Managing Safety Hazards in Electric Cable Splicing and Termination

Miriam Eduful and Simon Sovoe

Abstract— **Different types of cable splicing and termination kits from different manufacturers are used in cable repairs. These kits are manufactured of materials of certain chemical compounds that can be harmful to personnel. In most cases, the splicing and the termination are accomplished by application of heat source. Dangerous chemical fumes are released if the splicing and the termination materials are heated to certain temperature. Also, physical contact with cable conductors like copper and aluminium without adequate hand wash can cause a serious stomach upset. It is found that contact with copper and aluminium conductors leave traces of copper and aluminium films in the hands. These are all poisonous chemical compounds that are injurious to human health. These chemicals and their effects on health are rarely known by most cable jointers. The paper identifies chemical compounds used in splicing and termination and examines the health effect. The chemical compounds were identified in a laboratory of Ghana Standard Authority. Some of the chemical compounds found include Methane, Acetophenone and Cumylalcohol. These are chemical compounds that can affect the health of the cable jointer. Regular education and training in risk management are critical in controlling occupational hazards.**

***Index Terms*— Cable Works, Cable Termination, Cable Splicing, Jointing Kits, Hazardous Compounds**

I. Introduction

DIFFERENT types of cable splicing and termination kits from different manufacturers are used in Electricity Company of Ghana. These kits are manufactured of materials of certain chemical compounds that can be harmful to personnel if the necessary safety procedures are not followed. The danger is more pronounced during the splicing and the termination process. In most cases, the splicing and the termination are accomplished by application of heat source which is mostly Liquefied Petroleum (LP) gas. Dangerous chemical fumes are released if the splicing and the termination materials are heated to certain temperature. This becomes harmful to the cable splicer if he/she does not follow the relevant safety procedure.

Physical contact with cable conductors like copper and aluminium without adequate washing of hand before eating can cause a serious stomach upset [1]. It is found that contact with copper and aluminium conductors leave traces of copper and aluminium films in the hands. These are all poisonous chemical compounds that are injurious to human health.

The paper identifies chemical compounds used in splicing and termination and examines the health effect. The chemical compounds were identified in a laboratory of Ghana Standard Authority. Some of the chemical compounds found include Methane, Acetophenone and Cumylalcohol. These are chemical compounds that can affect the health of the cable jointer. Regular education and training in risk management are critical in controlling occupational hazards.

II. Methodology

Generally, the study adopted three main approaches namely, review of pertinent literature, administration of questionnaires and chemical analysis at the Ghana Standard Authority. This section describes in detail, the approach and the methods used in the investigation. It should be noted that where the word 'accessories' are used refers to cable splicing and termination materials. Also, for clarity and easy flow of discussion, the word "cable splicing and termination" will occasionally be replaced with "cable works".

Literature reviewed provided general information and understanding on some chemical compounds used in the cable splicing and termination works. However, it was hardly found that the people who are directly involved in the use of medium cables and their accessories are themselves aware of these chemical compounds and the effects on their health.

The next stage of the investigation was to find the awareness level of the cable jointers in relation to these chemical compounds in cable works. As a result, a sample size of 45 was chosen out of 50 cable jointer in the Tema Region of Electricity Company of Ghana (ECG).

A. Framework for Data Analysis

The questionnaire was structured to elicit from the cable jointer whether, 1- they are aware of any harmful chemical compounds in cable works, 2- the effects of these chemical compounds on their health, and 3- they are familiar with any precaution necessary to mitigate impact of the effects.

The questionnaire was in two parts: Section-A and Section-B. Section-A was aimed at reliability and future verification of the information provided in the questionnaire. As a result, the section sought for personal profile of the cable jointers. This included their gender, job position, age group, academic qualification and number of years of experience on the cable works.

In section-B, their awareness level in relation to hazards in cable splicing and termination were examined. Among

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others, Section-B sought whether 1- they know the chemical content of cable termination, 2- they know the health effects of these chemicals, and 3- they know of any precautions to take to reduce the effects of these chemicals.

B. Proportions and Confidence Intervals

Proportions and their respective confidence intervals were calculated using the following relations:

$$\hat{P} \pm Z_{\alpha/2} * \sqrt{\frac{\hat{P} * \left(1 - \hat{P}\right)}{n}} \quad (1)$$

Where $\hat{P}$ is the proportion property, $Z_{\alpha/2}$ is the critical value (1.96 at 95% confidence level) and n is the sample size.

C. Method used - Chemical Analysis

To identify levels of chemical compounds in the cable materials, samples of splicing and termination kits were sent to Ghana Standard Authority for chemical analysis. The samples included insulation tubes, soldering sticks, bitumen, cleaning solvent, and semiconductor material and mastic tape. Ghana Standard Authority (GSA) was asked among others to test for the presence of the following harmful chemicals: silicon, asbestos and lead. The GSA used conventional methods for the various tests. These tests, as given by the GSA are explained below for each of the harmful compounds.

D. Method used in Silicon Testing

Silicone was detected by a method known as Fourier Transform Infrared Spectroscopy (FTIR). In this method, some degree of molecular identification by comparing the suspected silicone contaminant with a known material is made. The technique is performed on a specific area of the sample. According to the GSA, there are other techniques that provide more definitive identification of silicone contaminants. One is electron spectroscopy for chemical analysis (ESCA), which is also referred to as X-Ray photoelectron spectroscopy (XPS). For volatile silicone contaminants, thermal desorption gas chromatography mass spectroscopy (TD-GC-MS) is used. In the case of the sample presented to the GSA, the TD-GC-MS was used.

E. Method used in Asbestos Testing

Various testing methods have been developed to test for the presence of asbestos. However, according to the GHA, Phase Contrast Microscopy (PCM) was used to measure asbestos fiber concentrations in the sample. The PCM technique has the advantage of fast turnaround time and low cost. The PCM is to detect asbestos larger than 0.25 microns (um) in diameter. According to the GSA, the Transmission Electron Microscopy (TEM) represents the most sophisticated technology available for characterizing asbestos minerals. Unfortunately, the GSA does not have such facility. The TEM technique is now the standard for most airborne investigations including post abatement clearance testing as well as diagnostic and environmental monitoring activities. The current revision of the National Institute of Occupational Safety and Health (NIOSH) Method 7400 is employed for PCM analysis.

F. Method used in Lead Testing

In the lead testing, the so called "triple nitrite, test" was used. It depends upon the formation of a hexanitrite of potassium and copper. This hexanitrite is readily identified under the microscope by its regular crystalline structure. Lead chromate, while very insoluble, is invariably precipitated in an amorphous condition so that identification is difficult. The triple nitrite test consists in adding small crystals, successively, of copper acetate, sodium acetate, and potassium nitrite to a drop of the lead solution which had been slightly acidified with acetic acid. Sodium acetate is added in order to buffer free mineral acids, which interfere with the test. The hexanitrite crystallizes in regular rectangular plates or cubes. The lead is present in such small amounts that considerable analytical skill is necessary to make an exact estimation.

III. Results and Discussions

Results in Relation to the Administered Questionnaires: In this section, results of the questionnaires are presented. The section first looks at the general profile of staff engaged in the cable works and proceeds to examine their knowledge on cable related hazards. It also examine whether the staffs has adequate knowledge on how to manage risk associated with cable works.

A. Age Group Distribution

Figure 1 shows proportions of age distribution of ECG staff involved in the survey. The respective confidence interval of the age distribution is also shown in Figure 4.2. As can be seen in Figure 4.1, majority of the staff engaged in the cable works are aged between 30 to 59 years with most of them fallen between 40 to 49 years. Generally, it should be noted that majority of the workers are advanced in age and are closed to retirement. Therefore, the nature of their work and its related hazards should be of major concern to the workers and the company. Ideally, a worker who has dedicated majority of his life working for a company should not retire with decease acquired from his occupation. The information on the age distribution is therefore important for hazards management in cable works.

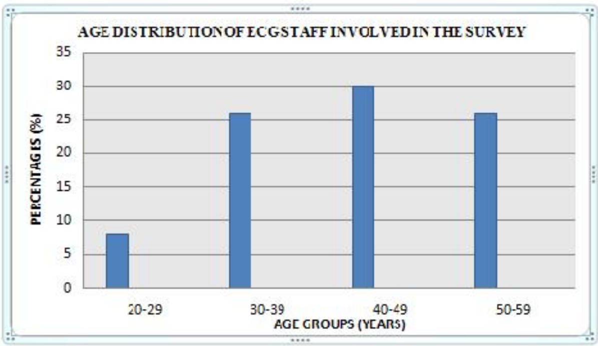

Fig 1: Age distribution of cable jointers

ISBN: 978-988-19253-0-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

B. Number of Years of Work Experience

Years of experience of the cable jointers are shown in Fig 2 and their respective confidence intervals shown in Fig 3. As can be seen from Fig 2 and 3, there is 95% confidence that proportion of cable jointers in ECG with more than 10years experience is between 50 to 77%. These years of experience and their confidence interval suggest that the majority of the cable jointers may have been exposed to different types of cables and may possibly have some knowledge in relation to hazards in cable works. However, response from the survey suggest otherwise. Detail on this is discussed in the subsequent section.

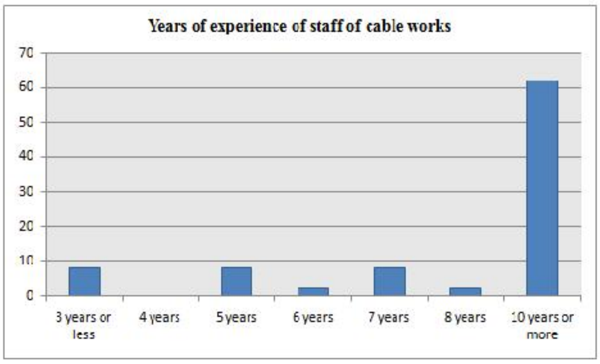

Fig 2: Years of experience of staff of cable works

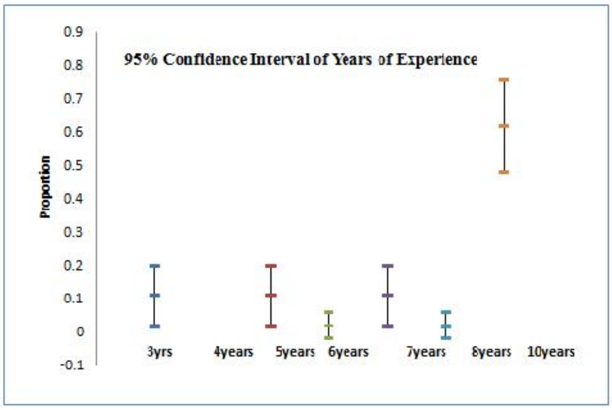

Fig 3: 95% Confidence Interval of Years of Experience

C. Health Effect of the Compounds

Result of the knowledge on the health implications from the chemical compounds is shown in Fig 4. Even though the majority (53%) of the cable jointers is not aware of the health effects of the chemical compounds, it appears they are conscious of safety precautions during cable works, refer to Fig 5.

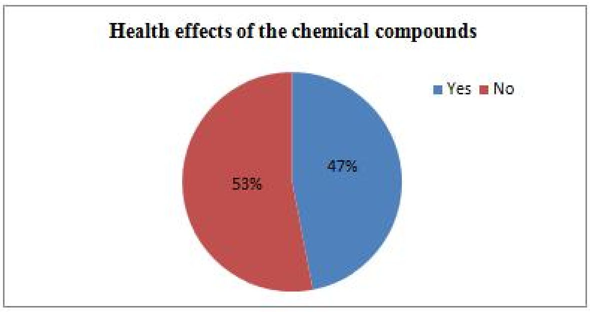

Fig 4: Health effects of the chemical compounds

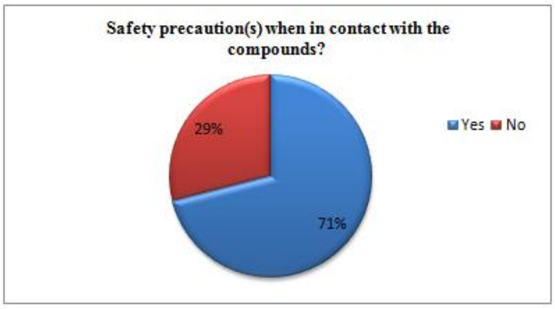

Figure 5: Safety precaution(s) when in contact with the compounds

D. Results of Laboratory Investigation Undertaken at the Ghana Standard Authority

Samples of cable termination and splicing kits that were submitted to the Ghana Standard Authority (GSA) for chemical analysis included copper, aluminium, lead, insulators, isopropyl cleaning solvent and bitumen.

Results for the copper, aluminium and lead samples showed 100% content of copper, aluminium and lead respectively. During cable works, cable jointers are likely to contaminate themselves with these chemical compounds. The likely health effects of these compounds are discussed below.

E. Toxicology of Copper

Free copper causes toxicity, as it generates reactive such as superoxide, hydrogen peroxide, and the hydroxyl radical [2]. These damage proteins, lipids and DNA. Copper poisoning can result in vomiting, hematemesis (vomiting of blood), and hypotension (low blood pressure).Chronic (long-term) effects of copper exposure can damage the liver and kidneys. However, these effects are sometimes controlled in victims as mammals have shown to have efficient mechanisms to regulate copper stores such that they are generally protected from excess dietary copper levels [2].

F. Toxicology of Aluminium

Respiratory effects, in particular impaired lung function and fibrosis, have been observed in workers exposed to aluminium dust or fumes. Occupational exposure studies and animal studies suggest that the lungs and nervous system may be the most sensitive targets of toxicity following inhalation exposure. A common limitation of these occupational exposure studies is that aluminium exposure has not been well documented.

G. Toxicology of Lead

Lead is toxic to many organs and tissues including the heart, bones, intestines,kidneys,and reproductive and ner vous systems. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behaviour disorders. Symptoms include abdominal pain, confusion, headache, anaemia, irritability, and in severe cases seizures, coma, and death. Routes of exposure to lead include contaminated air, water, soil, food, and consumer products. Occupational exposure is a common cause of lead poisoning in adults. Prevention of lead exposure can range from individual efforts to nationwide policies, example -

ISBN: 978-988-19253-0-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

laws that ban lead in products, reduce allowable levels in water or soil, or provide for clean-up and mitigation of contaminated soil, etc.

H. Results for Insulators

Samples of insulator materials submitted for the analysis included cross-link polyethylene (XLPE) and polyvinylchloride (PVC). The samples were tested for the presence of asbestos and any harmful chemical compounds. From the results, presence of asbestos was not found. However, in relation to the XLPE, the chemical compounds in Table 1 were found.

Table 1 Chemical compounds of XLPE insulator.

XLPE INSULATION	
Methane	0.08%
Acetophenone	0.6%
Cumylalcohol	1.2%

Source: Ghana Standard Authority laboratory results, 2015

Methane: The main health hazard associated with methane is that it is highly combustible. Mixtures of 5 to 15 percent methane in air can be explosive. Also, large concentrations of methane in enclosed areas can lead to suffocation as large amounts of methane will decrease the amount of available oxygen in the air. The effects of oxygen deficiency are nausea, headaches, dizziness, and unconsciousness. Fortunately, methane content found in the XLPE sample was very insignificant to pose any health hazards.

Acetophenone: Acute (short-term) exposure to Acetophenone vapour may produce skin irritation and transient corneal injury in humans. No information is available on the chronic (long-term), reproductive, developmental, or carcinogenic effects of Acetophenone in humans [3] . EPA has classified Acetophenone as a Group D, not classifiable as to human carcinogenicity.

Cumylalcohol: Contamination with Cumylalcohol can severely cause irritation to the lungs, mucous membranes, and respiratory tract. To minimize the effect of Cumylalcohol, it is recommended that OSHA approved respirator is worn when working with this material.

In relation to the PVC samples, no harmful substance was found. The only health implication with PVC is that, when burned PVC can generate health and environmental effect. The combustion by-products produced when PVC is burned include smoke, acid gases and organ chlorine compounds. Low acid gas PVC compounds are available with the addition of ruminated and antimony flame-retardants. These reduce the potential Hydrogen Chloride (HCl) concentration from levels of 20-36% down below 14% [4] [5].

I. Results for Isopropyl cleaning solvent and Bitumen

Isopropyl Solvent: It was identified as a chemical compound with a molecular formula C3H7OH.Early uses included using the solvent as general anesthetic for small mammals and rodents by scientists and some veterinarians. However, it was soon discontinued, as many complications arose, including respiratory irritation, internal bleeding, and visual and hearing problems. The compound acts as central nervous system (CNS) depressants. Symptoms of isopropyl alcohol poisoning included headache and dizziness. Poisoning can occur from ingestion, inhalation, or absorption; therefore, well-ventilated areas and protective gloves are recommended when handling the compound.

Bitumen: Generally, the bitumen is the residue of the direct distillation of crude oil produced by high temperature carbonization of coal. From the chemical analysis, the following chemicals were found, see Table 2.

Table 2: Chemical composition of Bitumen.

Chemical Composition of Bitumen	
Carbon	87%
Hydrogen	8%
Sulfur	5%
Nitrogen	1%
Oxygen	1%
Metals	2000ppm

Source: Ghana Standard Authority laboratory result, 2015

Bitumen is usually applied hot. Hot bitumen gives off fumes, which can cause respiratory tract or eye irritation. Apart from this temporary irritation, under normal conditions there is no evidence that working with bitumen is hazardous to worker health. The risk of exposure to this hazard - and, therefore, the potential health impact on workers - is minimised through good temperature control, working practices and appropriate work-wear.

IV. Conclusions

The main objectives of this paper was to identify chemical compounds used in medium voltage cables, determine their potential impact on health of cable jointers and where necessary recommend precautions to be taken during cable termination and splicing works. Major findings from the study are as follows:

Methane, Acetophenone and Cumylalcohol were found in XLPE cable insulation. These are chemical compounds that can affect the health of the cable jointer in many ways [6].

Lead was found in some cable insulation. Lead is toxic to many organs and tissues including the heart, bones, intestines, kidneys, and reproductive and nervous systems.

Cable jointers can be poisoned from isopropyl cleaning solvent. Poisoning can occur from ingestion, inhalation, or absorption. The solvent also acts as central nervous system (CNS) depressants.

Bitumen gives off fumes, which can cause respiratory tract or eye irritation. This is a serious health hazard to cable jointers.

A. Recommendations

Based on the above findings, the following safety precautions are recommended:

Bitumen: risk of exposure to bitumen fumes can be minimized through good temperature control, working practices and appropriate safety wear. Therefore, in handling bitumen, a well-ventilated areas and protective gloves are recommended.

ISBN: 978-988-19253-0-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Lead: Occupational exposure is a common cause of lead poisoning in adults. Prevention of lead exposure can range from individual efforts to nationwide policies. To reduce the effect of lead poisoning, regular medical checkups and thorough hand cleaning with detergents are recommended. Utility companies are also advised to discourage the use of lead cables.

Regular education and training in risk management are critical in controlling occupational hazards Accordingly, regular training on occupational hazards is therefore being recommended.

Personal protective equipment (PPE) includes gloves, respirators, hard hats, safety glasses, high-visibility clothing, and safety footwear. These are basic protective-gear that should always be available to the worker and steps should be taken to enforce

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ISBN: 978-988-19253-0-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)