FIRE INVESTIGATION

A New Concept

CHARLES B. HOBSON

FIRE INVESTIGATION

ABOUT THE AUTHOR

Charles B. Hobson has over twenty years of experience in private fire investigation undertaking investigations for insurance firms and attorneys and is a former Air Force fire fighter and station fire chief. He is a member of the National Association of Fire Investigators and is a board-certified Fire and Explosion Investigator and Fire Investigator Instructor. He is also a certified Fire Investigator of the Illinois Chapter of the International Association of Arson Investigators and the Missouri State Fire Marshal's Office. Currently, he is President and Senior Fire Consultant for CH & Associates, Inc., a fire and legal investigations firm in Collinsville, Illinois.

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By

CHARLES B. HOBSON
C H & Associates, Inc.
Collinsville, Illinois

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PREFACE

Fire investigation has been around almost since the beginning of time, at least ever since man discovered fire. Man has several reasons for wanting to find out how and why a fire started. The primary reason that is expressed by those people concerned with the engineering aspect of fires is threefold: to save lives, reduce property damage, and to prevent them from happening again. On the other hand, the investigator will say that the primary reason is to prove arson and to put the guilty party in jail. Taken all together, we can say that the reasons for wanting to find out the how and why of fires is to save lives, reduce property damage and obtain convictions where arson and fraud are involved.

For years, fire investigation has been considered an art practiced by those who would determine the cause of a fire based on teachings which I will call "old firemans' tales," which in reality is actually just "hand-me-down" information with no basis for justification in actual scientific teachings. However, there is hope. Some investigators have been borrowing from the engineers to understand the scientific basis of fire dynamics and the development of fire. Many of the books on fire investigation have been written by these so-called "experts" from the old firemens' school of thought, and these books only serve to perpetuate the misconceptions that some are starting to realize exist.

This book, I hope, will serve as a new approach to fire investigation. It investigates and attempts to explain the scientific principles of fire dynamics and how to apply these to practical fire investigation.

The discipline of science follows a proven six-step procedure to solve a problem: (1) develop the problem and its parameters; (2) gather all of the available data; (3) analyze this data; (4) develop a hypothesis; (5) prove or disprove the hypothesis; and (6) arrive at a conclusion. In fire investigation, the problem is already established: to determine the origin and cause of a fire.

This book stresses the need to gather all of the available data, and we go into detail on how to obtain this information through step-by-step procedures in processing the fire scene and identifying and gathering the data. Unfortunately, too many arson investigators tend to gather only that data which supports a conclusion that they may have in their minds. Over and over I stress the importance of maintaining an open mind when it comes to gathering data and determining conclusions. Later, I will show you how to analyze the data and develop a hypothesis as to how the fire developed, which is covered in depth.

Part II of the book will help you discover motives for arson-related fires and show you where to look for insurance fraud and arson-for-profit fires, including fires started to cover business losses.

C.B.H.

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I would also like to thank Bill Buxton, because this book probably wouldn't have been written if he, now my competitor, hadn't started me in fire investigation in the first place.

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Chapter 1

INTRODUCTION

Fire and arson investigation is, in a sense, a relatively new field. Although fire fighters have for years been determining the probable cause of a fire, it was not until recently that the determinations have started to have some actual basis in fact. Science has now entered the picture. While there are a number of universities and colleges which offer courses helpful to the fire investigator, such as courses in fire behavior, fire science, fire fighting and fire protection engineering, there are only three which offer courses leading to a four-year degree in fire investigation. There is very little formal education programs available to the general population. The National Fire Academy and the Bureau of Alcohol, Tobacco and Firearms offer formal training for fire and law enforcement personnel. On-the-job training is just about as scarce. This is provided by some fire and police departments for their own people. Several insurance companies have established their own special investigation units. So, for someone wanting to learn fire investigation, this leaves only self-help training. Here again, we have several problems. There are not really that many textbooks on fire investigation available, and some experts are saying that these are full of errors.

Determining the origin and cause of a fire can be compared to solving a jigsaw puzzle. There is one major difference, however: in working the jigsaw puzzle you can be fairly certain that all the pieces are there to start with. In working a fire scene, you never know if you have all the pieces to start with or not. First you have to find them, identify them, and then fit them into the proper sequence and perspective to determine the series of events leading up to the fire.

Currently, fire investigation is an art and has not quite reached the stage of being a science. It is practiced by those who would deduce what happened and the series of events which lead up to the fire and the destruction of the structure involved.

Much of the knowledge possessed by those who practice the art is information that has been passed on from one investigator to another. It is something we have been told and accepted, with little if any of it based on scientific learning or on facts that can be proven. However, science is now lending a helping hand. It is now providing facts and knowledge based on provable and repeatable experiments. Unfortunately, this scientific approach is slow in being disseminated and even slower in being accepted. Too many people in the field are still more influenced by the "old firemens' tales" than by the newer information obtained from controlled scientific studies and tests.

Also, unfortunately, there are still a number of investigators who are totally arson oriented. That is, they approach a fire investigation with a predetermined probable cause of arson in mind. When they arrive at the fire scene, the majority of their efforts are aimed at proving arson rather than determining the true cause of the fire. This philosophy can only hinder a proper investigation, which when properly undertaken is tedious and time consuming. It leads to many incomplete investigations along with improper solutions. These in turn lead to costly legal problems for insurance companies and disastrous results for the innocent insureds.

What are some of the requirements and qualifications for a fire investigator? I feel that since during the determination of a fire cause you must deal with a number of disciplines, I feel you must be a fairly knowledgeable individual capable of dealing with physics, chemistry, electricity, gas and other sciences. The investigator should be inquisitive and have a natural curiosity and not be willing to accept just any answer. He should have the ability to analyze large quantities of information, and he should, above all, seek the truth, whether it serves his purpose or not. Fire investigation requires extensive examination of sometimes large piles of debris. The ability to lift heavy loads and be capable of physical exertion along with climbing ladders and stairs and sifting through piles of dirt is a necessary part of the job.

The next item we want to talk about is the equipment that a fire investigator will need as any everyday part of his job. First is that of clothing and safety equipment. As I have said and about which you should have no doubt, fire investigation is a filthy job, just plain dirty. So you will at least want a good pair of coveralls. Even in the summer, long sleeves are preferable for the protection they provide. You may also want a coat of the type known as a fireman's bunker coat. Next, you will need and should always wear at a fire scene a hard hat. Safety goggles are also to be considered a necessity. A dust mask also comes in handy. A good pair of gloves are also essential. You might want to think about two pairs—one leather and one heavy rubber. Good footwear is very important. You should obtain a good pair of boots with a steel shank and toes, at the very least. More desirable is a pair of fireman's hip boots. These provide protection to your shins and thighs when you fall through a floor, and no matter how careful you are you ultimately will do so.

Now that you are properly dressed for the fire scene you will need some tools to do your job. After the proper clothing, the most important item will be that of lighting equipment. The interior of a boarded-up fire scene can be totally dark. Just any old flashlight won't do. The ideal answer is a portable generator with flood lights. This can get expensive as well as cumbersome. In some instances, however, you may wish to rent one. If you don't have this, at least have several multi-cell lights available, and don't forget some extra batteries.

Now you have the job of cleaning out the fire scene. Probably the first item you will need is a shovel. I would recommend both a square-tip and a pointed-tip shovel. My own preference is for long handles, as it's easier on the back. Of course, short-handled ones are easier to transport. You should also consider a pick. A rake is essential. You will want to consider some of the smaller garden variety of trowels and rakes. These are useful for clearing away the final layer without destroying evidence. Now you will need a broom along with several paintbrushes. A squeegee, mop and bucket will also come in handly. In the process of clearing the debris, you may encounter the need for a saw. A good buck or crosscut saw comes in handy. If you have a portable generator, you might consider an electric chain saw. Don't even consider using a gas-powered one. If you don't find some accelerants, this might mess your case up good. Talking about saws, don't forget a good hacksaw along with several extra blades. Pry bars, hammers and even a small-handled axe will come in handy. When you get around to looking at the furnace or fuse box, you will need screwdrivers, pliers, wrenches and wire cutters. I also recommend a middle size bolt cutter.

You will need several tapes for measuring. I use both a 100-foot and a 30-foot tape. You need a clipboard to draw on and a pad of paper. Some prefer graph paper. Don't forget something to draw and write with. I prefer a pencil because I do make a mistake now and then. While on this subject, let's not forget probably the most important item: a notebook.

If you find evidence, you may need a pair of tweezers to pick up things. You will also need something to put the evidence in. Use clean paint cans for any evidence which may have traces of an accelerant. You can get these from the local paint store in several sizes. I use mostly pint and quart sizes. You can use plastic and paper bags for some of the evidence. You will also need masking tape to seal the cans and something to mark them with.

One way to learn about fire investigation is to read. Also, since many disciplines are involved, you will need to have some idea where you can go for reference. As I said before, a number of experts feel that the current fire books contain errors. I quite agree. However, I have listed a number of current textbooks and you will have to make up your own mind. A number of the publications that I have listed can be obtained through your local library and through inter-library loans:

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Chapter 2

PRINCIPLES OF COMBUSTION

Just what is combustion? You have probably heard the definition: *combustion is rapid oxidation accompanied by heat and light.*

Basically, combustion is the chemical process of oxidation. In oxidation, substances combine with oxygen. This combination causes a change in their chemical constituents or components. In this process, they become new chemical compounds with different properties and characteristics. One of the better known forms of oxidation is where iron and oxygen combine. When this happens, a new compound, ironoxide (better known as rust), is formed. These chemical reactions involve an exchange of energy. Heat is one form of energy. The amount of heat developed by this process may be a very low level, almost unmeasurable, such as occurs with the rusting of a nail. On the other hand, it may be a very high level of heat such as in a fully involved house fire.

Substances react to chemical change in one of two ways. One, they give off heat during the course of their reaction. This process is known as **exothermic reaction.** Or they absorb heat during the process. This is known as **indothermic reaction.** For our purposes in the study of fire, we can say that the process of oxidation or combustion is the former, or an exothermic, reaction in that it gives off heat.

Oxidation as it takes place during a fire is a very complex process. However, the explanation of how oxidation and combustion of various fuels takes place can, for our purposes, be broken down into two categories or groupings.

DIRECT OXIDATION (TYPE 1 COMBUSTION)

This means that a fuel in its *natural state* can mix directly with oxygen and all that is required for combustion to take place is for a source of heat or ignition to be applied. Type 1 combustion basically applies to fuel already in a gaseous state. There are, however, several solid fuels which are classified in this group, such as **charcoal** and **sulphur.** Also included due to its low flashpoint is **gasoline.** The basic characteristic of this group is that it does not require the application of heat to convert it into a form (volatiles) that will oxidize.

SEQUENTIAL OXIDATION (TYPE 2 COMBUSTION)

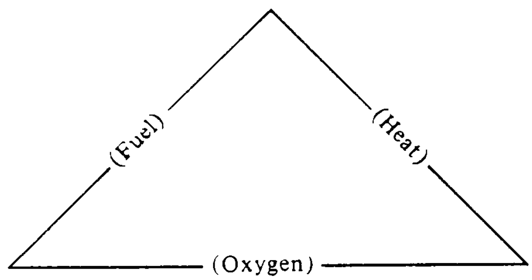
This involves most of your ordinary combustibles, both liquid and solid, which will not oxidize in their natural state and require conversion to volatiles by the application of heat before combustion will take place. This conversion takes place in liquids through a process known as **evaporation** and in solids through a process known as **pyrolysis.** Pyrolysis is the chemical decomposition or other chemical changes that takes place in a solid as the result of the application of heat, regardless of the temperature involved.

An example of type 2 combustion is the burning of paper or wood. Both paper and wood are complex chemical compounds. They are made up of, among other things, carbon, hydrogen, and oxygen which are united in a mixture of molecules. In order to burn, these molecules must be broken down or pyrolyzed to produce combustible gases (volatiles) which can unite with oxygen in the air. This in turn forms a combustible mixture which will ignite from any available source.

As these materials burn, they generate heat. This heat in turn causes further decomposition or pyrolysis of the fuel adjacent to the flame. This process causes an increase in the size of the flame which in turn produces more heat. Here we have created a cycle of ever-increasing burning. This is known as **sequential** or **type 2 combustion.**

In the beginning, we have all been taught that we need three elements to have a fire. This is known as the **fire triangle.** For fire we need **oxygen, fuel** and **heat** or energy as a source of ignition. These three elements are shown in the following illustration.

Oxygen is probably the most plentiful and most readily available of the three elements. We live at the bottom of a sea of air. This air or atmosphere is made up of several gases. Of these gases, oxygen composes 21 percent of the mixture. It takes a minimum of 16 percent oxygen to support combustion. In addition to the oxygen in the air, there are a number of substances that contain or are capable of producing oxygen. These agents are capable of causing rapid oxidation of other materials in the manner associated with burning. These agents are known as **oxidizing agents.** These agents cause reactions that give off heat.



OXIDIZING AGENTS

In general, the oxidizing agents that we may encounter and be concerned with in fire investigation will contain one or more of the following elements.

1. Oxygen (Oxides)
2. Oxygen and Nitrigen (Nitrates and Nitrites)
3. Oxygen and Chlorine (Chlorates)
4. Oxygen and Sulphur (Persulfates)

So far in relation to a fire situation, we have only considered the addition of oxygen to a substance or oxidation. It also works the other way, i.e., the subtraction of oxygen from a substance. Chemically, this is known as **reduction** or **redox.**

When combustion of ordinary materials takes place in a closed space and oxygen is kept from entering this space, the combustion process does not continue at its normal rate and the fire is said to be oxygen starved. When this happens, the burning process no longer produces the completed combustion product of carbon dioxide. Instead under this restricted burning process a **reducing agent** (i.e., carbon monoxide) is produced. The presence of carbon monoxide in a fire zone results in a **reduced atmosphere.** This atmosphere seeks oxygen in any form and from any source. If this reduced atmosphere is ventilated and oxygen supplied, rapid oxidation takes place and an explosion may occur.

The second element which is required for fire is **fuel.** Basically, all fuels are carbon based. They range from simple gaseous hydrocarbons to solids of a complex chemical nature. All will burn under appropriate conditions. The fuels react with oxygen-generating by-products and release heat. The flame you see is the visible portion of the oxidation process. Flame is a gas phase phenomenon. Fuel, as we know it, comes in three forms: **gas, liquid** and **solids.** However, with the exception of gasoline and those solids listed under type 1 combustion, both liquid and solid fuel must be converted to volatiles before combustion can take place.

The first form of fuel which we are going to examine is that of gas. Gas is the primary form of fuel involved in all combustion. Gas is the only form of fuel which can combine with oxygen and result in combustion. There are a number of elements which are gaseous in their natural state. Some of these such as methane, or natural gas, and hydrogen are combustible. Others such as helium and carbon dioxide are not combustible. Even if the fuel is gaseous and combustible, this is still one other requirement that must be met before combustion can take place. The fuel gas or vapor must be mixed with air (oxygen) in a certain proportion to produce a mixture that will burn or explode. This percentage varies with the type of gas involved. Here we can have one of three conditions. The first is where the mixture of gas to air is too low producing a mixture that is too lean to burn. Next we have what is known as the explosive range. This extends from the lowest percentage of gas to air that will sustain combustion, which is known as the **lower explosive limit**, or LEL, to the highest percentage of gas to air that will sustain combustion, which is known as the **upper explosive limit**, or UEL. The third area is that region beyond the upper explosive limit where the mixture of gas to air is too rich to burn. You may understand this better by comparing it to the carburetor of an automobile where when you are not getting enough gas to run it and it is said to be "too lean" or where you get too much gas and it said to be "too rich."

The upper and lower explosive limits vary with the type of gas involved. The following chart gives some of the more common gases and their explosive ranges:

	Explosive Limits	
Name	**Lower**	**Upper**
Butane	1.6	8.5
Carbon Monoxide	12.5	74.5
Ethyl Alcohol	3.2	19.0
Gas, Natural	4.8	13.5
Gasoline	1.3	6.0
Hydrogen	4.1	74.2
Methyl Alcohol	6.0	36.5
Naphtha	1.2	6.0
Propane	2.3	9.5
Toluene	1.2	7.0

The mixing of gas and air to form a combustible or explosive mixture can take place in one of two ways. In some instances both will be involved. The first is a chemical process called diffusion; the other is mechanical mixing. The characteristic that affects both methods is known as vapor density, i.e., the weight of the gas in comparison to air. Naturally all those vapors which are heavier than air will tend to fall until they hit the floor or some other obstruction. At this time they will spread out in the same manner as a liquid. Those that are lighter than air will rise until they hit the ceiling or some other obstruction, where again they will spread horizontally. When this occurs, there will be two separate layers. Where these layers meet or interface, they will tend to mix or defuse into each other. The rate at which they will mix is controlled by the vapor density of the two liquids. The greater the difference in the density, the less mixing that will occur. This can be compared to the mixing of two liquors in a mixed drink such as a zombie. At the interface of the two liquors they will mix with each other. Another factor that affects the rate of diffusion is the temperature differential between the two gases or liquors. Again, the greater the differential, the less mixing.

The other method by which mixing is accomplished is pure mechanical mixing such as stirring cream into your coffee. Most of this mixing is accomplished by the movement of air currents within a room or space. Even in a totally closed or sealed system, injection of the gas itself will set up a movement in the air currents as a result of the movement of the gas through the air. These movements are due largely to differences in the density and temperature of the gas. This difference will initiate an up or down movement which in turn will create air currents. Also, the operation of a mechanical ventilation system such as a furnace or air conditioner will set up air movement, including the movement of people or pets within a room or space. As the gas mixes with the air, it will establish itself in layers of varied percentages ranging from too lean to too rich, with an explosive layer at one of the interfaces. The configuration of the layers will depend on the density and whether we are dealing with a high accumulation or a low accumulation. When an ignition source is introduced into this layer, an explosion or fire results.

The second fuel we want to discuss is that of a liquid. Liquid in its natural state will not burn. This of course does not apply to gasoline or the other highly flammable liquids with a flash point below that of normal ambient temperature. Most liquids require temperatures of 100° F or so to create volatiles. So we can say that combustible liquids must be converted into a gaseous state before combustion can take place. The physical state of being a liquid is only an interim state for a large number of materials, a state which is governed by temperature. By raising or lowering the temperature the state of the substance can be changed from solid to liquid to gas. Ice, water and steam are examples. The state in which we are interested is the gaseous or vapor state. I am sure you have all heard of the term **evaporation.** Evaporation is the process where a liquid is changed to a vapor by the application of heat. The higher the heat, the faster the movement of molecules that make up the liquid. This continues until the molecules are moving fast enough to escape as vapor or steam. The liquid is a compound made up from various elements. These elements all have different boiling points. Due to this, the various elements escape at different times. Since the more volatile elements have lower boiling points, they are the first to escape as steam. As they are driven off, they mix with the oxygen in the surrounding air. If the rate at which they escape is sufficient to form a combustible mixture and a source of ignition is present, then combustion results.

In many cases the temperature is not high enough to drive off sufficient molecules to form a combustible mixture. In this case no fire occurs even though a source of ignition is present.

The temperature at which a liquid gives off enough vapor to form a mixture which will flash but not sustain burning when a source of ignition is introduced is known as the **flash point.** The temperature at which sufficient vapors are produced to sustain burning is known as the **fire point.** Usually this is just a few degrees above the flash point.

Up to this point when speaking of liquids we have used two terms to describe them: **flammable** and **combustible.** Just what is the difference? The difference is the flash point. Liquids with a flash point of 100° F or below are classified as flammable liquids. Thus, gasoline with a flash point of −45°F is considered to be a flammable liquid. Those having a flash point of 100°F or higher are considered to be combustible. Home heating oil with a flash point of 130°F is classified as combustible. The term combustible is also properly applied to solid fuels such as wood or paper.

In my high school chemistry class our instructor conducted an experiment. He put some kerosene in a glass beaker. He then tried to light it by