

PREDICTION OF TEMPERATURE DISTRIBUTION DURING FLASHOVER  
CAUSED BY BACKDRAFT FIRE

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Report submitted in partial fulfillment of the requirements for the award of the degree  
of Bachelor of Occupational Safety and Health

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**SUPERVISOR'S DECLARATION**

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for award of the degree of Bachelor of Occupational Safety and Health.

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**STUDENT'S DECLARATION**

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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**Dedicated to my beloved family, supervisor, and friends.**

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**LIST OF SYMBOLS**

% Percentage

**LISTS OF ABBREVIATIONS**

CO	Carbon Monoxide
COHb	Carboxyhaemoglobin
HCN	Hydrogen Cyanide
HRR	Heat Release Rate
IFSTA	International Fire Service Training Association
ISO	International Organization for Standardization
LPG	Liquefied Petroleum Gas
M CH <sub>4</sub>	Total fuel mass flows into the compartment
M total	Total gas mass in the compartment
NFPA	National Fire Protection Association
LEL/LFL	Lower Explosive Limit or Flammable Limit
UEL/UFL	Upper Explosive Limit or Upper Flammable Limit
UL	Underwriters Laboratory
Y <sub>f</sub>	Mass fraction of unburned fuel
Y CO <sub>2</sub>	Mass fraction of carbon dioxide
Y CO	Mass fraction of carbon monoxide

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## ABSTRACT

The effect of ventilation on fire development is one of the most important phenomena to understand modern compartment fire behavior, causing fire behavior shifted from traditional fire behavior to modern fire behavior. Ventilation controls the growth of the fire process and this creates problem in describing fire activities in some ways posing potential hazards to firefighters during fire ground. Backdraft is one of the most deadly fire phenomena in a ventilation limiting building. Backdraft develops from an oxygen starved fire and yet, continue to produce a fuel-rich environment in the compartment. If an opening is made and fresh air is allow to enter the compartment, high temperature hot gases remained in the compartment will rapidly burn once in contact with the incoming fresh air, resulting a fireball associated with a blast wave. Identifying factors that contribute to this extreme fire phenomenon is important. In this paper, a meta analysis of results from related multiple studies to understand and to analyze the meaning of the results obtained of a collection of studies The effect of varying the ventilation by means of changing different geometries of the openings, the location of ignition source, and the mass fraction of unburned gas are discussed. . The results acquired from the meta analysis have shown that the smaller the change of the geometry of the opening, the further the location of ignition source from the opening of the compartment and when the mass fraction of unburned fuel remained in the compartment exceeds a certain critical value, the easier for the backdraft to occur. In addition, the analysis also show that the key parameter determining the backdraft occurrence is the mass fraction of unburned fuel, followed by the ventilation condition.

## ABSTRAK

Kesan pengudaraan kepada perkembangan pembakaran adalah salah satu fenomena yang penting untuk memahami tingkah laku bangunan api moden yang menyebabkan tingkah laku api beralih daripada tradisional kepada moden. Pengudaraan mengawal pertumbuhan proses api dan ini menimbulkan masalah dalam menerangkan aktiviti api yang berpotensi untuk membahayakan anggota bomba semasa aktiviti pemadaman api. Backdraft adalah salah satu daripada api yang paling maut untuk bangunan yang mengalami kekurangan oksigen. Backdraft berkembang daripada api yang mengalami kebuluran oksigen dan, terus menghasilkan persekitaran yang kaya dengan bahan api di dalam ruang bangunan. Jika pembukaan dibuat dan oksigen memasuki ruang bangunan, gas yang bersuhu tinggi di dalam ruang tersebut akan membakar dengan pantas selepas berhubungan dengan udara yang mengalir masuk, daripada inilah terhasilnya bola api diikuti oleh letupan. Adalah penting untuk mengenal pasti faktor-faktor yang menyumbang kepada fenomena ini. Dalam penyelidikan ini, satu meta-analisis dijalankan terhadap keputusan dari pelbagai kajian yang berkaitan untuk memahami dan menganalisis makna sebalik keputusan yang didapati daripada koleksi kajian daripada aspek-aspek berikut: perubahan dalam pengudaraan dengan menukarkan geometri bukaan, lokasi sumber pencucuhan, dan pecahan jisim gas yang tinggal sebagai produk pembakaran telah dibincangkan. Keputusan yang diperolehi daripada meta-analisis telah menunjukkan bahawa perubahan geometri yang lebih kecil, lokasi sumber pencucuhan yang jauh daripada bukaan dan pecahan jisim bahan api yang tinggal sebagai produk pembakaran melebihi nilai kritikal tertentu, lebih mudah untuk Backdraft berlaku. Di samping itu, analisis juga menunjukkan bahawa parameter utama yang menentukan Backdraft adalah pecahan jisim bahan api yang tinggal sebagai produk pembakaran, dan ini diikuti oleh keadaan pengudaraan dalam ruang bangunan tersebut.

## **CHAPTER 1**

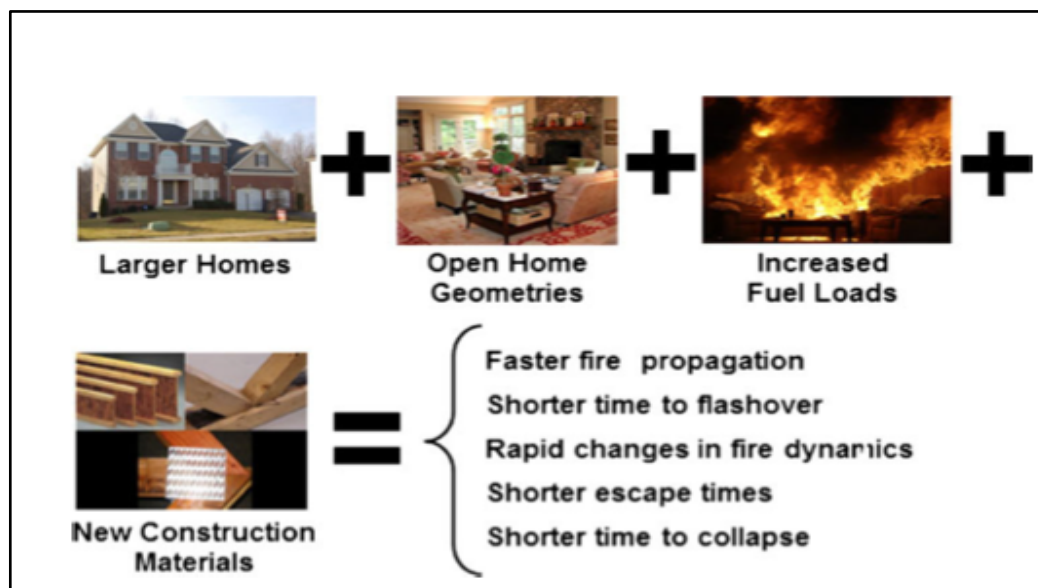
### **INTRODUCTION**

#### **1.1 INTRODUCTION**

This chapter dealt with the general idea of this study in conjunction with the problem statements, objectives, significance of study, scope of study and the limitation of study.

#### **1.2 BACKGROUND OF STUDY**

The behavior of compartment fire today has changed steadily over the past several decades from a traditional fire behavior to a modern fire behavior, and they hold significant challenges for firefighters safety. As a consequence of the changes to the modern fire environment, which can speed up the stages of fire development and creating a high probability for the occurrence of ventilation-limited fire, causing conventional firefighting methods are not effective enough to protect the firefighters. These changes of fire environment include larger homes, different home geometries, increased synthetic fuel loads, and changing of construction materials. Several experiments were conducted to compare the effects of fuel loads changing in residential houses and the results revealed that flashover times of less than five minutes was needed when they used to be on the order of 30 minutes (Kerber, 2012). Owing to these changes, fire behavior should be understood thoroughly as to improve our situational awareness, especially for firefighters to make a correct decision on the fire ground.



**Figure 1.1:** Modern Fire Formula

Source: Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes. [Image]. (2012).

While seeming to be so fundamental, basic fire behavior is the starting point for understanding the modern fire development. The definition for and the differences between flashover and backdraft are important in development of fire control operations. A backdraft is defined as a smoke explosion that can occur when additional air is introduced into an oxygen-exhausted fire environment and heated gases enter their flammable range, igniting with explosive force. In contrary, flashover is known as the sudden involvement of a compartment caused by thermal radiation feedback (Flatley, 2005).

How does a backdraft differ from a flashover? The main difference between backdraft and flashover is that backdraft is an explosive and an “air-driven” event while flashover is not and it is a “heat-driven” event. The shock waves during a backdraft will break the confining structure and part of the structure may collapse. Sudden increased in ventilation triggers a backdraft to occur when an opening is made. Meanwhile, flashover is a rapid-fire development but it stops short of an explosion’s speed of chemical reaction. The radiated-heat back into a burning compartment will raise the gases and the content in the compartment to the auto-ignition temperature, triggering a

flashover. Notable changes occur when the fire transits from fuel controlled to ventilation controlled, and these changes have a great impact of firefighters tactics based on the stage of fire development. The temperature curve for flashover, which has only one temperature peak, on the other hand, temperature in backdraft may have more than one peak value (Zhang et. al., 2014).

Backdraft and flashover need to be understood, as several factors are to increase their likelihood of occurrence. Both extreme fire behaviors are equally dynamic and deadly. Recognizing the signs and being able to develop tactical strategies will give a chance for survival.

### **1.3 PROBLEM STATEMENT**

In the field of fire safety, lack of available and organized scientific information and lack of sustained research in fire contributed to the lack of awareness and knowledge regarding fire behavior and its causation factors among both firefighters and civilians. The problem in describing fire activities in some ways presents potential hazards to firefighters, specifically, during fire ground. This failure of recognizing fire activities has lead to the high percentage of firefighters injuries and fatalities, mostly resulting from extreme fire behavior (flashover and backdraft), in which the conventional methods are not effective enough to suppress the fire and protect the firefighters from performing their tasks. However, predictability of extreme fire behavior is difficult because the occurrence of such fires is dependent, to some extent, on their environment.

Lack of predictability, high spread rates, high fire intensities and area-wide spot ignitions of extreme fire behavior reduce fire suppression effectiveness and threaten firefighters safety. Flashover and backdraft are known to be the leading cause that contributes to the injuries or fatal of firefighters (Table 1.1). The tragic loss of firefighters and civilians is due to the lacking of understanding of fire behavior in the compartment fires resulting from the dynamic changes in fire environment. NFPA reported that from 2010 to 2012, United State fire departments recorded an average of 31.2% of firefighters injuries was due to the fire development.

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