JEMMME, *Vol.3, No. 1, May 2018*
ISSN 2541-6332
e-ISSN 2548-4281

Thermal Characteristic of Fire Resistance Electrical Cable for Residential Wiring Installation

Yunita Sari[a] and Mochammad Syamsul Ma'arif[b]
[a] Department of Mechanical Engineering, Faculty of Engineering, State University of Jakarta
Kampus A, Jl. Rawamangun Muka, Gedung L, Jakarta, Indonesia
Telephone +62-21-4751523, 4786480
e-mail: yunitasari@unj.ac.id

[b] Department of Mechanical Engineering, Faculty of Engineering, Brawijaya University
Jl. MT Haryono 167, Malang, Indonesia
Telephone +62-341-554291
e-mail: syamsulm@ub.ac.id

Abstract

The objective of the research was to investigate thermal characteristic of electrical cable for residential wiring installation in order to acquire the initial data for fire protection study especially connected to short circuit. The research methods were testing the characteristic of cable by differential scanning calorimetry (DSC), fire resistant test, and current injection test according to International Standard IEC 60332-1-1. The results of the test were: differential scanning calorimetry gave the flame temperature of the cable was 310^{0}C, fire resistant test shown the length of charred/melted cable was 65 mm and fire was extinguished in 10 s after the source of flame was cut, the current injection test showed that for current of 60 A, the cable started to melted and produce smoke after 270 s. The result showed that the cable complies with the specification, i.e. flame retardant cable or fire resistance cable as proved by test results and can be concluded that the cable gives adequate protection to the fire. Also, it can be concluded that whenever short circuits occur, the cable able to withstand the high current and temperature for prolonged time and may only resulted in charred or melted only and doesn't make the cable came into flame/fire. Even if the fire is occurred in the cable as results of short circuit, the propagation is relatively not existed.

Keywords*: thermal characteristics; electric; cable; residential*

1. INTRODUCTION

The research was initiated by several residential fires incident which caused by short circuit. The main trigger of the incidents was the use of non-standard cable in residential electrical wiring which can't withstand the high current and also high temperature which leads to the short circuit. As efforts to improve fire safety standard for residential electric wiring installation, the thermal characteristic of electric cable was need to be investigated since it provides the initial data to protect the electric wiring installation from the danger of fire caused by short circuit.

This effort was in line with the development of Undergraduate Program of Fire Protection Engineering, Department of Mechanical Engineering, State University of Jakarta, the only one of such undergraduate program in Indonesia, which focused on the research of flame retardant or fire resistance material especially in Research Laboratory of Fire, Material and Safety Engineering. Also, the research has another objective in giving contribution in developing fire protection technology especially for residential electrical wiring installation.

As commonly known, fire is not occurring by itself but rather as product of chemical process which involved fuel with oxygen and helped by heat. The theory is known as fire triangle as shown in Figure 1.1.

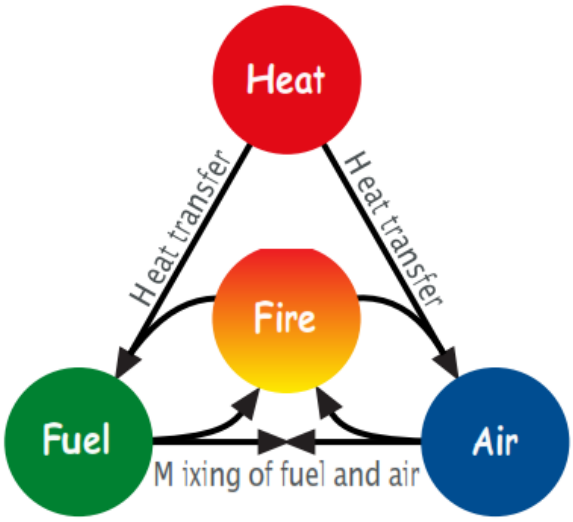

Figure 1.1 Triangle of Fire

Fire is triggered by source of fire such as cigarette, matches, or short circuit; and because of the presence of flammable substance like the things made of paper, wood, or cloth will make the fire propagate and spread then make the surrounding area become hotter. When the material in surrounding area is converted into flammable gas and the temperature is high enough, flashover wills occurs and makes all the area consumed by fire in which temperature may rise to 1200^0C.

Electrical cable is consisted of two components, i.e. conductor and isolator, with the conductor mays takes form of copper and aluminum. Copper for electrical cable has, at least, purity of 99.9%. The conductivity of copper is much depending on its impurity and for example alloying with 2% of Fe can increase the intrinsic resistance of copper up to 10%. The hardness of copper also has influence on the conductivity. The soft copper with 100% IACS (International Annealed Cooper Standard) conductivity has tensile strength of 195-245 N/mm^2 while hard copper with tensile strength of 390-440 N/mm^2 has only 97% IACS or roughly 3% lower than conductivity of soft copper. Aluminum as conductor also need to be in pure condition, commonly as high as 99.5%. The conductivity of aluminum also is influenced by its hardness by is not prominent as in copper. Soft aluminum with conductivity of 61% IACS has tensile strength of 60-70 N/mm^2 while conductivity of hard aluminum with tensile strength of 60-70 N/mm^2 has only 1% lower than the soft one.

As material for isolator in electric cable usually take form of thermoplastic and thermoset. There are several thermoplastic polymers which usually used as isolator material for electric cable such as polyvinylchloride (PVC) and polyethylene (PE). The electrical property of PE is considered better than PVC but it has drawback in its tendency to burn. When it is caught in fire, the flame will propagate even though the source of flame already cut off. Therefore, is almost rarely used in high current electric cable.

Test conducted in the research was Test on Electric and Optical Fiber Cable under Fire Conditions according to IEC (International Electrotechnical Commission) Test Standard Number IEC 60331: Tests for Electric Cables under Fire Conditions – Circuit Integrity. The test is intended to be standard for fire resistance cable. The cable is tested under fire condition with temperature reach minimum 750^0C and is expected to keep its integrity during the test. The test is commonly used as standard in testing of flame propagation in cable, especially for flame retardant cable. Flame retardant cable is the fire resistant cable designed to resist flame propagation along cable route in fire situation.

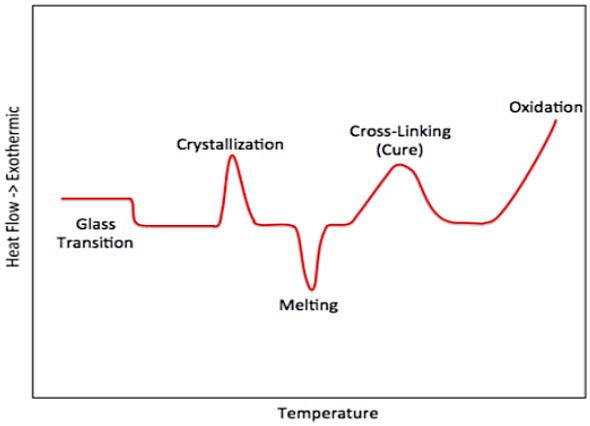

Figure 1.2 Curve of DSC

Figure 1.2 depicts the curve characteristic of typical DSC test while Figure 1.3 shows the structure of PVC polymer. Figure 1.3 gives electrical data on the cable used in test.

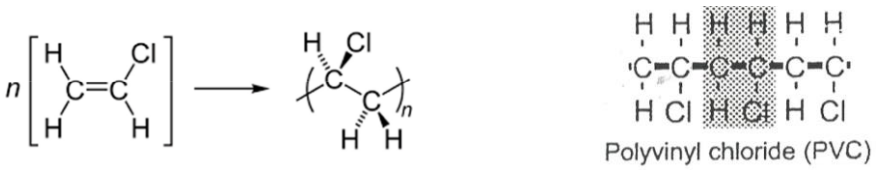

Figure 1.2 Structure of PVC polymer

Electrical Data

Nom. Cross. Sec.	Conductor DC Resistance at 20° C	AC Resistance at 70° C	Inductance	Current-Carrying Capacity at 30° C		Short circuit current at 1 sec
				in air	in ground	
(mm^2)	(Ω/km)	(Ω/km)	(mH/km)	Max, (A)	Max, (A)	Max, (A)
1.5	12.1	14.478	0.328	20	23	0.17
2.5	7.41	8.866	0.304	26	31	0.29
4	4.61	5.516	0.303	34	40	0.46
6	3.08	3.685	0.288	44	50	0.69
10	1.83	2.190	0.269	60	68	1.15
16	1.15	1.376	0.255	79	88	1.84
25	0.727	0.87	0.255	105	114	2.88
35	0.524	0.627	0.246	129	137	4.03
50	0.387	0.464	0.247	162	168	5.75
70	0.268	0.321	0.238	203	206	8.05
95	0.193	0.232	0.238	250	247	10.93
120	0.153	0.184	0.233	289	281	13.8
150	0.124	0.150	0.233	330	315	17.25
185	0.0991	0.121	0.233	381	356	21.28
240	0.0754	0.093	0.232	451	412	27.60
300	0.0601	0.075	0.231	517	464	34.50
400	0.0470	0.060	0.229	594	524	41.20

** For further information about rating factor for certain cable arrangement can be found on supplementary technical information*

KMI Wire and Cable | kabelmetal INDONESIA | SMK3 PER.05/MEN/1996 | ISO 9001 QUALITY ASSURED FIRM | ISO 14001 ENVIRONMENTAL SYSTEM | OHSAS 18001 HEALTH & SAFETY MANAGEMENT SYSTEM

www.kmi.co.id

PT KMI Wire and Cable Tbk reserves the rights to change the data content without prior notification

14233-03 Rev. 2.0 / 2009

Figure 1.3 Data of Electric Cable

2. METHODS

The method in determining thermal characteristic of flame retardant and fire resistance of residential electrical wire was given in Figure 1. It consisted of DSC test, flame test, and current injection test.

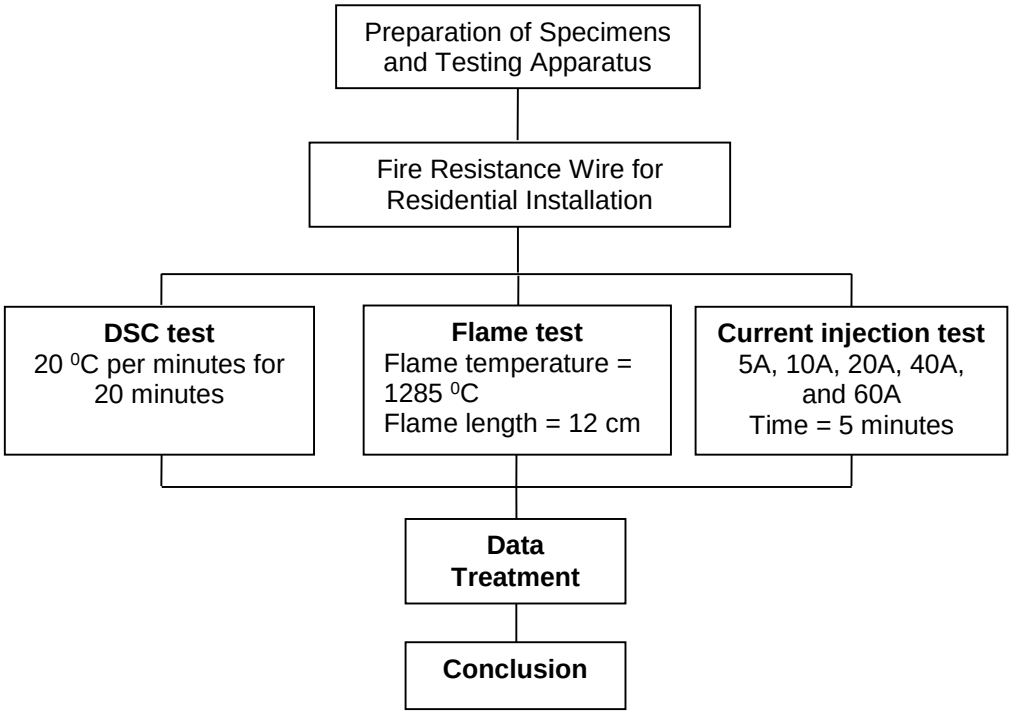

Figure 2.1 Flowchart of the research

The tests were conducted according to International Standard IEC 60332-1-1 Test on Electric and Optical Fiber Cable under Fire Conditions. The specimen for the test was electrical cable for residential use with compliance to IEC standard (Figure 2.2). The DSC test was conducted with heating rate of 20^{0}C per minutes for 20 minutes (Figure 2.3). Flame test was using flame temperature of 1285^{0}C with flame length of 125 mm and current injection test was conducted using current of 5A, 10A, 20, A, 40A, and 60A for 300 seconds (5 minutes).

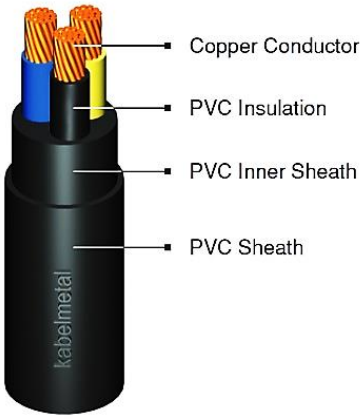

Figure 3.2 NYY 3x (1.5-400) mm^2 0.6/ 1kV cables
(Source: KMI Wire and Cable)

Figure 3.3 Current Injection Apparatus

3. RESULT AND DISCUSSION

3.1 DSC test result

The Differential Scanning Calorimetry test used 10 mg weight specimen. The test gave the result for cable's melting point of 310^{0}C.

3.2 Flame test

The flame test was conducted on 600 mm vertical cable by propane torch for 60 seconds and shown that propagation of fire was 65 mm. The fire was shut off after 10 second of fire source's cut off. The fire consumed lower section of the cable along 125 mm of length. The test was shown in Figure 3.1.

a. b. c.

Figure 3.1 Flame test
a. Length of flame, b. temperature of flame, c. flame test

3.3 Current injection test

Current injection test was conducted by recording the temperature rise for every 30 seconds and shown that for current of 60 A in 270 seconds the cable started to charred and produced smoke. The specimen of current injection test was given in Figure 3.2.

Figure 3.2 Specimen of current injection test

4. CONCLUSION

In accordance with its specification, i.e. flame retardant wire or fire resistance wire, and from the test results which consisted of measurement of melting temperature, fire propagation, and current injection tests, the conclusion was the wire in the residential wiring installation gives good degree of protection against the fire especially caused by short circuit. In the event of short circuit when the wire receives huge amount of current and high temperature produced, it most likely that the wire only experience charring or melting and the fire will not occurred. In the worst case when the fire may exist, the propagation of fire can be considered not exist.

In the future, the research on the analysis of wire material difference claimed to be flame retardant or fire resistance with common wire generally used in residential electricity installation need to be conducted. It is important to do so because the fire in residential area is commonly initiated by short circuit.

REFERENCES

[1] Callister W.D., Material Science and Engineering, an Introduction. Singapore: John Wiley & Sons Pte. Ltd. 2003

[2] International Electrotechnical Commission. 60227. *Polyvinyl Chloride Insulated Cables of Rated Voltages up to and including 450/750 Volt*. Geneva. IEC Central Office. 1997.

[3] International Electrotechnical Commission. 60332-1-1. *Test for Vertical Flame Propagation for a Single Insulated Wire or Cable – Apparatus*. Geneva. IEC Central Office. 2004.

[4] International Electrotechnical Commission. 60332-1-2. *Test for Vertical Flame Propagation for a Single Insulated Wire or Cable – Procedure for 1 kW Pre-Mixed Flame*. Geneva. IEC Central Office. 2004.

[5] USAMC, Engineering Design Handbook Electrical Wire and Cable. Washington D.C.: AMC Pamphlet. 1969.

[6] Yang, L. *Preparation and Characterization of Fire Retardants Methyl Vinyl Silicone Rubber Based Cable Covering Materials*. International Symposium on Safety Science and Engineering. China. 2012: 552-555.

[7] Kumar, A. & Gupta, R. K., Fundamental of Polymers. San Juan: McGraw-Hill. 1998.

[8] Moore, G. F. Electric Cables Handbook, 3rd Edition. Oxford: Science Ltd. 1997

[9] Anixter. Technical Information Handbook Wire and Cable. 5th Edition. 2013

[10] William A. T., Electrical Power Cable Engineering. 3rd Edition. New York: Marcel Dekker, Inc. 2003.