fuse trace in the DC line has more dendrite and broken crystal, and very few in the AC line. The macro characteristics and the fuse trace structure caused by second short circuit are basically consistent in both AC and DC lines. The insulation layer at the short circuit point has been totally carbonized. Because of the serious fire, the carbonization degrees of the internal and external layer are basically consistent. Most of the shapes of the fuse trace are circular. The transition region between the fuse bead and the wire is very obvious. The structure of the fuse trace is in the shape of coarse columnar crystal and more irregular holes. There are just more holes inside the second short circuit trace in the AC line.

2.2. Overloaded trace

Overloaded wire will lead to overloaded trace in the whole loop. It is quite different from the short circuit fuse trace at the short circuit point. The temperature will rise when the wire is overloaded. The crystal configuration inside will have a change. The metallographic structure is changed from the original deformed grains to the equiaxed grains. Thus, metallographic structure intensity is greatly reduced. The phenomenon of scarring will appear on the copper wire. The phenomenon of uniform section breaking will appear on the aluminum wire.

The wire where insulation layer exists (often seen below 3 times of the rated current) can be judged whether the heat come from inside or outside through the internal and external surface carbonization discoloration of the insulation layer, through the distribution of grains in the metallographic structure (especially 1.0mm wire). Accordingly, we can judge whether electricity current happens. We can determine the multiples of the overcurrent according to the depth and discoloration of the carbonization, the grain size and the distribution law of the grain and the distribution law of the electric current. As to the sample where fuse traces come into being (Greater than 5 times of the rated current), we can judge whether the trace is caused by the overcurrent or not according to the structure form and the grain size around the transition regions. As to the sample where the insulation layer has been totally burned up, but the fuse trace hasn’t been formed in the line core. A short section of the wire is analyzed, no difference is found between the external heating and the internal current heating. So we cannot identify it. But we can determine whether overcurrent phenomenon exist according to the structure change in the different positions of the same wire [2]. (The overcurrent trace characteristics remain the same across all the line. However, external fire heating trace will make different positions have different characteristics due to different temperature in different positions)

2.3. Poor contact trace

Qi Zibo, Zhang Ming and others conducted experiments of the sockets in the situation of static contact area decrease and contact vibration. They concluded the fire risk of the sockets in the forms above. On the basis of simulation experiments, they analyzed and summarized the extracted poor contact trace using technical methods such as macro analysis, micro morphology analysis, surface composition analysis, metallographic analysis. They put forward the identification technical methods and the criterion for the socket poor contact trace. They come up with the following conclusions: the poor contact of the sockets would bring about great fire risks; the macro characteristics of the malfunction sample were obvious; the cause of the fire can be preliminarily identified in the case of no trace damage; by means of metallographic methods and composition analysis, the reason of the socket trace formation can be identified [3].

There are 3 kinds of conditions for poor contact trace: first is that poor contact leads to high contact resistance, the temperature at the contact point will rise and the discoloration trace will come into being; second is that the loose joint may cause electric arc which will give rise to discoloration trace; third is that poor contact will damage the insulation and cause short circuit trace. Specific trace features are as follows: local color change at the joint, dent will occur on the surface, what is more serious, the phenomenon of the ablation and even partial fuse occur; the insulation layer at the junction of the joint is heated, the inner insulating tape will have the phenomenon of burning and charring which can cause insulation when it is more serious; the electric spark is produced at the loose joint point which can cause ablation trace; melting trace, especially in the copper and aluminium joints.

2.4. Electricity leakage trace

The main reasons of electrical fires caused by electricity leakage: leakage point is usually in the case of bad contact (such as socket and switch connector), which will result in heavy contact resistance and make overcurrent protection device hard to activate, electric arc will appear at the fault point which will cause fires; the zero line and ground line for protection choose a small cross-sectional area, when larger leakage current passes, the increasing temperature of the wires will cause fires; in wet conditions, when leakage current flows through the wood surface fiber, wood carbonization will cause fires; the poor joint of the zero line and ground line for protection will also cause fires; continuous electricity leakage will produce electricity leakage voltage, fire can spread to items nearby such as water pipes and gas pipes through electricity arc.

Electricity leakage traces usually occur on the electrical wires, electrical equipment and metal structure. When the electricity leakage traces are extracted in the fire scene. We should focus on the electrical wires, electrical equipment and metal structure parts. Like wires in electrical circuits, fuse traces will be left in the insulation damage place, and other parts of the wire insulation are still intact; the metal shells or the wiring conductors of an electrical apparatus have melting holes or melting traces; melting traces are left on the metal components near the wire cables; melting traces are left at the contact part of the steel structure or between the structure and the wire.

The leakage current melting trace is usually formed at the local point of the metal structure. The melting point of steel structure is very high, once the electricity leakage trace came into being; it's very hard to be damaged by the high temperature and the flame of the fire which will provide a good basis for the identification of this kind of fire. The characteristics of this trace are that the steel structure surface of the electric arc erosion has electric spark traces and has pitting holes, electricity fuse traces. Holes and gaps form when it is serious. The circuit has no leakage protection device or the device becomes invalid. Normally the protection device doesn't work, but when large current leakage or electricity leakage fire leading to a short circuit happens, the protection device will also work [4].

3. Problems and suggestions in the identification of trace evidence

When trace samples are produced in the laboratory, standards and conditions cannot stay the same which will bring about great differences between the experimental results and conclusions. For instance, when short circuit trace sample is made, because of the different cooling conditions, there is a big difference between the metallographic structure and the micro morphology of the samples. When Wang Lifen and Ye Shimao produced copper wire short circuit samples, they chose 3 kinds of cooling methods; the findings showed that copper wires before they were melted were similar with what was stated before. The microstructures of copper wires were thick equiaxed grains with no holes. The microstructures of copper wires after they melted were mainly equiaxed branch grains and Cu_2O-Cu eutectic structures; sometimes there were a small number of holes. Thus, the relevant contents of the proposed national standards should be revised in time. The simulation process of laboratory sample preparation needs standardization and normalization.

We are short of considering the related factors on the actual fire, which may lead to errors or mistakes in the identification of trace evidence. For example, the short circuit traces of fire may be destroyed under the action of high temperature flame, especially for cable fires. A short circuit happens in a certain place; the short circuit happens on the outer surface of the cable core at the start and then ignites the insulation layer. The short circuit happens in the cable core. Under the effect of the heavy electric arc and flame, the original fuse trace of first short circuit is easy to be destroyed. The remained trace reflects the characteristics of the second short circuit fuse trace [5].

In the course of fire investigation, trace evidence of electrical residues is very common. The electrical trace evidence must be connected with other evidences. We should build a three-dimensional distribution system in which the fire point is the center in order to reveal the law of the combustion and its changes during the development of fire. The trace evidence inquest in the fire reflects everywhere in the fire investigation process. It concerns extensive experience knowledge and identification techniques. In order to meet the needs of the development of fire investigation technology, knowledge and conceptual system of electrical fire investigation must be established to explore more scientific method and technological means of the trace evidence inquisition [6].

4. Tag

Although the discipline and knowledge system of fire investigation is still very imperfect, it is gratifying that more and more people begin to care about the fire investigation, and actively participate in the relevant work and research, which will become the inexhaustible power and power source of the fire investigation.

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