THE INVESTIGATIO ROM DIFFERENT

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ABSTRACT

Fire is either man-made or natural. Sometimes it is started on purpose and other times it is an accident. Fire has a purpose, but comes with risks. This study was purposely conducted to identify the differences of fire growth pattern from different combustible materials, present and evaluate the temperature data obtained from the early fire growth stage to the decay stage of each combustible materials and also to identify which type of materials is the highly combustable materials. Each type of materials have its own fire growth pattern. The materials used for this research are the solid state of matter which consists of plastics, papers, woods and the combination of all the solid materials. The method have been used for the study is using fire simulation in the Fire Detection and Supression Simulator (Comprehensive Instrumented Type), Model FDSS-CI which is made of high quality 3 inter-connected chamber and integrated with Thermocouple, Smoke Detector and Control Room . The data was analyse using the Central Fire Detection and Execution System Software (C-FIDES). The finding of this study shows that the mixture of solid that consist of paper, wood and plastic is the most highly combustible materials followed by paper, wood and lastly plastic materials. Besides that, solid mixture combustion shows the highest reading during the fully developed stage which is 138°C followed by paper, wood and plastic. The most short time taken for each combustible materials to achieve rapid growth stage is solid mixture within first 2 minute and followed by paper, wood and plastic. Solid mixture that consist of paper, wood and plastic more easy to ignite followed by paper, wood and plastic. The most rapidly undergo decay stage is paper which is start to decay in the tenth minute followed by solid mixture, wood and plastic. There are several recommendations that can be suggest for the future study. The future study may compare the combustion of wood with coating and wood without coating. Other than that, used materials with different state of matter such as liquid and gaseous and lastly, researcher do combustion in the real home to get the real situation and prediction for fire occurence.

ABSTRAK

Api terhasil daripada kegiatan manusia atau semula jadi. Adakalanya kehadiran api disengajakan bagi fungsi-fungsi tertentu dan ada masanya ia adalah kemalangan. Api bukan sesuatu yang memudaratkan, tetapi kehadirannya akan mendatang risiko. Kajian ini dilakukan untuk mengenal pasti perbezaan corak pertumbuhan api dari pelbagai jenis bahan yang mudah terbakar, menunjukkan dan menilai data suhu yang diperolehi dari peringkat awal pertumbuhan api ke peringkat pereputan setiap bahan dan juga untuk mengenal pasti jenis bahan yang paling mudah terbakar. Setiap jenis bahan mempunyai corak pertumbuhan api yang berbeza. Bahan-bahan yang digunakan untuk kajian ini adalah terdiri daripada bahan pepejal seperti plastik, kertas, kayu dan kombinasi semua bahan-bahan pepejal tersebut. Kaedah yang telah digunakan untuk kajian ini ialah dengan menggunakan simulasi kebakaran di Pengesanan Kebakaran dan Penggantian Simulator (Teralat Jenis Komprehensif), Model FDSS-CI yang diperbuat daripada 3 ruangang yang saling bersambung dan bersepadu dengan pengganding suhu, alat pengesan asap dan bilik kawalan. Data ini dianalisis menggunakan Perisian Pengesanan Kebakaran Tengah dan Sistem Pelaksanaan (C-FIDES). Hasil kajian ini menunjukkan bahawa campuran pepejal yang terdiri daripada kertas, kayu dan plastik adalah bahan yang paling mudah terbakar diikuti oleh kertas, kayu dan bahan-bahan plastik. Selain itu, pembakaran campuran pepejal menunjukkan bacaan tertinggi pada peringkat maju dengan bacaan suhu 138°C diikuti oleh kertas, kayu dan plastik. Masa yang paling pendek yang diambil bagi setiap bahan untuk mencapai tahap pertumbuhan yang pesat adalah campuran pepejal dalam 2 minit pertama dan diikuti oleh kertas, kayu dan plastik. Campuran pepejal yang terdiri daripada kertas, kayu dan plastik lebih mudah untuk menyalakan diikuti oleh kertas, kayu dan plastik. Yang paling pesat menjalani peringkat pereputan adalah kertas yang mula reput pada minit kesepuluh diikuti dengan campuran pepejal, kayu dan plastik. Terdapat beberapa cadangan untuk penambahbaikan untuk kajian masa akan datang. Kajian seterusnya boleh membandingkan pembakaran kayu tanpa salutan dan kayu dengan bahan salutan. Selain itu, bahan-bahan yang digunakan dipelbagaikan seperti menggunakan cecair dan gas dan akhir sekali, penyelidik melakukan pembakaran di rumah yang sebenar untuk mendapatkan keadaan sebenar dan ramalan yang tepat sekiranya berlakunya kebakaran.

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LIST OF ABBREVIATIONS

CTIF	International Technical Committee for the Prevention and Extinction of Fire
C-FIDES	Central Fire Detection and Execution System Software
CO_2	Carbon Dioxide
DoH	Department of Health
LCD	Liquid-Crystal Display
MODEL FDSS-CI	Fire Detection and Supression Simulator (Comprehensive Instrumented Type)
NFPA 921	National Fire Protection Association
NIST	National Institute of Standards and Technology
PAHs	Polycyclic aromatic hydrocarbons
PPE	Personnel Protective Equipment
SOP	Standard Operating Procedure
TIC	Thermal imaging camera

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter discuss the background of study, problem statement, research objectives, research questions, scope of study, significance of study, and lastly for this chapter is the operational definition of the study.

1.2 BACKGROUND OF STUDY

Fire actually is the common element among us which is very crucial for us because it is always exist in our daily life. The occurences of fire is an unavoidable but we as human need to learn how to reduce the potential of fire occurences. Normally, the fire form can result in conflagration which is highly potential in physical damage through the burning. Humans began to master fire some one million years ago, first by simply controlling and guiding natural fires, then by harnessing and carrying these fires, and by discovering how to light their own fires (Stewart 1956; Sauer 1975; Schiile 1990). They observed that the game they hunted congregated on the new flush of grass after lightning-strike fires, and mimicked this process.

Ever since, throughout the world and throughout history, humans have relied on fire as a simple, effective, and easy tool to manage their environment (Thomas 1956; Pyne 1995). Aboriginal Australians burned to control habitats for hunting and gathering (Lewis 1989; Braithwaite 1991), English aristocrats burned moorlands regularly to manage grouse habitat (Maltby et al. 1990), and Native Americans burned the Great

Plains to improve ungulate grazing.These practices continue today, as ranchers in Kansas and South Africa bum to manage their rangelands, as foresters in the southern U.S. or in India bum to encourage certain forest habitats, or as Brazilian peasants bum to improve pasture and prepare crop fields (Mistry 1998).

As the world's people became increasingly mobile, they encountered the fire habits of other peoples. Ancient sailors from Carthage skirting the West African coast saw the terrific annual pasture-renewal fires of the Sahel (Bartlett 1956), while early colonists in the eastern United States watched as the Native Americans burned the forests, creating open woodlands and vegetation mosaics (Sauer 1975; Cronon 1983; Denevan 1992). Increasingly, when one culture met another, people commented on the fire habits of the others. Often, notions about fire were different, this is especially true as the industrial cultures of Europe set out to conquer the agricultural and pastoral people elsewhere in the world (Pyne 1997). The Europeans at least the intellectual, urban, ruling class generally saw the fires as negative and destructive.

According to the Centre of Fire Statistics of CTIF, at the beginning of the 21th century, the population of the Earth is 6300 000 000 who annually experience a reported 7 000 000 to 8 000 000 fires with 70 000 to 80 000 fire deaths and 500 000 to 800 000 fire injuries. At the beginning of the 21th century, the population of the Europe is 700 000 000 who annually experience a reported 2 000 000 to 2 500 000 fires with 20 000 to 25 000 fire deaths and 250 000 to 500 000 fire injuries. Based on the Council of Canadian Fire Marshals and Fire Commissioners (2001), in the year 2001, 55 323 fires were reported in Canada, resulting in 338 deaths, 2310 fire related injuries and over a billion dollars in property loss. From those fires reported, 39% occurred in residential settings and accounted for 81% of all fire fatalities.

In Malaysia fire losses run into millions of ringgit annually. Fire has claimed many lives, caused injuries and extensive damage to properties and the environment. Between year 1985 until 1997, the Department of Fire and Rescue Malaysia stated that the number of false fire alarms is 13249, the number of fire breakouts is 163153, the number of deaths is 729, the number of injuries is 1045 and the estimated loss is 3 728 987 millions Ringgit Malaysia. The occurrence of residential fires has been greatly reduced (roughly 50%) in the last 20 years.

This is mainly due to increased public awareness of fire prevention strategies, improved building techniques, faster response of emergency services and implementation of stricter fire codes (Forintek Canada Corp.,2002). This progress has been abetted by increased knowledge of fire and smoke behaviour in structures due to ongoing fire research activities, which include a combination of large-scale fire testing, laboratory and field-testing and computer modelling. The wind generation system will be used in future research to study wind pressure distribution on the burn structure and how this affects fire behaviour and heat and smoke movement inside the structure (Weisinger *et al.*,2004). The ability to understand and quantify the thermal development of compartment (room) fires is of great significance to the fire protection industry. Knowledge of compartment fire temperatures allows for prediction of hazardous conditions, property and structural damage, ignition of objects, changes in burning rate and the onset of flashover (Walton *et al.*,2002).

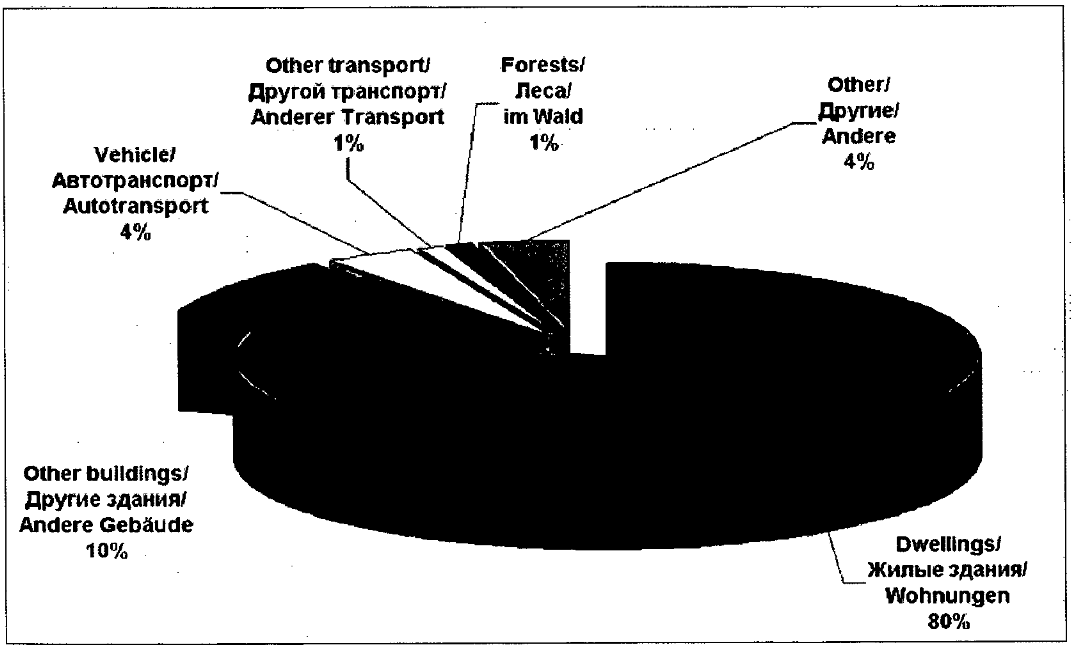

Figure 1.1 General Distribution of Fire Deaths by Fire Origin in Countries of the World

Source : The Centre of Fire Statistics of CTIF

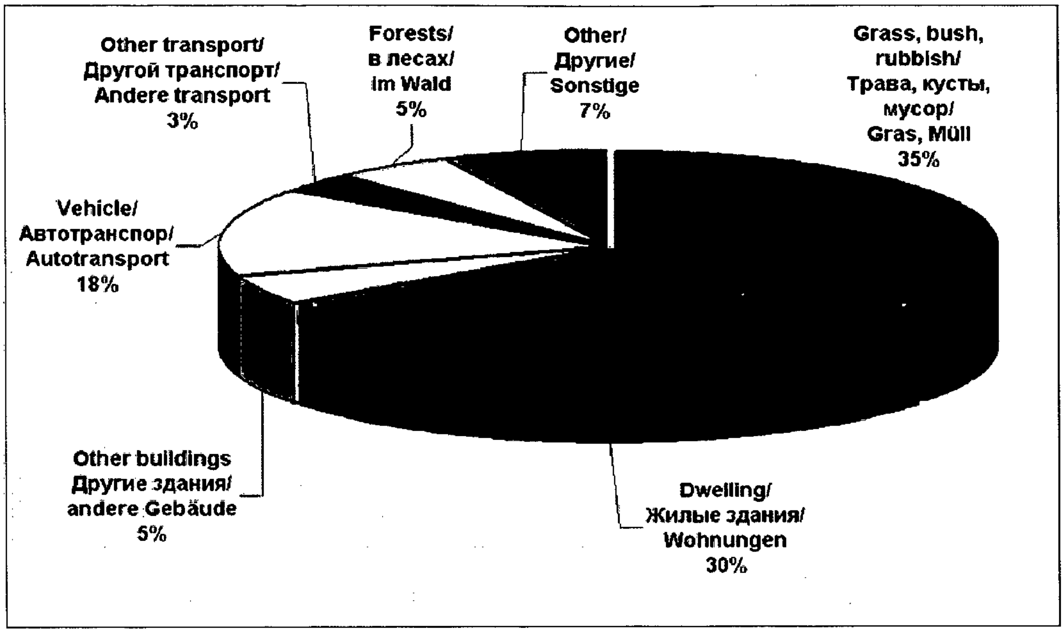

Figure 1.2 General Distribution of Fires by Fire Origin in Countries of the World

Source : The Centre of Fire Statistics of CTIF

1.3 PROBLEM STATEMENT

Lately, fire problems has become an important and urgent issues and we need to foster public awareness among people. The destruction of property and loss of life due to fire has become matters of public concern. This is because the flame can cause a lot of damage to people.

Fire in the building is a great danger to life, damage property and loss of life. Therefore, the fire in Malaysia has become a matter of public concern. The hazard of fire is often defined as its potential to do harm to life and property. The vision of both victims and fire fighters is effected during fire, because of smoke most people get in such situation.

During fire, the formation of CO is rampant as O_2 disoriented. It is the smoke and fumes in the gas that kill people, not the flame. CO is harmful and toxic. It is odourless and invisible. It can numb human's brain, and kill them. Exposure to fire works for a long time in the night can rob life and properties.

In order to prevent fire occurrences and the loss of lives, injuries and extensive damage to properties, it is important to educate the public. Thus, through this study, we intended to identify the fire growth graph according to different combustible materials and the graph can help in identifying the most dangerous part in fire development. So that, people are able to predict the appropriate time in save themself from any fire occurence. This study attempts to help people and give some education information to reduce the occurrences of fire and to become more aware of fire hazards surround them.

1.4 RESEARCH OBJECTIVE

The objectives of this study is:

1.4.1 To identify the differences of fire growth pattern from the different combustible materials.

1.4.2 To present and evaluate the temperature data obtained from the early fire growth stage to the decay stage of each combustible materials.

1.4.3 To identify which type of materials is the highly combustable materials.

1.5 RESEARCH QUESTION

From the study there are three research questions which are :

1.5.1 What is the differences of fire growth pattern from the different combustible materials?

1.5.2 What is the temperature data obtained from the early fire growth stage to the decay stage of each combustible materials?

1.5.3 Which type of materials is highly combustable?

1.6 SCOPE OF STUDY

In executing the research, the scope limitations need to be considered to prevent a very wide scope of research and an unfocused study. This research presents a study of the development of fire growth pattern using different combustible materials from the early fire growth stage to the decay stage of each burning. This research was carried out based on burning of different type of materials in fire chamber which is located in Universiti Malaysia Pahang, Gambang Campus. This study focused on the differences of each fire growth pattern and the temperature data obtained during burning process of each materials from early stage to the decay stage. Besides, this research also present which category of materials is the highly combustIble materials. The materials for combustions are choose based on the solid state of matter. The materials that will be used are plastic materials, wood, paper, and combination of all the things which are normally highly contributing in fire occurence.

1.7 SIGNIFICANCE OF STUDY

This study was purposely conducted to identify the differences of fire growth pattern from different combustible materials. Through this study, people can be educate and aware that each type of materials has different fire growth pattern. Thus, it give them awareness related to danger or fires from each stage. So that, they can protect themselves or improve their safety at home or on their workplace from fire hazard.

Besides that, this study used to identify which category of materials is the highly combustible materials. So, this study is very helpful for providing fire learning and fire prevention guidelines to the public about which material is the highly combustible materials and lower combustible materials. So, people also can take correct precaution step if fire occurs according to the type of materials. Besides, people also can predict the time taken to the fire to reach the most dangerous phase and they can save their life in that time.

1.8 OPERATIONAL DEFINITION

Induction Phase

Pre Fire Stage - At the pre fire stage, the existence of fire can be extinguished or can be control at any time with proper supervision. The tecnique of intervention can be trough education and environmental monitoring.

Incipient Fire Stage - At the incipient fire stage, a fire in its beginning stage. The heat, oxygen and a fuel source combine and have a chemical reaction resulting in fire. This is also known as "ignition" and is usually represented by a very small fire which often (and hopefully) goes out on its own, before the following stages are reached. Incipient stage fires can be controlled with portable fire extinguishers and small hose systems.

Rapid Growth Phase

Fire Threat Stage - Fire threat stage is the starting point where fire can be out of control or the best time to react on total extinguishing of fire. This could be a vital point to be alert about the danger of fire and once the fire becomes well established locally it will continue to grow as long as fuel and oxygen are available.

Fire Growth Stage - Fire growth stage is where the structures fire load and oxygen are used as fuel for the fire. There are numerous factors affecting the growth stage including where the fire started, what combustibles are near it, ceiling height and the potential for "thermal layering". It is during this shortest of the 4 stages when a deadly "flashover" can occur; potentially trapping, injuring or killing firefighters.

Fully Developed Phase

Fire Fully Developed Stage - Fire fully developed stage is when the growth stage has reached its max and all combustible materials have been ignited, a fire is considered fully developed. This is the hottest phase of a fire and the most dangerous for anybody trapped within.

Decay Phase

Fire Decay Stage - This phase consists of fire decay stage and fire extiguished stage. Fire decay is usually the longest stage of a fire, the decay stage is characterized a significant decrease in oxygen or fuel, putting an end to the fire. Two common dangers during this stage are first – the existence of non-flaming combustibles, which can potentially start a new fire if not fully extinguished. Second, there is the danger of a backdraft when oxygen is reintroduced to a volatile, confined space

Fire Extinguished Stage - Fire extinguished stage is when the fire is fully end and after that, serious study which must be done in order to check whether if there is any defect on the structural and services and of course is there any facilities including loss of properties.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Based on the National Institute of Standards and Technology (NIST) , fire dynamics is the study of how chemistry, fire science, material science and the mechanical engineering disciplines of fluid mechanics and heat transfer interact to influence fire behavior. In other words, fire dynamics is the study of how fires start, spread and develop. Fire can be described in many ways. According to National Fire Protection Association (NFPA 921), fire is defined as "a rapid oxidation process, which is a chemical reaction resulting in the evolution of light and heat in varying intensities". According to Webster's Dictionary, fire is "an exothermic chemical reaction that emits heat and light". Fire can also be explained in terms of the Fire Tetrahedron which is a geometric representation of what is required for fire to exist, namely fuel, an oxidizing agent, heat, and an uninhibited chemical reaction.

Fire development is a function of many factors including fuel properties, fuel quantity, ventilation (natural or mechanical), compartment geometry (volume and ceiling height), location of fire, and ambient conditions (temperature, wind, etc). The Traditional Fire Development curve shows the time history of a fuel limited fire. In other words, the fire growth is not limited by a lack of oxygen. As more fuel becomes involved in the fire, the energy level continues to increase until all of the fuel available is burning (fully developed). Then as the fuel is burned away, the energy level begins to decay. The key is that oxygen is available to mix with the heated gases (fuel) to enable the completion of the fire triangle and the generation of energy.

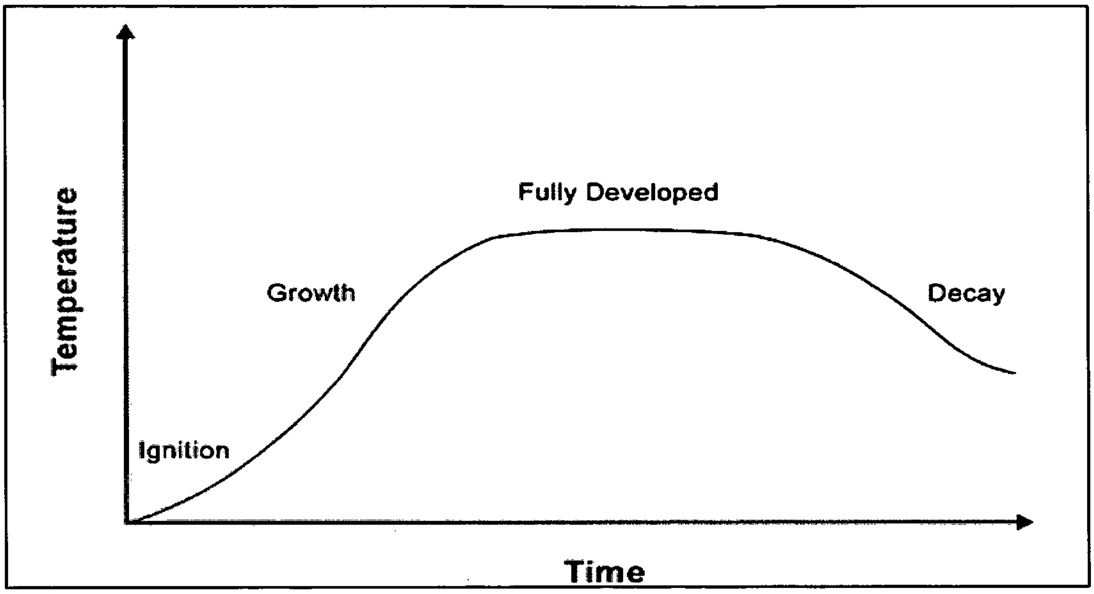

Figure 2.1 The Traditional Fire Development Curve

2.2 FIRE GROWTH GRAPH

According to Myburgh (2012), the transitional nature of fire in a building can be devided into 4 different phases. They start with induction or ignition phase which consist of pre fire and incipient fire stage, rapid growth phase which are consist of fire threat and fire growth stage, fully developed phase that consist of fire fully developed stage, and lastly decay phase that consist of fire decay and fire extinguished phase. Walton *et al.* (1995) list these fire growth stages as ignition, growth, flashover, fully developed and fire decay. International Fire Service Training Association (1998) stated that the first phase which is ignition is when the element of fire are meet together and materilas are starting to burn. The second phase is when the smoke is in smouldering that is when visible by-products are released or emitted. While for the third stage is about heating, glowing, and gaseous stage of fire. When comparison is make through all the phases, it is shows that the least productive time to start the fire extinguishing process would be in the fully developed phase. The growth of the fire depends on the availability of the elements of the fire triangle (Davis, 2000). When comparing these stages against a timeline and plotting physical intervention by fire fighters, it is evident that fire fighting will start, in a worse case scenario, during the fully developed phase of the fire.

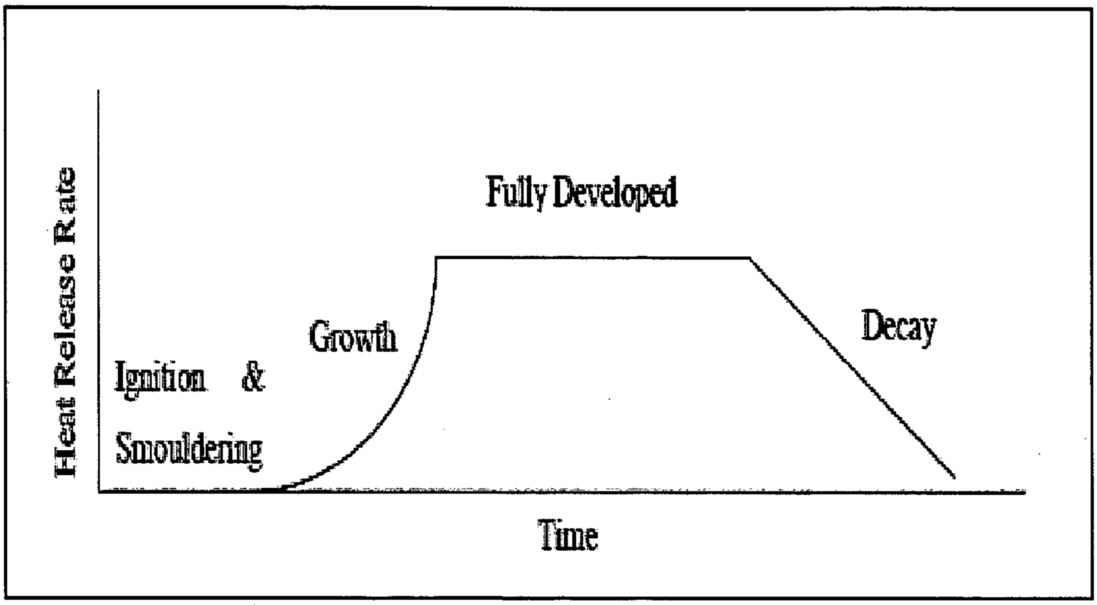

Figure 2.2 Typical Fire Progression

Source : Davis (2000)

According to Hartin (2008), the part of the process of reading the fire involves recognizing the stages of fire development that are involved. Remember that fire conditions can vary considerably throughout the building with one compartment containing a fully developed fire, an adjacent compartment in the growth stage, and still other compartments yet uninvolved. Recognizing the stages of fire development and likely progression through this process allows firefighters to predict what will happen next (if action is not taken), potential changes due to unplanned ventilation (such as failure of a window), and the likely effect of tactical action. Compartment fire development can be described as being comprised of four stages: incipient, growth, fully developed and decay. Flashover is not a stage of development, but simply a rapid transition between the growth and fully developed stages.

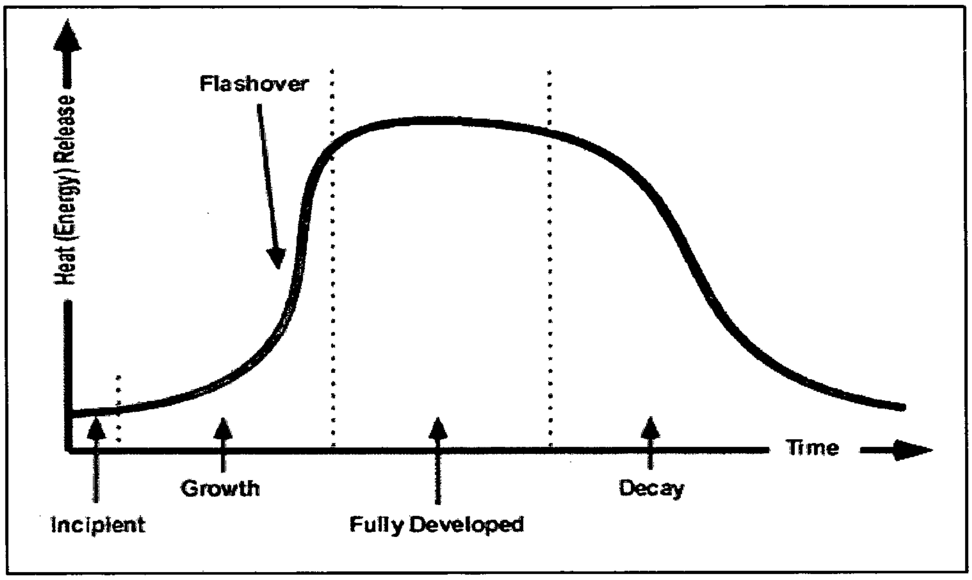

Figure 2.3 Fire Development in a Compartment
Source : Hartin (2008)

2.3 INDUCTION PHASE

Based on Karlsson et al (1999), ignition can be considered as a process that produces an exothermic reaction characterized by an increase in temperature greatly above the ambient. It can occur either by pilotedignition (by flaming match, spark, or other pilot source) or by spontaneous ignition (through accumulation of heat in the fuel). The accompanying combustion process can be either flaming combustion or smoldering combustion.

2.3.1 Pre Fire Stage

Fire is a process where oxidation takes place resulting in rapidly producing heat and light. Four basic elements are needed to ignite and sustain a fire; reducing agent, heat, self-sustaining chemical chain reaction and an oxidising agent (oxygen). These four components are called a fire tetrahedron. During the combustion process the fuel is being oxidised (burned). The energy component of the fire tetrahedron is heat and when heat comes into contact with fuel, it provides enough energy to ignite the fuel. This causes a continuous reaction where the ignition of vapours and gases, resulting from the burning of the fuel keeps the reaction going according to Hartin (2008). Karlsson et al (1999) also stated that after ignition and during the initial fire growth stage, the fire is said to be fuel-controlled, since, in the initial stages, there is sufficient oxygen available for combustion and the growth of the fire entirely depends on the characteristics of the fuel and its geometry.

2.3.2 Incipient Fire Stage

According to Ohlemiller (2002), incipient fire stage also known as smouldering, that can be describe as the thermal breakdown and the chemical of materials in a normal oxygen environment, but in the absence of flaming. Smouldering combustion progressess at a much slower rate that flaming combustion, most commonly involves a porous fuel materials and is sustained by the heat given off during oxidation at the fuel surface. Ohlemiller also stated that smoldering combustion may occur in the initial stage of a fire and can provide a pathway to flaming combustion from a heat source which is insufficient to directly produce a flame. Smoldering is a form of incomplete combustion due to the lower temperatures involved, and therefore may yield a much greater quantity of toxic products than flaming combustion based on Department of Health, DoH (1996).

A study by Artin (1998) into fire risks to historic religious buildings the risk of the incipients fire-pread as a process that may begin with a slow growth, smouldering process that may last a few minutes to several hours. The duration is dependent on several factors such as the type, its physical arrangement and available oxygen. This period is characterised by heat generation and an increasing production of smoke, which may be noticed as the first indication that incipient fire development is underway. At some point there may be enough heat to initiate the onset of open visible flames. At this stage, the fire dynamic changes from a relatively minor incipient development phase to a more serious event with rapid fire development. The life safety protection provided by sprinklers or heat detectors may be delayed for most all of the incipient stage of the fire spread due to insufficient temperature rise at the sprinkler or detector head until the fire size increases. On the other hand, smoke detectors or smoke alarm may give a significantly earlier warning of fire before the rapid growth phase commences which is stated by Collier (1996).

Based on Hartin (2008) study, going back to the basics of fire behavior, ignition requires heat, fuel, and oxygen. Once combustion begins, development of an incipient fire is largely dependent on the characteristics and configuration of the fuel involved (fuel controlled fire). Air in the compartment provides adequate oxygen to continue fire development. During this initial phase of fire development, radiant heat warms adjacent fuel and continues the process of pyrolysis. A plume of hot gases and flame rises from the fire and mixes with the cooler air within the room. This transfer of energy begins to increase the overall temperature in the room. As this plume reaches the ceiling, hot gases begin to spread horizontally across the ceiling. Transition beyond the incipient stage is difficult to define in precise terms. However, as flames near the ceiling, the layer of hot gases becomes more clearly defined and increases in volume, the fire has moved beyond its incipient phase and given adequate oxygen will continue to grow more quickly.