

FLAME RETARDANTS CHARACTERIZATION ON DISTRIBUTION BOXES USING
THERMOMECHANICAL AND THERMOGRAVIMETRIC ANALYSERS

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Specially dedicated to.....

My beloved parents and my sister

My supervisors and my friends

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ABSTRACT

Fire is the phenomenon in which the liberation of light and heat in consequence with the combustion process which can cause damage, loss of life, loss of belongings and human misery. Earlier investigation concluded that there are many reasons which cause the ignition of fire, partly influenced by low usage of fire retardant materials in our life. Fire retardants are commonly used as components formulated in objects to prevent the start and the spreading of fire. The investigations showed that the highest percentage of fire cases occur in residential area was partly due to the failure of distribution boxes (DB). In this study, a few local brands of DB were characterized based on their manufacture contents and mechanical strength. All samples were analysed through screening test using Fourier Transform Infrared Spectroscopy (FTIR). The results found the samples had similar composition and contain high percentage of acrylonitrile butadiene styrene (ABS), a thermoplastic polymer that is widely used in electrical appliances. Thermomechanical Analyser (TMA) was used to characterize the physical changes of ABS at certain conditions by determining the glass transition, which is the reversible transition in amorphous material from solid state to molten state. The T_g of samples were recorded between 105°C - 110°C and were within the range of ABS transition temperature (104°C - 110°C) that matched with ASTM standard. The thermogravimetric analyser (TGA) measured the sample's weight loss at linear increase temperature programme. The changes in weight of samples at a range of 420–450 °C show the degradation value of styrene acrylonitrile (SAN) copolymer in single stage decomposition.

ABSTRAK

Kebakaran adalah fenomena di mana pembebasan cahaya dan haba akibat proses pembakaran yang boleh menyebabkan kerosakan, kehilangan nyawa, kehilangan harta benda dan kesengsaraan manusia. Kesimpulan dapat dicapai melalui penyiasatan yang dilakukan iaitu terdapat banyak perkara yang menyebabkan kejadian api, sebahagiannya dipengaruhi oleh kadar penggunaan bahan perencat api yang rendah dalam kehidupan kita. Perencat kebakaran biasanya digunakan sebagai komponen tambahan dalam objek untuk mencegah permulaan dan penyebaran api. Siasatan menunjukkan bahawa peratusan tertinggi kes kebakaran berlaku di kawasan kediaman, sebahagiannya disebabkan oleh kegagalan fungsi kotak fius (DB). Dalam kajian ini, beberapa kotak fius jenama tempatan telah dicirikan berdasarkan kandungan pembuatan dan kekuatan mekanikal bahan tersebut. Semua sampel telah dianalisis melalui ujian saringan menggunakan spektroskopi inframerah. Hasil kajian menunjukkan bahawa komposisi sampel adalah serupa dan konsisten antara satu sama lain dengan kehadiran peratusan akrilonitril butadiena stirena (ABS) yang tinggi, polimer termoplastik yang digunakan secara meluas dalam peralatan elektrik. Penganalisis Termomekanikal (TMA) telah digunakan untuk mencirikan perubahan fizikal ABS pada keadaan tertentu dengan menentukan peralihan kaca, yang merupakan peralihan berbalik dalam bahan amorfus daripada keadaan pepejal kepada keadaan lebur. Suhu peralihan kaca (T_g) sampel yang diuji adalah di antara 105°C - 110°C konsisten dalam julat suhu peralihan ABS (104°C - 110°C) juga sepadan dengan piawaian ASTM. Penganalisis Termogravimetri (TGA) juga telah digunakan untuk menentukan kadar kehilangan berat sampel pada program suhu kenaikan linear. Perubahan berat sampel pada suhu $420\text{-}450^\circ\text{C}$ menunjukkan penguraian kopolimer stirena akrilonitril (SAN) pada penguraian tahap tunggal.

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LIST OF SYMBOLS

Min	-	minute
mg	-	milligram
mL	-	millilitre
mm	-	millimetre
mN	-	milli newton
cm	-	centi metre
cm ⁻¹	-	per centimetre
°C	-	Degree Centigrade
µm	-	microcrometer

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In this world, fire can cause damage, loss of life, loss of belongings and human misery. Unfortunately, the significant of the destruction happened may come from deliberately ignited fires. Fire is the phenomenon in which the liberation of light and heat in consequence with the combustion process. A statistic beginning from January to June 2012 was performed by the Forensic Unit of Fire Brigade to determine the causes of fire based on certain cases. From the statistic, the causes of fire on buildings revealed that 2317 investigations had been done on different category of buildings and the cases were classified according to natural, accidental and arson cases (*Statistical Investigation of Fire*, 2012). The numbers of residential cases investigated were the highest. The investigation concluded that the causes of fire were mainly due to failure of electrical wiring. Apart from that, the overloaded electrical usage also could lead to fire resulting from ignition of sparks of electrical appliances. Fire outbreaks in our country have also increased, partly influenced by low usage of fire retardant materials in electrical equipment or parts.

Fire retardant materials are materials which have low flammability, good thermal insulation, anti-electrostatic and anti-bacterial properties (Kozlowski *et al.*, 2010). Flame retardants are components which can create barrier towards fire and these substances usually been added to products to increase their resistance towards ignition, slow down the flame spread, suppress smoke and prevent polymers from melting. Some examples of flame retardant products are home furniture, paints on

walls, fibres and electrical appliances. Many electrical appliances are commonly constructed using plastic solid case to protect the interior part and act as electrical insulator. These plastics are made up of polymers, such as acrylonitrile butadiene styrene (ABS). Any product manufactured should be added with flame retardant compounds for safety precautions. Flame retardant agents such as brominated and chloride types, phosphorus containing, halogen containing, metallic oxides and silicon containing were the most viable chemicals added to plastics in order to increase the durability towards fire. Didane *et al.*, (2012) reported that halogen-containing chemicals that were used as fire retardant products need to be replaced by phosphorus chemicals due to environmental concern, carcinogenic effects and high toxicity. Although the chemical used was compatible in resisting of and anti-flammable, its impact and effect towards human and environment should be a concern to everyone.

Flame retardant materials can be analysed through several methods using instrumental analysis such as pyrolysis Gas Chromatography-Mass Spectrometry, Chemical Ionization (CI), Gas Chromatography Flame Ionization Detection (GC-FID) and also Scanning Electron Microscopy- Energy Dispersive X-ray spectroscopy (SEM-EDX). Apart from that, the non-instrumental methods in analysing flame retardant materials include the detection of the amount of smoke emission, the thermal analysis properties of materials by using thermogravimetric analyser (TGA) and thermomechanical analyser (TMA). This instrument is the most suitable method in analysing organic products from flame retardant polymers and analysing the thermal degradation products of polymers (Dimitrov *et al.*, 2008). This method also is a well-established technique because it does not require any sample preparation and only use in minute amount for analysis. The TMA and TGA results will show the mechanical and dimensional change of materials at certain temperature conditions and also provide information about the strength and quality of materials.

This study is more concerned and focused on the analysis of flame retardants on distribution box solid cover. The goal of this project is to determine whether flame retardants were used in the manufacture of solid covers on distribution boxes. The durability and quality of materials from different brands are also determined by burning under constant conditions. Apart from that, analysis on mechanical structure and dimensional strength of materials is assessed by using TMA and TGA instrument.

The significance of this study is to investigate and determine the best distribution boxes available in our local market with respect to its resistance to fire. The analysis also could provide information which can be used as reference for the manufacturers in designing DB according to the specified characteristics as well as to create awareness for consumer in ensuring the safety of electrical appliances used.

1.2 Problem Statement

Many accidental fire cases are mainly caused by overloaded usage of electricity. The power source of electricity is controlled by the distribution box located in our houses. The distribution box controls the overflow of electricity and prevents any overloaded usage of electric. The over usage of electrical sources in the house can ignite sparks and eventually lead to starting of fire in the distribution box. Although the distribution box is covered with a solid case, some of the materials are not manufactured with flame retardant compounds and low resistance towards fire which caused spreading of fire to other objects near them. Also, some contractors tend to use a cheaper distribution boxes neglecting the safety aspects of the materials. In this project, different brands of distribution boxes commonly used in residences and factories were analysed using TGA and TMA to determine which DB is manufactured at the highest standard.

1.3 Objectives

The objectives for the project are:

- i. To investigate and determine whether the distribution boxes (DB) are manufactured according to standards.
- ii. To determine the physical changes of material using TMA and chemical dimensional change of materials using TGA.
- iii. To observe and compare the durability of materials burnt at constant conditions.

1.4 Significance of Research

The significance of this study is to provide information and documentations for the organization that give authorization to all electrical appliances manufactured such as Standards and Industrial Research Institute of Malaysia (SIRIM) and *Jabatan Bekalan Elektrik dan Gas Malaysia*. Furthermore the findings in this study could create awareness among consumers and contractors on the uses of flame retarding distribution boxes in residences and factories. Additionally, we could also identify and determine whether the materials used are made up of flame retardants and compare its durability towards fire in terms of its mechanical structure and strength.

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