Guide 4

FIRE INVESTIGATION

INVESTIGATIONS

This Book was originally created in 1996-97 for manual implementation by Fire Investigators, as a supplement to a training film on the topic. It is out of print, and no longer available from the publishers or Emergency Film Group. It is the fourth of four such guides created by and containing material copyrighted by Ludwig Benner Jr.

It is posted here for reference by Fire Investigators who are interested in exploring alternative methods for fire investigation and fire investigation quality assurance processes

Guide 4

FIRE INVESTIGATION

To complement the Emergency Film Group's
Fire Investigation video

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PREFACE

Guide 4, **Fire Investigation,** is the fourth in the Investigations series. It complements the Emergency Film Group's **Fire Investigation** video, produced in cooperation with IFSTA. Other guides and videos in the Emergency Film Group's series include:

Introduction to Investigation covers the basic investigation process and general investigation procedures.

Accident Investigation covers mechanical accidents such as those resulting from misuse of equipment, occupational illness, line-of-duty death, and motor vehicle accidents.

Hazmat Investigation covers investigations of hazardous materials incidents, leaks, spills, and explosions.

These videos and guides are available from IFSTA.

INTRODUCTION TO FIRE INVESTIGATION

A fire investigator provides much of the knowledge base on which many others act. This knowledge base is used by fire officials and others to develop and assess fire prevention programs. It is also used by firefighters to develop improved response methods and resource deployment. The fire investigator's work is important to and relied on by many people, including those whose lives are spared when the lessons learned from the investigator's efforts are implemented.

This *Guide* is written for those who are genuinely interested in developing new knowledge from investigations to serve all users of their work. It is designed to help fire investigators accomplish this by giving proven insights into the fire and the investigation processes and procedures to achieve good investigation results.

An investigator requires general *knowledge* about the fire process, the investigation process, and the investigation tools used during investigations. This *Guide* gives the fire investigator practical guidance to learn all the lessons available from every fire investigated as quickly and efficiently as possible. It is for investigators who want to really understand what happened and why it happened, rather than just to gather and report data.

The video **Fire Investigation** provides many useful techniques and tips to help the investigator do many investigation tasks well. This *Guide* focuses on the overview, approach, and tasks rather than to repeat information about investigation techniques in the film. The *Guide's* objectives are to help the investigator do quick, efficient, and consistent investigations.

The investigator's goal is to do good investigations.

WHO SHOULD USE THIS GUIDE?

- Fire investigators can prepare for fire investigations, check off tasks to do during their investigations, and check the quality of their work.
- Criminal investigators can prepare for the fire investigation aspects of arson investigations, identify the role of arsonist actions in a fire, and check the quality of the fire investigation aspects of their work.
- Managers responsible for establishing fire investigation programs can use the *Guide* to establish specifications for fire investigations, with which they can improve an investigation program, and judge its quality and value over time.
- Fire investigation supervisors can complete specific investigations on budget and on schedule and control testing expenses.
- Industry safety personnel can help them prepare for and do fire investigations.
- Training or seminar leaders can help trainees build their general fire investigation knowledge and skills.
- Data analysts can help them analyze episodic fire reports and other information from which they wish to identify problems disclosed by others' experiences.
- Expert fire investigators can improve their efficiency and effectiveness and evaluate their own performance.
- Designers can identify the kinds of processes and problems they need to design out of their work products.

CHAPTER 1
GENERAL PREPARATIONS FOR FIRE INVESTIGATIONS

What fire investigators do during an investigation is determined primarily by what they are asked to do by whoever is paying for the investigation. They also are influenced by the nature of the fire; how they think about "fires"; their preparations; the knowledge, skills, and tools they bring to each investigation; and how well they apply their knowledge, skills, and tools.

As a fire investigator, you need to prepare for investigations by ensuring that you:

- Know your investigation objectives.
- Know your limitations.
- Recognize others' interests.
- Know your investigation procedures.
- Prepare the equipment you will need.
- Know work product quality-assurance procedures.
- Know sources for help.
- Prepare responders to help.
- Know what to do if incendiary origin is suspected.
- Know contents of this guide.

For purposes of this *Guide*, a fire is defined as a special kind of undesired *process* that produced a loss outcome. Your fundamental objective is to gain an understanding of and be able to describe what happened during that loss-producing fire process and explain why it happened.

You do this by acquiring and working with data created before, during, and immediately after the fire. You can find such data from people and in things available after the fire. An important *investigation task goal* is to observe, document, organize, and test those data *promptly, objectively,* and *efficiently*. This permits you to describe accurately what happened during the fire and why it happened, at reasonable cost.

KNOW YOUR INVESTIGATION OBJECTIVES

Fires may be started deliberately or begin accidentally or naturally. Traditionally, fire investigators have conducted fire investigations to determine the origin and cause of a fire or to help develop evidence to support an arson case in court. Investigators start their investigations by trying to locate the area of origin, with a starting assumption that it was deliberately set. An important goal for investigators is to be able to recognize indicators that a fire was either started deliberately or pre-configured to grow quickly at the earliest stages of an investigation. If a criminal investigation is initiated, the investigation will range far wider than the fire scene, and the investigation tasks change.

This *Guide* is based on a broad view of the fire process, which results in broad investigation goals. Fires are investigated to:

- Identify fires of incendiary origins.
- Prevent fires.
- Lessen the loss from fire.
- Improve suppression procedures or equipment.
- Evaluate effectiveness of codes and standards.
- Evaluate training.
- Evaluate design practices, protective equipment, and performance improvement recommendations.

All these results depend on an understanding and explanation of what happened. When the right set of tools is applied, the work products accomplish these objectives and satisfy other needs, such as supporting claims settlements.

After you develop a sound understanding of what happened, you should be relatively certain whether the fire was incendiary, accidental, or natural and thus be able to offer a "cause" as defined in NFPA 901, *Standard Classifications for Incident Reporting and Fire Protection Data*. You should also be able to fill in most of the other blanks on forms called for by most organizations sponsoring investigations.

Fire investigators may get involved in many kinds of fires such as house fires, vehicle and equipment fires, commercial and industrial fires, brush fires, and major forest fires. Investigators spend more time investigating structural fires than open fires, so most of the discussion here focuses on those kinds of fires. However, the procedures are applicable to all types of fires.

If a fire has been started deliberately, the investigation objectives change. For a suspect to be prosecuted, the investigation has to develop "evidence" to "prove" that the suspect was the perpetrator and to show that the perpetrator had the motive, means, and opportunity to start the fire. Another objective is to ensure that any evidence acquired will meet admissibility tests established by courts.

KNOW YOUR LIMITATIONS

Before you begin a specific fire investigation, you should determine the scope of your investigation. Fire is a process that produces unwanted harm or losses. You should have a clear understanding of what parts of the process to address in your investigation.

- Should you investigate only the fire origin or also the progression and extinguishment of the fire?
- Should you explore the events leading to the coming together of the fire ingredients or just pinpoint the origin?
- Should you document how the losses occurred or simply report the loss estimates?
- Should you document and describe the amelioration efforts by responding personnel or simply refer to someone else's report? Time or caseload may limit your ability to explore all aspects, so you may have to pick one or several as your focus.

If the fire is of incendiary origin, a criminal investigation expands the scope of an investigation beyond the fire scene and the gathering, preservation, and use of evidence. You should know the limitations imposed on you by law. In those circumstances, the site becomes a crime scene and should be so marked. The limitations affect:

- Decisions made during the investigation
- Access to the privately owned sites after the fire is out
- How you ask witnesses questions
- Procedures for documentation of objects thought to be "evidence"
- The handling, examination, and disposition of objects and records

When a fatality is associated with a fire, clarify your role in the investigation with respect to the victims. If you are expected to participate in that aspect of the investigation, clarify your tasks with respect to identifying the victim or victims, the kind of data you gather about the victims, and what the victim did during the fire.

Any time a person is fatally injured in a fire, be prepared to work through the reasons for the death in the following sequence:

- Homicide
- Suicide
- Accident
- Natural causes

If the body of a victim is found at the site, qualified medical help should be brought in to join the investigation. Generally, the local medical official in the jurisdiction where the fatality occurred will be in charge of the determination of the cause of death, autopsies or other forensic pathology efforts, and reporting of those findings. You could help prepare to identify the actions of the fire or combustion products on the victims and the timing of those events relative to the victim. Arrange with the medical examiner to get information about what the medical examiner thinks happened during the fire, based on the examination (or reading of the injuries) of the victim.

How Much Time You Have. Each fire is different. Frequently, the fire investigator has one opportunity to find the data needed, with limited ability to return to the scene for follow-up data gathering. Different organizations have different objectives. This means that the effort required to investigate a specific fire may vary from fire to fire and organization to organization. Consideration of these differences may result in the allocation of different time budgets for certain investigations. The key point is that the time should be tailored to the investigation demands.

NOTE: If you do not already have them, you should work out some "rules of thumb" for establishing the scope of the investigation and the time to devote to it. Generally, the greater the size of the actual or potential loss, the greater the amount of time you should allocate. Fires with multiple victims or casualties among responders thus would merit much more time than a fire in an abandoned barn. Fires in facilities where escaping hazardous materials could pose a threat to a neighboring community would merit more time than a vehicle engine fire on a busy highway. You may want to work out some sort of loss type versus allocated time workload planning matrix as part of your preparation for investigation tasks.

Where and how you can access expert help. You are an *investigation* specialist, with specialized *investigation* knowledge, skills, and tools. Although you may know a lot about the fire process, you may need help from others with specialized knowledge, skills, or tools. This help may range from experienced engineers to evidence technicians. The time to identify and arrange for those kinds of help is *not* in the midst of an investigation while data sources are vulnerable to continuing change — line these up beforehand.

The work products you have to deliver. You should know what you are expected to produce and deliver at the end of your investigation process. If the new knowledge gained by your investigation efforts remains in your head, it serves little purpose. Some investigations may not warrant any deliverables other than a standard reporting form, while others may reward more extensive work products.

How your investigation and outputs will be judged for acceptability. Try to identify the specification or criteria for the quality of your work products. It is always nice to know who will judge your work and how it will be judged so that you can work towards those criteria. This is especially true for fire investigators who must deal with difficult and diverse circumstances.

Part-time investigators worry about their regular responsibilities while they are investigating. This can distract them during investigations, motivate them to skip over needed investigation tasks, or reduce the time they devote to the investigation tasks. (*If relevant*, determine who will cover your regular work assignments while you are investigating.)

Do no damage!

You should know how to avoid damaging your potential data sources. You should also know how to get help in preserving data before you disturb, damage, or destroy (change) anything you may want to look at later. Few problems frustrate fire investigators faster than discovering what they are observing was altered since the fire ended. This is difficult because the fire, flashover, fire suppression, and overhaul can damage, destroy, or otherwise change evidence. Sometimes, just walking though charred debris can harm vital sources. A way around this problem is to photograph or videotape everything at the fire scene before you step on it.

RECOGNIZE OTHERS' INTERESTS

Investigators need to recognize that a willing witness during an investigation is much more helpful than an antagonized, threatened, or intimidated witness. Therefore, you should practice your witness interview skills by asking objective questions, and maintaining an open, cooperative mind-set. Another skill you will need is to be able to recognize what people think is in their best interests, so you can use that information to your mutual advantage during interviews.

Another aspect of this preparation is to determine beforehand the interests of law enforcement personnel in the investigation, particularly in suspicious surroundings. (See Appendix B, "Criminal Investigation Decision Model.")

Any parties with a financial stake in the fire have an interest in the investigation findings. For example, you may encounter an investigator whose only interest lies in determining the "cause" so that the cost can be assigned to one or another of the participants or litigants. Different people have different interests and needs. Your organization's interests come first. If you describe what happened adequately and convincingly, you will serve others' interests satisfactorily too.

KNOW YOUR INVESTIGATION PROCEDURES

Part of your personal preparations must include practicing the investigation process to build your fire investigation skills. Even Babe Ruth did not start hitting home runs his first time at bat. These tasks are not addressed elsewhere. To prepare adequately, you should be able to:

- Think of and describe each fire as a process.
- Track actions of those people and objects that produced the fire outcome.
- Transform data into documented analytical event-building blocks.
- Organize your information quickly by building time/actor matrix work sheets or a "mental movie."
- Identify and record causal relationships among the interactions.
- Make informed guesses about gaps in understanding, and know how to verify your guesses with data.
- Discover, define, and assess problems and needs.
- Formulate and recommend effective actions to fix problems.
- Do a quality assurance check of your completed work products.

The methods require occasional use to stay proficient. As part of your skill development efforts for investigations, you can practice using these procedures whenever you are trying to understand something that has happened. You do not need to wait for fires. Try to track the development of other problems.

Once you get used to using them, you will find more and more opportunities to apply them to learn from your everyday experiences.

PREPARE THE EQUIPMENT YOU WILL NEED

You will need specific investigation equipment and tools on short notice to investigate a fire. What you need will vary with the fire and your objectives. You should know how to figure out what you need and where you can lay your hands on what you need when assigned to an investigation. In addition to recommended investigation tools and personal protective equipment, you should consider including:

- This *Guide* as a reminder checklist and "how-to" resource
- Several 3- x 3-inch Post-it™ notepads to record the data in a working format
- A bound notepad to keep together any notes you make
- Pens
- Crime scene tape
- A 35 mm camera with extra batteries and at least three extra rolls of 36-exposure, fast (400) color slide film
- A small handheld tape recorder (with extra tapes and batteries)
- A volt/ohm meter
- Other tools described in the video and NFPA 921 6-4.1

You should not have to lug every tool to every fire. Select personal safety protective equipment commensurate with the threats likely to be encountered at a fire site. You may need PPE if sources of data at the site are in risky locations. Make sure that you are trained and ready to use any required equipment!

KNOW WORK PRODUCT QUALITY-ASSURANCE PROCEDURES

This *Guide* assumes that you want to perform high quality investigations. The process relies heavily on you to check your own investigation work against your investigation objectives and quality-assurance standards as your investigation proceeds. The procedures in this *Guide* can help you do this quickly and efficiently, as your data come in. The key yardsticks for assessing the quality of any investigation or work product will be your objectives. Therefore, make sure that they are stated in terms you can use to decide whether your work is okay.

KNOW SOURCES FOR HELP

As a trained investigator, you are the person at the scene with the best *investigation* knowledge, skills, and tools. You also know a lot about fire origin and fire behavior. Still, at times during an investigation or during the recommendation development process, you will need information from someone who knows how things work. You may need to find out about the design and intended operation of a building, vehicle, facility, or equipment — *the system involved* — in more detail than you know it. Know what kind of help you might need, keep aware of who is available or whom to ask about help, and know how to access their advice on short notice during an investigation. You may need in-house expertise or contracted services. In all cases, you should be able to access needed services that were arranged prior to the incident.

Prepare Responders to Help

Fire investigators have one additional source of help, usually within their own organizations — response personnel who extinguished the fire. In preparing for investigations, you should work with anyone who might respond to prepare them to observe and report to you what happened during the fire while they were on scene. This preparation can include guidance and training for reporting events in the form of who or what did what, in what sequence or time, and whom or what that action affected. That is how you need their data to work with it.

KNOW WHAT TO DO IF INCENDIARY ORIGIN IS SUSPECTED

The investigation of accidental or naturally occurring fires is not constrained much by requirements of law. The conduct of crime investigations, on the other hand, must meet stringent requirements imposed by law and the courts. Those requirements affect "evidence" acquisition and control, decisions about witness apprehension and interrogation tasks, site search and seizure or access, and involvement of counsel — among other considerations. If you start your investigation by assuming the fire was started deliberately with the intent to cause damage, you are not likely to do anything that would compromise your "evidence." Call a criminal investigator into the case if you find evidence to support such a charge and if you are not trained in criminal investigations. Recognize the investigation decisions they face (See Appendix B, "Criminal Investigation Decision Model") and be helpful. If it turns out that a fire was accidental, it is still a good idea to do the investigation methodically and follow chain of custody practices, documenting sources well, and maintaining confidentiality during the investigation.

KNOW CONTENTS OF THIS GUIDE

Investigators should know and be prepared to apply the contents of this *Guide* before starting an investigation. Investigators can benefit from reading this *Guide*, getting familiar with the Table of Contents, and knowing where to locate specific help or checklists during the first few investigations when they use the procedures.

CHAPTER 2
SPECIAL FIRE INVESTIGATION KNOWLEDGE

Fire investigators need knowledge of investigation principles and practices to guide their observations and frame their questions at a fire site. Knowledge of past fire behaviors is also helpful for investigators.

Fires have been investigated for a long, long time. As a result of this experience and research over the last several decades, fire development and fire behavior have been documented to a substantial degree. Thus you have available to you substantial knowledge of fire initiation and fire spread processes. You must know how to apply such knowledge to investigations. Additional knowledge about electrical systems and basic physics are also important. Much of this knowledge can be found in the appendices, NFPA or IFSTA publications, or basic physics texts.

FIRE PROCESS KNOWLEDGE

Fire initiation and fire behavior are two elements of a fire process that produces losses. You should be prepared to examine more than "fire" behavior. If you accept that a "fire" is a loss-producing process, you will recognize that the process has its origins in design, code, and managerial-type actions before the coming together of the fire ingredients. The process continues during the following:

- The coming together of the fire ingredients
- The ignition and growth of the fire and its accompanying heat and reaction products

- The impingement of the fire, heat, and reaction products on exposures
- The harm experienced by those exposures due to the fire, heat, reaction products, debris, or other risk raisers
- Fire suppression or control efforts and effects
- Injury or damage mitigation efforts and effects

To illustrate the fire process knowledge needed by investigators, a general descriptive model of the process was prepared for this *Guide*. That model is shown in Appendix A, "Investigator's Fire Process Model." Each numbered element of the Investigator's Fire Process Model is discussed in the following material. It incorporates basic ideas in NFPA 550, *Guide to the Fire Safety Concepts Tree,* a qualitative guide to fire safety strategies that was first created in response to deficiencies in fire codes observed in high-rise incidents. The purpose of the Investigator's Fire Process Model is to help you do data searches efficiently, do a complete and systematic investigation, and recognize when you are done.

The Model uses the time/actor matrix format you should use to organize your investigation data. It is in effect a *general fire process flowchart* format rather than the logic tree format found in NFPA 550. This format, technically called *multilinear* events sequencing, is used so that you can recognize time relationships among the many events that are occurring during the fire process and also see examples of some of the many different "actors" involved in a fire.

The arrows in Figure A.1 show which events lead to subsequent events. This is a general model, so it does not show many details. For example, for Heat.1 to heat the fuel, other "actors" would have to do something; someone would have to turn on the heat source if it is an appliance. Thus, as you use the model, recognize that the links on this model only show the flow of events in general terms but do NOT show all the necessary and sufficient events required to produce the outcome. You have to supplement the events shown with additional events in specific investigations.

FIRE PROCESS MODEL ELEMENTS

With a few exceptions, fires require heat to launch a reaction between some fuel and oxygen. Fuel is what burns, yielding heat by its reaction. Oxygen reacts with the fuel exothermally (giving off more heat than it needs to keep reacting) to contribute more heat energy to the incident.

Element 1 of the Model is the fuel, a material or substance that can burn. Fuels are all around us, but even with heat flowing into a fuel, a fire will not always occur. A liquid fuel may just evaporate without igniting and dissipate into the atmosphere. A solid fuel may get too hot to the touch, but it does not always ignite. For a visible fire to begin, something else is necessary — this is sufficient oxygen.

Element 2 of the model is heat that is a form of energy (thermal) that is required in one form or another for a fire to begin, spread, and do harm. Heat or thermal energy may take one or more of several forms. Sources of thermal energy may range from an open flame producing desired heat in a furnace to the sun's rays, dripping hot particles, materials combining slowly with oxygen, matches, electrical arcs, and others. These energy sources exist all around us but by themselves they do not always result in a fire.

Element 3 of the model, oxygen, is a part of our environment and exists all around us. Thus you should expect this fire ingredient to be present in a fire until it can be ruled out. Whether or not a fire ignites, Element 4, char, may form on the surface of a heated carbon-bearing object . When oxygen is present along with heat and fuel, fuel may ignite and produce another heat source — Element 5 — along with other products of combustion and also visible flames.

You need to try to understand the interactions among the Model elements during an investigation because these interactions vary from fire to fire. Also, you will see some exceptions to these interactions in unusual fires involving some chemicals.

To save space on the Model, each "actor" is assigned a row number. The row numbers are used with the actor name in the following sections. Fuel occupies Row 1, Heat.1 occupies Row 2, etc.

Fuel — Element 1

Fuel is the term generally used to describe what burns. The term is an "abstraction" or blanket word used to describe many specific entities. In investigations, to understand a process, you need to work with specific names of objects before you can describe what they did in a fire incident. You should start by naming distinctive objects that are unique in each fire.

Describe fuel in specific terms so that you can distinguish what each fuel did during the fire. The fuel that warmed initially is a different fuel that ignited and that fuel is different from the fuel that fed the fire growth, or a flashover. In the Model, fuel is Element or Actor 1, with the solid form named 1.1, liquid fuel named 1.2, and vaporized fuel named 1.3 to distinguish between them.

In the Model, three "fuels" are shown to remind you that you may be dealing with three forms of fuels in a given fire; they are shown as solid, liquid, and gaseous. When you encounter these different forms in an investigation, you should exercise care to ensure that you name each form differently.

Most fuels that you encounter are "carbon based," which means they contain carbon atoms. Occasionally, you will encounter some exceptions among certain chemicals (for example, like nitrates, hydrogen, or radioactive materials.) If you describe the fuel properly, the fuel characteristics will surface, or you will know what you have to look for in other references.

Most fuels produce a visible flame when they burn. Flame involves a gaseous phenomenon. To produce flame, a solid or liquid must be converted into a vapor. Gasoline vapor, not liquid gasoline, burns with a visible flame. This can occur in several ways, as shown in Appendix A, "Investigator's Fire Process Model," with Elements 1.1 (solid), 1.2 (liquid), and 1.3 (gas). Obviously, if you can keep a material in a solid form, you can control successfully the risk of fire. So, during your investigations, you want to know how any solid (Element 1.1) became a burnable fuel. That process involves one of the following changes:

1.2 A solid may be converted to a liquid by:

- *Melting*. A solid may change to a liquid when warmed, like water does when ice melts. Examples include "plastic" materials such as insulation around wires, furniture covering, kitchen utensils, and fixtures.
- *Decomposition or pyrolysis*. As wood heats, it begins to decompose, throwing off gases and vapors. As wood continues to heat, the pyrolysis effects move deeper into the wood, leaving a growing char layer on the surface.

1.3 Vaporized fuel gas capable of burning can be formed by:

- *Sublimation of a solid*. A solid material changes directly from a solid to a gas. Examples: Hexamethylenetetramine used in ASTM D2759-76 tests or when water is added to carbide, the carbide changes from a solid to acetylene.
- *Evaporation of a liquid*. A liquid changes directly into a vapor when it evaporates from an open container or spill.
- *Boiling of a liquid*. A liquid changes directly into a vapor when its temperature rises to its boiling point at whatever pressure surrounds it. Boiling depends on both temperature and pressure.
- *Decomposition of a liquid*. A liquid may decompose and turn into a gas, as when molten polyurethane vaporizes in a fire environment.

These conversions all depend on heat energy flowing into the material. They can be very complex, and you should refer to references such as NFPA 921 or Drysdale (1985) for more detailed descriptions of these or other mechanisms.

Sometimes, how the fuel came into existence can be important to your investigation. If the fuel is in a location where it is not expected, you may have to pursue how it got there. The source may be very obscure in accidental or naturally occurring fires. For example, some bacteria can produce a flammable gas in contaminated water under unusual conditions and that gas has resulted in losses when it was ignited.

> *Your challenge is to identify and describe what happened to place the fuel where it was and what was done for it to be in a gaseous state just before it ignited. This may include determining the pre-fire description of what was in a structure if you find that any objects or people had to take some specific action to change the fuel to prepare it for oxidation to begin.*

Heat — Element 2

Heat is thermal energy. Heat plays several roles in a fire. In addition to heating the initial fuel source, heat stimulates the initial oxidation reaction. It then plays several roles in the growth and spread of the fire. It also plays a role in damaging objects and hurting people. Significantly, heat that does all those things usually comes from different sources. It is essential for you to determine the *source* of heat every time heat does something during a fire. Do not just use heat as the stressor or actor when you develop your description of what happened. Specify the heat source(s) for each action heat does. This is another example of why you need to *watch your language* when you investigate — use specific words. Make sure every different actor has a different name, like Heat.1 or Heat.2 for heat energies from sources 1 and 2, etc.

Some heat energy is also always present in all objects and people in our environment. For example, our bodies are normally warm to the touch because they are constantly producing heat energy. Heat energy wants to migrate from warmer objects to colder objects. Thus to get a heat *flow*, the heat *source* must be warmer than the heat *receiver* or *receptor*. Whenever you see a heat *flow*, you should think in terms of the heat *transmitter* and the heat *receiver* or *receptor* (object or person) and what the receptor did when heated.

Heat does not always affect fuels adversely. You need to understand what heat did to fuels and oxygen during a fire process. The key to understanding heat's role is the concept of *change*. You need to look for the change in *heat energy levels* and *resultant flows*. Changes in heat energy levels require some energy input from some energy source into an existing heat source. (See

Appendix C, "Energy Sources," for a list of possible energy sources you can use as a checklist if the source of the change is not obvious.)

The direction of heat flow is always from a warm to a cooler location. Keep thinking about heat flows in terms of the heat transmitter and receiver — the object that absorbs the heat which flows. The flow or heat transfer rate depends on the initial temperatures of the transmitter and receiver, the quantity of heat initially available to flow, and what barriers influenced the rate of flow. Watch for changes from the intended flow path and rate to an unintended flow path and rate. Changes in flow paths require changes in the barriers controlling the heat energy or some external action such as a person setting a thermostat to an unintended setting. In that case, the changemaker is a person. In a lightning strike, the lightning is the changemaker.

Your challenge is to understand the changes in the source and actions of heat transmitters and receivers and the heat flow paths and flow rates in a specific fire. You need this so that you can describe what the heat source did to change the fuel into a vapor and make it vulnerable to ignition.

Oxygen — Element 3

For most carbon-based fuels, an oxidation reaction requires oxygen to begin and progress. Oxidation is the chemical reaction during which oxygen interacts with the fuel and produces a heat of reaction. Oxidation rates at normal temperatures are very slow for most materials and so there is little heat buildup. However, when the temperature of the material or surroundings rises, the oxidation rate increases until some reactions reach a point where they give off more heat than required to start the reaction. When that happens, the reaction can begin to produce visible flames and more heat and become self-sustaining.

Because oxygen is present in the air all around us, you should consider it to be present in any fire until you can rule it out in special cases. Oxygen also may be present *within* certain classes of chemical materials called "oxidizers." Generally, these oxygen-containing chemicals react much more rapidly and give off more heat than materials oxidized by atmospheric oxygen.

Your challenge is to determine and describe who did what to bring the heat, fuel, and oxygen together and what each then did to produce an ignitable mixture. Whenever chemicals are involved, your challenge is to determine the name, nature, composition, and properties of the chemicals and what they did prior to ignition.

Char Forms — Element 4

Charring is a change in the physical surface condition or state of a carbon-bearing material subjected to heat energy. You can use charring as a rough measurement tool to identify what happened during a fire. Charring can occur before and after a material ignites, so it is shown as Fire Process Element 4.

Like other terms, *char* is a term used to describe a range of conditions. When you investigate, think of char as a general term that covers any *changes* that occur because of the action of heat or flames on the surface of an object or person. That enables you to deal with any changes in the surface appearance of any object, including "charred" or blackened wood surfaces, changes in painted surfaces, and changes in metallic surfaces or barriers of any kind.

Carbon-Based Materials

As heat energy impinges on a cooler object, the temperature of the object rises, starting at the surface and forming a thermal gradient from the surface toward the center of the material. As a heat source continues to heat a carbon-bearing solid, a thermal transformation (or pyrolysis) process begins. Pyrolysis of wood leaves almost pure carbon residue on the surface after the gases and volatile liquids leave the surface.

This residue or "char" has distinctive patterns that can help you identify the heat energy that flowed into the object to produce the observed change in its surface condition. The char is one form of "witness plate" to events affecting the base material on which the char is formed. Char may form at temperatures below ignition temperature if exposed to heat, such as a high-pressure steam line or heating device, over a long period of time. You have to look at the heat source that produced a char before you can interpret char in an investigation.

The rate at which pyrolysis occurs depends on the intensity and duration of the heat input and the properties of the material. Wood begins to discolor and chars at 200° to 250°C in fires but can discolor and char at lower temperatures (>120°C) if exposed for a long period of time. The physical structure begins to break down rapidly at temperatures over 300°C. Investigation literature indicates a charring rate of 0.6 mm per minute, but it can increase as the heat flux increases. For example, in a compartment fire, heat can build up char on the surface at a rate as high as 4.4 mm per minute. Thus you should use char depth only as an *indicator* of the exposure time *range*, because it does not form uniformly in all fires. The video and references describe ways you can use char patterns on wood and other surface changes to try to interpret the action seen by the object needed to produce the outcome you observe.

Changes in Other Materials

Nonorganic materials, such as metals or ceramics, may also undergo surface changes when exposed to external heat, but the changes are not called chars. At low temperatures, these changes may be difficult to observe. Aluminum, for example, forms up to three types of oxides when heated in air. Each oxide forms at a different temperature. By analyzing the oxide, the temperature to which the aluminum was exposed can be identified much more precisely than for organic materials. In addition to oxide formation, changes in the physical properties, such as the surface hardness, ductility of ferrous materials, or separation of conduits or wiring, may also occur during exposure to heat.

Internal heat may also affect noncarbon materials. For example, an electrical wire carrying current in excess of its rated capacity may begin to overheat, which changes the appearance and properties of the wire.

Your challenges are to:

- *"Read" the surface conditions and appearance of objects you find.*
- *Identify and describe the actions by the heat source(s) that produced the pattern(s) and changes or effects you see.*
- *Estimate the approximate times to produce the conditions you observed. See the references for additional help about "reading" chars and other surface changes.*

You may want to consult materials experts if such data about the fire are needed as "proof" of what happened for a court case.

Vaporized Fuels Disperse

Model Element 1.3.1 is the first action by the vaporized fuel after it forms. You need to understand the *dispersion* of the vaporized fuel — where did the vapor go, and what did it do after it formed and before it ignited? When you investigate a fire, what the vaporized fuel did after it formed can determine what happens next during the fire process or when no fire follows. Leaking natural gas may disperse throughout a home before it finds an ignition source, and if you open the windows, it may dissipate without ignition. Gasoline can evaporate, but if it disperses in a strong wind, the likelihood of it catching fire is very remote. If a fuel vapor is lighter than air after it forms (or buoyant), it probably will rise toward a ceiling indoors and indefinitely outdoors. On the other hand, if a fuel vapor is heavier than air, it will disperse along the floor or ground in a still environment and may flow down steps or into openings before it ignites.

The fuel vapor movement must involve dispersion in an oxygen-containing atmosphere, and it must mix with the oxygen. If a fire resulted, it must reach an ignition heat source. You should recognize that this *may* mean the vapor moved away from the heat source that vaporized it in the first place to another ignition heat source. It also has probably occurred to you that understanding this fuel vapor dispersion in near misses may help you understand fire situations better.

Your challenge is to track where the fuel vapor went and what it did after it formed to create the flammable mixture that ignited in a specific fire or dissipated before it was ignited.

Fuel Vapors Ignite (1.3.2)

Element 1.3.2 of the Model is the second action by the vaporized fuel. This event is the *first ignition* of the fuel vapors. Ignition is that process by which a rapid *exothermic* reaction of a fuel vapor and oxygen mixture begins, which then flashes through the mixture as a flame.

Ignition may be "piloted" or "spontaneous." *Piloted* ignition involves an ignition energy source other than the fuel/oxygen mixture, such as an electrical spark, independent flame, hot particles, or surfaces. *Spontaneous* ignition involves flame developing spontaneously within the vapor/oxygen mixture without such an energy source. Both ignition types are dependent on the fuel vapor and air mixture's upper and lower "flammability" limits, as well as how the "receivers" react to the heat input. The flame front progresses along the pathway defined by the flammability range of fuel/oxygen concentration gradients throughout the mixture. The video shows this happening in the sequence where spilled gasoline is ignited.

Actual ignition may also depend on the intensity of the ignition source, turbulence affecting the mixture, or any contaminants that would absorb some ignition energy. For example, using a match to light an accelerant outdoors on a very windy day is more difficult than on a still day.

Your challenge is to identify and describe the ignition energy source and what it and the fuel vapor mixture did to initiate the change from a volatile fuel vapor/air mixture into a flaming fire.

Oxidizing Vapors Form Reaction Products

The third action by the vaporized fuel, or Actor 1.3, is to form reaction products. After ignition occurs, you need to identify the reaction or combustion products which the oxidation of the fuel began to produce. These reaction products include heat, flames, gases, smoke, particles, or deposits. Their formation is influenced by the conditions resulting from other actions during the fire. Oxygen-rich fires produce different reaction products (more complete burning) than oxygen-starved reactions (more smoke, carbon monoxide, etc.) Fires involving plastics produce different reaction products than wood. However, all reaction products go somewhere and do something during a fire and become an actor to track to learn what it did.

Heat

Heat formed by the exothermic oxidation reaction has to go somewhere and do something, moving as heat energy through something by conduction, as radiant heat energy through space, and by conduction on moving air currents. Thus the fire provides a new heat source after it is ignited. During your investigation, try to determine how much heat was created by the initial oxidation reaction and how quickly, because that is one of the ingredients necessary for the fire to spread.

Flames

Flames indicate where the fuel vapors were burning. The formation of initial flames is useful to you because if observed, it can give you a time benchmark relative to other events. Smoke can provide a similar benchmark event, if observed.

Gases

The gases generated by a fire depend on the materials present, the heat flowing into the material, and the heat generated by the reaction(s). Gases can leave tracks *on* or *in* people (if they breathe them) and in or on objects when they are heated or absorbed. Be alert to special kinds of gases when chemicals are involved because the heated gases can condense on cooler surfaces where they may be seen as solids or liquid deposits.

Smoke

Smoke is a by-product of incomplete oxidation reactions during fires. Smoke moves during a fire. Its movement can help you identify the sequence of what happened. Smoke leaves several kinds of soot or deposits tracks on surfaces as it contacts and passes by them. These tracks on things can be "read" by investigators.

People may also observe smoke movement. Between the tracks and the people, you usually can find out where the smoke started and what it did during the fire.

Particles or Deposit

An oxidation reaction may produce particles or "deposits" that are found elsewhere later. During your investigation, it is helpful if you can determine what particles might have formed when the fuel vapor ignited because that may be different from what was produced after that time.

Your challenge is to identify what was left after the fire, the fuel(s) involved in the ignition, and what it or they did to produce the initial products of combustion. Whenever the gases — rather than smoke — damaged or injured anyone or anything, you need to find out (if you can) what the gases were and whether they were generated by the initial reaction or by subsequent reactions.

In a few instances, you may be able to get hard data to show that a toxic gas was generated and present by analyzing fluid specimens from people or absorbent materials exposed to the fire's by-products. For example, cyanide has been detected this way after a fire. Read the smoke deposits and dispersion patterns in combination with the chars so that you can describe where and how gases formed.

Heat Produces More Fuel Vapors — Element 5

Flames can generate more heat than required to sustain the initial reaction, producing rising temperatures in excess of the initial ignition temperature and inducing the material involved to undergo further burning. This is referred to as Heat.2 (Actor 5) in the Model to distinguish this heat from the previous heats.

The *rate of combustion* immediately after ignition usually increases in fires because more heat (from the flame) impinges on the original fuel source. The rate may be determined by the chemical kinetics or the fuel vaporization and mixing rates with the oxygen supply.

Heat.2 also heats other nearby fuels in its dispersion path. This can be a self-accelerating process as each new fuel vapor drives off the fuel produced due to Heat.2 added to the total amount of heat energy present in the fire.

> *Your task is to identify the new fuel vapor sources that the initial oxidizing reaction produced and track where they went and what they did after they formed.*

Flame Spread — Element 6

This is the fire growth element of the Model. Flames (Actor 6 in the Model) spread by advancing through the fuel vapor and air mixture and by advancing from the initial fuel to other fuels. This stage of the fire process is sometimes viewed as the "free-burning" phase of a fire.

Typically, the actors that spread the flames include the thermal energies produced after ignition, the specific additional fuels present, and the oxygen in the atmosphere surrounding the flames. Sometimes the gases formed during early oxygen and poor combustion may play a role. Changes in the energy flow patterns can result in the fire spreading to adjacent fuels as the heating, vaporizing, ignition, and flaming cycle continues. As a fire grows, the combustion reaction raises the level of heat energy to which other fuels are exposed, unless that energy can be absorbed in the environment surrounding the fire.

Your challenge, in any fire, is to identify and describe:

- *The successive heat sources, fuels, oxygen sources, or any other objects or people (actors) that contributed to the growth of the fire*
- *What they did or the changes they introduced to produce the fire growth observed*
- *The relative timing of those fire-spreading events*
- *Their effects on other people or objects*

Make sure that you identify and describe new post-ignition heat source(s) created by the flames after they started and the actions of each heat source in the fire's growth, decay, and extinguishment. Investigators also need to understand those actions to develop recommendations for the reduction of future fire risks. Ways to do this are discussed in the next section.

Fire Spread Tracks

As fire spreads, the actions of the heat energies leave "tracks" in the objects they affect. Those tracks can take several forms, such as:

- Surface charring of carbon-based (organic) materials
- Changes in the shape, color, texture, or internal characteristics of other objects
- Molten, fused, or resolidified residues or deposits
- Odors
- Particles, either flaming or nonflaming (smoke)
- Volatile solvent and accelerant residues

Your challenge is to find and "read" what all those tracks can tell you so that you can describe what happened (who or what did what) to spread the fire. The video offers you helpful tips for reading them, and NFPA references may also be helpful.

Flashovers

Some fires grow in a confined space or compartment until they reach a "flashover" stage or the transition from a localized fire into a fully developed fire. Flashover involves a very rapid transition from localized burning to the rapid burning of all the combustible surfaces in the room, compartment, or confined space. The process is highly dependent on the specifics of a fire and where it occurs. It involves actions by the original fire, gases, heat, other fuels, and oxygen in the compartment or confined space or within objects that constrained the fire development.

Your challenge, when a flashover occurs, is to determine and document:

- *What happened (who or what did what) to enable the fire to produce the conditions before the flashover and the actual flashover*
- *The effects of the flashover on the compartment occupants or contents when it occurred*
- *Any effects external to the compartment following the flashover*

Flames Subsided (6.1)

The next action by the flames (6.1) in the Model is the change from a spreading fire to one that is subsiding, for whatever reason. At some time during a fire, the amount of heat produced by the fire peaks and then begins to decline. After a flashover occurs, all the combustibles in a compartment will be burning, and the heat production rate will be at a maximum, producing temperatures as high as 1,100°C. These rates will continue until the rate at which volatile vapors are generated begins to decrease. This can occur when:

- Volatilized fuel sources are exhausted
- Fuel vapors escape unburned with the smoke and gases
- Something constrains the airflow
- Responders' extinguishing efforts reduced the volatile generation rates
- Responders' efforts absorb enough of the heat energy being generated

When this happens, the flames begin to subside during the later stages and eventually die back to reach a smoldering state.

Look for events such as:

- Something interfering with the continuing supply of oxygen needed to sustain the fire growth
- Actions of other actors such as insulating materials, special coatings on materials, and char buildup
- Responders applying water

Be alert to such actions at all stages of the fire because of the potential for the discovery of new ways to reduce fire losses.

Your challenge is to describe what happened (who or what did what) to make the fire subside and why that happened.

Heat.2 Harms People, Objects — Element 7

This Model actor focuses on the *loss* that occurred. Exposed people and objects may be harmed by the combustion products, depending on what both the combustion products and people or objects did during that stage of the fire. Harm from combustion reaction products like heat, smoke, or gases occurs over time, during which the exposure as well as the impinging combustion reaction products are doing something. If the people survived, such data are easier to get. A medically competent authority should identify events injuring people from the injuries observed. Remember, you need to understand the energy source that produced the injury or harm before you can begin to act to reduce losses.

> *Your challenge is to determine what each impinged exposure did to either become vulnerable to the harm or escape the harm. You can learn from both successful actions and harmful actions.*

Emergency Response Actions — Element 8

Actor 8 of the Model, responders, is shown to provide for actions by fire and rescue personnel and other "responders" (people or objects) during a fire. The dotted arrows indicate some of the intervention points where emergency actions to stop the process might have been introduced. Intervention can take place at any block or link of the Model. Be alert to any actions that might have occurred, whether planned or not. If you look for such actions and their effects, you are likely to gain some useful insights.

Trained firefighters and off-site personnel generally do not intervene in a fire until it has becomes visible and attracts the attention of someone who gets them to the scene. In some fires, other individuals may intervene because they are near the fire, or have seen something that attracts their attention, and they take actions to suppress or extinguish it or perform rescues. Response actions by people on the scene at the start of a fire can include fleeing the fire themselves, attempting to rescue others from the fire, or attempting to extinguish the fire with a fire extinguisher or blanket.

Objects intervene in other ways. An alarm such as a smoke or heat detector can sound, a sprinkler may allow water to flow, a fire door may close, or a damper in a ventilating system may close.

> *Your challenge is to try to discover what people or objects did to intervene in the fire process, when they did it, and the effects or consequences those actions had on the outcome.*

Overhaul (8.1)

Another action by responders (Actor 8) is the overhaul at fires. The need to ensure that fires do not restart is genuine, and the nature of fire residues may require responders to move them or put water on them. Overhaul actions complicate your tasks in that the "end state" of the fire is disturbed before you have an opportunity to document it.

Overhaul actions change the fire scene and also affect investigations. If possible, train firefighters or medical response personnel to minimize changes to the fire debris during overhaul or medical response activities.

> *Your challenge is to determine and describe these actions and their effects on the fire or "witness plates" or where they are pertinent to the course of loss events during the fire. Identify and describe what additional losses may have been introduced in the debris and whether that affected the investigation.*

You may be tasked to assess the effectiveness of the response actions. If so, you can use the Time/Loss Analysis tool to determine the performance by both people and objects, if during the investigation you collect the data needed for that analysis. See Appendix F, "Time/Loss Analysis for Investigators," for these procedures.

Fire Investigation Process Knowledge

Fire investigators also require investigation process knowledge. This includes basic investigation knowledge as well as special fire investigation knowledge.

Basic investigation knowledge includes investigation concepts, principles, and procedures and the challenges previously described. These are described in detail in *Guide 1 Introduction to Investigation*. The essential highlights are presented here.

Fire investigation requires two distinct steps. The first step is to gain new understanding and knowledge about what happened and why it happened. The second step is to *use* that understanding to identify problems to fix and develop recommended actions to fix them.

What Is Being Investigated?

One key concept for fire investigators is to view fires as *processes* that produce undesired losses. Think of the loss-producing process broadly when investigating fires. A fire loss involves much more than an insurance claim. You need to think of the term "loss" broadly and should include:

- Injury to people or animals
- Damage or destruction of objects

- Illness due to exposure to fire
- Disruption or delay of important or vital activities
- Reduced production
- Loss of confidence in regulations or of credibility of response organizations
- Environmental harm or degradation
- Diminished capacity
- Many other kinds of undesired outcomes
- Definitions of losses or at least a list of the losses you find

Another way to look at what is being investigated is in terms of your focus on fire origin categories and, when fatalities are present, the manner of death:

Fire

- Started deliberately (crime)
- Started accidentally
- Started naturally

Fire With Fatality

- Death by homicide (crime)
- Death by suicide
- Death by accident
- Death by natural causes

Think of these possibilities — in the order listed — as you start a fire investigation. In other words, assume that a crime has occurred until you know enough to describe one of the other origins or manner or death.

Why Investigators Investigate

Determining what happened and why it happened is what investigators do. Why do they do it? This section looks at what produces satisfactory outputs and achieves investigation objectives.

Reasons People Want Investigations

In addition to those reasons cited in the video, people want investigations for the reasons cited in the discussion of investigation objectives. Each objective represents a "customer" for your investigation work products. In addition to the customers indicated, you have media interest. Invariably, media reporters and others ask investigators, "What caused this fire?" This question usually can be answered with a good description of what happened and why it happened. Interestingly, so can the questions posed by other customers. This leads to an important concept:

A valid description of what happened can serve all your customers' needs.

All customers have their own particular fire investigation objectives. Usually more than one customer must be satisfied. Remember:

Investigator's "customers" are any people that use information the investigator produces.

You should be aware of whom your investigations impact and who has an interest in your investigation. Investigations impact people who are involved in fires, as well as people who have to pay for the loss or corrective actions — now and over time. Others interested in fires may include:

- Property owners
- Tenants
- People using the property involved
- Neighbors
- Designers of facilities or equipment involved
- Anyone writing fire protection regulations — this might include local governmental response or law enforcement groups or state or federal agencies (who may also send investigators)

The media also needs special care. This can get complicated when investigators from several organizations, both private and governmental, get involved in an investigation.

Whose Investigation Is It?

Who is the "boss" of your investigation, and who makes final investigation decisions? Local fire department officials usually are the first involved in the fire response and investigation. In some industrial or transportation fires, other officials may become involved in the fire investigation. Each investigator must determine who wears the "BOSS" hat (if anyone), the pecking order for talking to witnesses, on-scene actions, the removal and testing of objects, and the releasing of information. The investigation will be easier for everyone concerned if it is conducted in a cooperative climate.

How Fire Investigators Investigate

How do fire investigators investigate? The short answer — for individuals without fire investigation training — *is the best way they know how.* Untrained fire investigators use mostly borrowed methods and techniques that include common sense, experience, and good judgment. These lead to completed forms and opinions about fire origins and causes. The results are well-intentioned and based on experience, but often they merely recycle prior knowledge.

Trained fire investigators have extensive guidance available to help them determine the origins of both accidental and suspicious fires. The techniques work well and have been effective for those purposes.

If you want to perform more valuable investigations, it is desirable to have broader conceptual guidance and training in systematic investigation methods. A systematized investigation process incorporates many tasks common to all investigations and some tasks or procedures specific to the type of incident. Common investigation tasks are described in *Guide 1.* Specific fire investigation tasks follow.

Systematic Investigation Process

Another concept to remember is that training in a preferred investigation process is needed to identify and define the questions you need to ask and the answers you need to get to produce your investigation work products quickly, efficiently, and consistently. A systematic investigation process provides:

- Unifying principles for thinking about fire processes
- Procedures to produce an orderly, consistent, efficient, and timely investigation
- Ways to apply logic tests as you get the data
- Ways to produce valid, reliable descriptions of what happened and why it happened
- Ways to discover and define problems and find options for successful remedial actions
- Ways to monitor changes to ensure they produced the desired results

Principles for Investigators

A fire is a loss-producing process. To understand that process, you investigate it. When you finish investigating the process, you should be able to flowchart it.

- *If you can't flowchart the fire process, you don't understand it.*
- *You know you understand the process if you can make it happen again.*

A key investigation concept is the idea of "change." A fire introduces many changes as it starts, grows, declines, and finally goes out. An investigator uses the changes that occurred and when they occurred as the basis for determining what happened. Thus awareness of the concept is essential for a successful investigator.

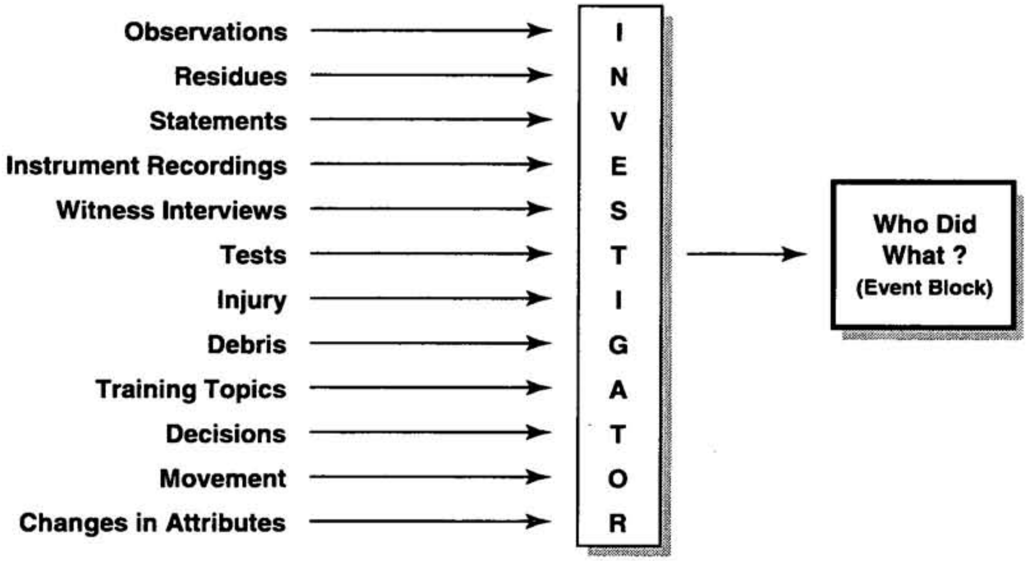
Observations

To investigate is to observe and inquire into what happened and why it happened or to examine systematically. Your observations will range from looking at objects to "reading" the information they hold to hearing (and seeing) what witnesses tell you.

> *An essential investigation skill is to be able to make observations and weave them into a description of what happened.*

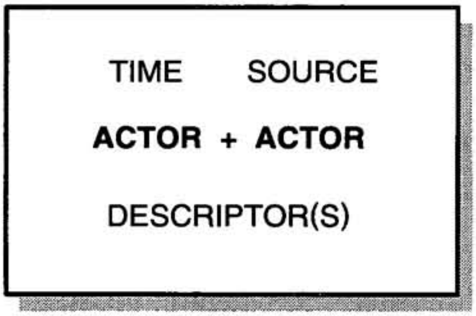
You must be able to take any observations of anything and transform them into descriptions of actions as described in Figure 2.1. This is a continuing challenge for you.

Figure 2.1 Investigators Data Transformation Challenge



A format that works well is the *"who did what when where"* format (Kipling's "faithful servants") shown in Figure 2.2 Event Blocks (or "events" for convenience).

Figure 2.2 Event Blocks



To transform and document the events you identify, use this simple procedure. It may sound tedious, but it really pays off throughout the entire investigation. It also helps you define what an *event* is and helps you use that term consistently.

1. Identify and record on 3- x 3-inch Post-it™ notes the name of the person or object (actor) that did something.
2. Record what that person, object, or actor did and any additional descriptive words needed to help visualize that action.
3. Enter the time, if you know it, or indications of relative times such as after or at the same time as another event, for example.
4. Enter the source (witness, object?)of the data you used to create the event block.

The source note helps you return to the source of the event should that be necessary. It also tells you what records to retain at the end of your investigation. Finally, if the event is controversial, you can list all the sources you have to support that block. If you are not sure who did something, or if you do not know yet what someone did, use a question mark or a tentative name to indicate what you do not know.

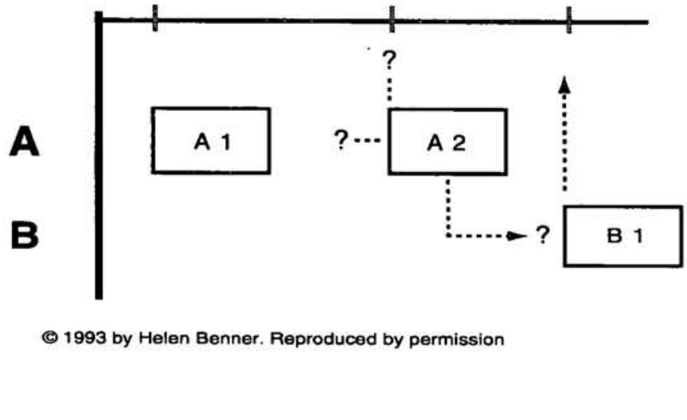
Data Organizing Tasks

As you identify events, it is essential for you to keep track of them and organize them so that they help you figure out what you know and what questions you still need to ask.

The easiest and fastest way to organize your information is to lay out your newly-acquired events on a matrix, with time and actor as the coordinates, as shown in Figure 2.3.

This procedure enables you to organize your information **as you get it** into a direct description of what happened by using the relative times or locations to sequence the events.

Figure 2.3 Placing Events On Matrix



As soon as you record your first observation as an event, you can start making your work sheet. Follow the example in Figure 2.3. You have learned about event A1 and placed it on your work sheet in the A row. You then learned about event B1, which happened after A1. You added a new row (for actor B) and placed event B1 on the work sheet along the B row, after A1 in time. Next you found out about another action by A, described by event A2. To place A2 in A's row on the work sheet, you need to determine *when* it happened relative to A1 *and* B1. The placement shown in Figure 2.3 indicates that you found it occurred after A1 and before B1. Use the left edge of your event block to indicate its time for placement purposes.

Each new event you learn about is added to the matrix in the same manner. You may have to slide the events along a row to make room for new events, and that is okay. This is a *work sheet* that grows as your understanding of what happened grows. Add rows when you discover a new actor was involved and events as you learn more about what each actor did.

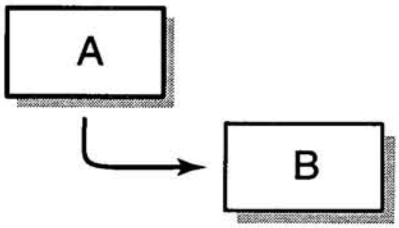
Logical Reasoning Tasks

By using event building blocks this way, you can quickly and efficiently put your events in the order in which you think they happened. This permits you to apply *logical reasoning tests* to your information, including sequential reasoning, cause-effect reasoning, and necessary and sufficient reasoning. These tests must be made in order to achieve valid descriptions of what happened.

Sequential logic. This is the reasoning used to put events into their proper time sequence. To understand *who* did *what when*, you have to put the events you learn about into their proper sequential order or in parallel on the matrix if they occurred at the same time. This logic involves visualizing *who* or *what* did *what when* so that they can be properly sequenced. For example, by reasoning about which event occurred first, you will state that event A had to happen before B.

Cause-effect logic. This is the reasoning you apply to events to determine whether one event led to another event. This establishes relevance and relationships among events you have identified. For example, when an event A occurs during a process, it may "cause" B or more events. If so, you show this by drawing a "causal link" from A to B.

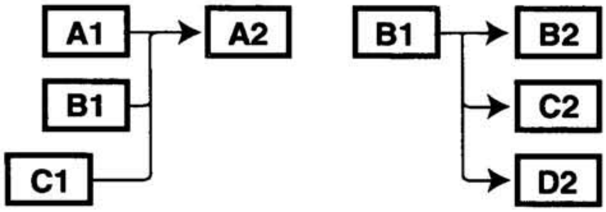
Figure 2.4



Necessary and sufficient logic. This is the reasoning you apply to pairs of events or events sets with identified cause-effect relationships to determine the *completeness* of your fire description. For example, necessary and sufficient tests may disclose that A1, B1, and C1 are all necessary (have to happen every time) for A2 to occur or that only B1 is necessary and sufficient for B2, C2, and D2 to occur every time. Other combinations may be possible.

Figure 2.5

Event-Sequencing Tasks



Some investigators apply sequential logic intuitively by capturing and organizing what they see in their minds in the form of "mental movies." They visualize the people or objects and what they did to advance the fire process. As new pieces of data become available, they fill in the gaps in their movie. Their mental movie helps them to put all the events they discover into sequential order — using time and space relationships they find.

Making mental movies is all right for small fires or if you are interested only in getting your facts in the right sequence. In more complicated fires, or in fires with high loss potentials, the movie can get so complicated that your memory begins to lapse or becomes confused. Sequencing the data tells you what happened, but you cannot really reliably analyze a mental movie with the additional logic tools you need to apply. Other people cannot see the mental movie in your head, so they cannot help you much with its development or offer you constructive critiques to help you with your investigation. You also find it difficult to communicate verbally what happened to other people so that they can draw conclusions solely from a movie in your head. This is why it is a good idea to document the events as soon as you can, rather than trying to memorize and test everything in your head. Not everyone can have Sherlock Holmes' analytical memory and skills.

Sequenced events usually will satisfy the need to determine the fire origin and cause. If you want to learn more from a fire or assess performance, you will not want to stop with the simple sequencing.

To understand why a fire occurred, you need to apply "cause-effect" and also necessary and sufficient logic tests.

This is when your documented event blocks and matrix *really* start to pay off handsomely.

Cause-Effect Logic Links

You may have noticed when working with Figure 2.3 that you looked at two events together to apply sequential logic tests when adding a new event to the matrix.

> *This event pairing procedure is the basis for analyzing all your investigation information as fast as you acquire it.*

By recording and organizing your observations this way, you are able to analyze very quickly all your information each time you add an event to your work sheets. As you place new events on a work sheet, you can look for cause-effect relationships between events and add causal links. For example, after placing A2 onto the work sheet in the position shown in Figure 2.3, ask yourself whether A1 made A2 happen. If it did, then link A1 to A2 with a linking arrow to show their causal relationship. Similarly, looking at A2 and B1, ask the same question — did A2 make B1 happen? If so, link the events. By examining events in pairs on your work sheet, you can add cause-effect links as you add events.

In the example, if A1 had to happen before A2 but something else had to happen between A1 and A2, you have a gap in your causal sequence. Show this situation with a question mark and arrows leading to and from the question mark.

> *Any gaps in the flow of the events tell you exactly where you need to get more observations, thus helping you focus your investigation efforts.*

Each time that you add an event, try to figure out the effects that event caused. After a few links are added, you will begin to see events that you recognize are part of the fire process but that are linked to a question mark or are not linked to anything yet. These show your known gaps in your description of what happened.

You will find a second type of gap when you do the necessary and sufficient logic test. This test shows you where one or more events must occur before the effect event would *always* occur. This is how you identify your unknown unknowns — the unknowns your data did not show you. The missing events point you to specific information you need and questions you need to ask and answer.

Mental movies can work similarly to pinpoint data you still need because a "blank" frame between two other frames points to a gap in what you need to know. This is a lot more efficient than other approaches where you "get all the facts" and then analyze them and draw your conclusions.

Filling Gaps

When you see gaps early in your investigation, you either:

- Get more observations about the actor for which data are missing to fill in the gaps.
- Identify the other actor(s) that probably did something during the gap, and get more observations about those actors to fill the gaps.
- Apply deductive logical reasoning to build logic trees to describe what you think might reasonably have occurred. After you have some realistic hypothetical scenarios, you can get more observations about events in those scenarios to determine which happened or which one was more likely to have occurred if you discover data for several pathways.

By concentrating on filling gaps, your investigation becomes focused, more efficient, and less time-consuming.

Additional Workload Approvals

Documenting observations on work sheets can help you manage your investigation costs and schedules by making judgments about the value of additional data. If the workload required to fill in the gaps will result in a cost or schedule budget overrun, get approval for the extra expenditures. With the matrix display of what you know and do not know, it is much easier to determine if the additional data-gathering effort is worthwhile.

Determining Completeness of What Happened

When you investigate a fire, how do you know when you know enough to end the investigation? The answer is by testing your description of what happened with good logic.

Each time that you link a pair of events, you establish a *cause-effect* relationship between the two events. To determine whether your description and explanation are complete, you have to perform a necessary and sufficient logic test procedure on *each linked event pair or event set* (more than two linked events). This is more difficult to do with mental movies. Such relationships usually are not considered if you are looking only for the origin and a simple cause, unsafe acts, or factors in a fire.

Necessary/Sufficient Logic Procedure

This is the task that separates average investigators from pros. It is also the part of the investigation process where the most learning occurs.

The logic testing procedure involves examining each linked event pair and asking yourself several questions. By linking the events, you know the causing event was *necessary* to produce the effect event. Then ask whether the causing event was *sufficient* — will it *always* produce the effect event each time it occurs? If the answer is "yes," this is all that you have to do. If the answer is "no," which is much more common, then you have to analyze how the system works. You will need to determine what else that people or objects had to do to make the effect event *result every time* it occurred, along with the original cause event. The aim is to define all the actions and the relative timing that had to occur to produce the next event *every time it occurs*. If you understand ALL the necessary and sufficient actions, you can make the fire happen again, or duplicate it. This is the real quality test of your work.

Explaining Why It Happened

When all the interacting events have been tested, a clear and complete explanation of why the losses happened becomes readily visible and easy to explain or understand on work sheets. Beginning with the last event, or outcome, you can trace backward to show what event(s) "caused" each event.

> *Use a question mark to indicate uncertainties.*

If you do not know what happened and cannot find out, say so before you turn in your work. Show a question mark on your work sheet at any uncertain actors, actions, events, times, or links where the work sheet is incomplete or uncertainty remains.

Documenting Visualization Aids

Documented visualization aids help you and your customers "see" what happened. This documentation can be photos, sketches, diagrams, maps, drawings, and similar graphics. It should capture the state of the site to help you recall details and help others visualize the scene when they try to visualize what happened from your work.

> *Caution: Whenever you put a dimension on any visualization aid, make sure that it is accurate if you have a way to confirm it, or indicate it is an estimate.*

Photographs. See Appendix E, "Photography Support for Fire Investigators," or NFPA 921 for specific guidance. Your objective is to record what you see in a way that lets you use it later to provide an overview and close-ups to make your points. Photograph the scene systematically

Sketches. Sketches are moderately detailed, artistic renditions of objects or relationships intended to highlight certain features that you consider relevant to understanding and visualizing what happened. You can use sketches to highlight details that are not apparent in photographs such as a pattern in a widely charred area. Sketches showing the relative location of objects, such as furniture, wiring, residue, or fire patterns, can focus on those aspects of a scene you want to emphasize. Using marked up photos might also satisfy this need too.

Your sketches may range from a detailed sketch of a small appliance or section of wire in a burned out room to the layout and separation distances or damages involving a cluster of buildings involved in a large fire. The objects sketched can range from heating or burn patterns to the location and placement of fire victims.

Label each object shown in a sketch with the same name used elsewhere in reports. A title block should show the sketch topic such as "Char pattern on staircase 1." You should also include a case identifier and other data to define the sketch and the data on the sketch.

See the following checklist for a list of the items to show when you prepare a sketch, diagram, drawing, or map.

Sketch Data Checklist

- ❑ A title block showing the name and location of the fire site
- ❑ The topic or main subject of the sketch or diagram
- ❑ A legend showing what the symbols represent
- ❑ Relative or actual dimensions of the objects or components
- ❑ A "north" indicator to orient the user, if relevant
- ❑ Distances between objects or a scale that can be used to measure them
- ❑ The case identifier
- ❑ The name of the person preparing the visualization aid
- ❑ Page numbers if more than one page is used
- ❑ The revision number and the date it was last revised
- ❑ The date of the fire

Diagrams. Diagrams are generally line drawings with symbols, designed to demonstrate or explain something or clarify relationships existing relative to the parts of a whole. For investigations, diagrams should contain the information shown in the Sketch Data Checklist.

Sketches or diagrams will probably be reduced to standard letter-size paper, so print with large letters that can stand reduction for reproduction. Graph paper works well.

Drawings. Generally, drawings are considered to be in the nature of a blueprint or plan, formally prepared by a designer or professional staff member and properly referenced and described. Building, equipment, highway, and process drawings, to name a few, are frequently referenced during investigations to get dimensions and understand relationships among parts of a whole. Usually sketches are used to describe the system parts.

Drawings help users visualize what happened or the progression of a fire through a structure. However, drawings can become too cluttered. Sketches can be edited and highlighted to emphasize specific points.

Maps. Maps with topographic features showing facility locations can be helpful when a fire covers a relatively large area. Examples include hazmat spill maps and aircraft wreckage distribution maps after an in-flight fire and breakup. They are also useful for depicting where objects moved in large facilities, showing emergency response or evacuation routes, and similar purposes. Maps also aid directional orientation. Do not get carried away with clever detail at the expense of basic data. Map preparation costs can rise quickly.

Completing the Investigation

The investigative actions and additional events on the work sheet prompted by the logic testing will complete your work sheet as much as the surviving data allow. A completed work sheet will contain only relevant events — linked events or events with a tentative link and question marks (?). See Appendix D, "Investigation Data Organization," for an illustration of the data shown on a completed work sheet.

Remove Unlinked Events

Remove events with no final links after you have exhausted your logic testing and possible hypotheses to establish links. Events with no links to the flowchart are irrelevant and are almost guaranteed to raise unnecessary questions from your customers.

Perform Quality Check

After you finish your investigation, check the quality of your work one last time. When you have entered your last possible event block on your work sheet and removed irrelevant (unlinked) event blocks, you have produced the best possible flowchart describing what happened and explaining why it happened.

The next task is to review the remaining linked events to ensure that each is properly formatted and then recheck the logic of your links and question marks one last time to ensure that the logic is valid and as complete as data permit.

Work Sheet Quality Checklist

- ❑ Check each actor name.
- ❑ Check each event block for sufficient logic.
- ❑ Check each action description.

- ❏ Use question mark to show all your uncertainties.
- ❏ Check each event format and source.
- ❏ Check each link for necessary logic.
- ❏ Check event pair and set for sequence.
- ❏ Remove unlinked events or note properly.

Prepare Deliverables

When your quality-assurance check is complete, you are ready to produce the deliverables from your work sheet. What you deliver depends on your customers. If you can use a neat copy of the work sheet as a flowchart of what happened, you will be able to communicate your findings more easily, show the problems and potential fixes, and save money. Support the work sheet with photos, sketches or diagrams, and drawings or maps to enable the users to visualize what happened and why it happened.

Investigation Data Sources

Fire investigators rely on data from people and objects to determine what happened and why it happened. Data from objects are generally more reliable than data from people if you know how to "read" objects. People think about and sometimes change their memories about what they did or saw. Objects react in a predictable manner.

In setting your data-gathering priorities, generally you will want to look over the available objects before you talk to people. *The exception* to this is that if responders are still on scene, you should talk to them before they leave.

Objects as Data Sources

> *Objects capture data through energy exchanges.*

Things serve as *witness plates* during many occurrences and capture much fire data during a fire. As energy impinges on an object, it changes in some way. For example, charring is a change that is easy to recognize. Objects are trustworthy witnesses. However, you have to know how to read what they have to say. Things will not "talk" to you, so you have to be able to "read" every bit of information the things "recorded." Data that you can get from objects depends on your "reading" skills. This is an area where you may need expert help.

Stressors and Stressees

To read data from things, think in terms of "stressor" and "stressee." The heat was the stressor — the energy source that introduced a change (charring) into the wood. The wood was the stressee, or stressed object. Sometimes a stressee becomes the stressor, as when an exposed fuel ignites to produce more heat and gases.

What this means for you is that interactions between objects are likely to be "recorded" by changes to both stressing and stressed objects in many cases. The challenge is to time the changes so that the initial stressor actor can be distinguished from the initial stressee. Apply sequential logical reasoning skills for this task.

Read "things" data to verify or supplement what people say. The basic approach is the same. Track the actions of people or things on other things from tracks left on witness plates during the fire.

Before disturbing things, photograph or videotape them! See Appendix E, "Photography Support for Fire Investigators." Keep written notes of what you photographed, or record your notes on your tape recorder. Capture ending states as you find them on arrival or on your walkthrough.

Getting Events From Objects

To get data for events from things, try to:

- Track successive changes of conditions required to produce the outcome.
- Use energy trace and barrier analyses technique to track energy flows into and out of the "object." See Appendix C, "Energy Sources," for a comprehensive checklist.

These data can be extracted by working backwards from observed ending or intermediate conditions, by:

- Observing the present condition of things changed during the fire
- Comparing the observed present condition with known pre-fire state(s)
- Tracking known or estimated changes and energy flows or stressors that induced changes from the beginning to the end of the fire process
- Transforming sequential changes of conditions into indicated stressor actions or stressor event blocks

Stressors = the actors for your things events.

In fires, stressors come and go, so usually only stressees will be available to "read." Stressors can become stressees during interactions with stressees (a hot plate before and after a fire) — that is why sequencing and timing require your special care.

In fires, you look for stressing energies in the following forms:

- Thermal energy
- Mechanical loads

- Electrical impulses
- Chemical reactions
- Ambient events
- People actions

See Appendix C, "Energy Sources," for a complete list of potential stressor energies.

The Six Ps

Data about actions by objects can be acquired by using the investigator's "Six Ps": papers, people, parts, positions, patterns, and properties.

Papers — are essential in arson cases. They may be useful if equipment is involved in the fire origin. Papers examined might include the following:

- Building fire inspection records
- Insurance documents
- Rental or lease agreements
- Deeds or property records
- Standard procedures
- Operating logs
- Correspondence about systems design
- Maintenance records
- Work orders
- Purchase orders
- Training records
- Safety analyses records
- Fire records
- Production records
- Regulatory directives such as recalls and maintenance directives
- Design applications or approvals
- Engineering change orders; etc.

People — ask them what they saw. Include the following questions during your interview:

- What did the smoke, flames, or other objects do before or during the fire?
- How did they operate the objects?
- How were they trained or instructed to operate the object?

- How did the object behave in various known circumstances?
- What conditions did they observe while the object was operating?
- What action did they take in response to what they saw the object doing?

Parts — look at parts to discover changes indicating exposure to high or low temperatures, effects of actions by parts that stressed exposures, and changes indicating sequence of stressor(s) progressing through the fire scene, chemical composition, etc. The term "parts" is used to define the stressor actions from effects.

Positions — look at which objects, such as switch knobs, glass inside or outside windows, structural members, access openings, and debris locations, came to rest during or at the end of a fire. This determines whether and how positions changed from pre-fire positions. The term "position" is used to define the effects of stressor actions.

Patterns — are used to infer or define stressor behaviors, intensities, exposure duration, and velocities. For example, look for patterns in char depth or char distribution, smoke deposits, spalling or ablation patterns, residues on objects, fragment distribution, chemical residue deposits, fire injuries to animals or damage to vegetation, thermal discoloration, damages to interacting parts, computer memories, electricity flows, radiation effects, water stains, etc.

Properties — are used to determine susceptibility of an object to effects of flames or heat. After fires, examine materials of construction or inherent properties of objects such as metallurgical properties of wires or fixtures, chemical composition of oxides, electrical resistance, concrete spalling, chemical or solvent contamination of debris, melting, or boiling points of materials involved or other physical properties.

The approach to reading events is to gather all the information you can before you do anything to damage or destroy what is available. The sequence is to:

1. Look at things.
2. Dismantle things.
3. Operate things.
4. Destroy things.

> *Keep in mind that your objective is to read events to add to the description or explanation of the fire.*

Testing Objects to Get Data for Events

As you learn about what things did and put them into your mental movie or onto your work sheet, you may find that you are having trouble getting the data you need. You may need help to understand how something works or was supposed to work before you can read what that something has to tell you. To keep from doing damage:

- Get help! Work with someone who knows the structure or equipment and how it is supposed to work before you do anything to it.
- Make a test plan describing *who* will do *what* to *what, when, where,* and *how*. Specify that experts give you outputs to fit into your mental movie or your work sheet. Settle your test plan *before* you sample, change, dismantle, try to operate, or test anything! (See *Guide 1* for test planning guidance.)

Indispensable rule: No plan, no tests!

Stick to your plan. Experts from other fields and laboratory personnel use investigation tests to serve their needs, which may be different from yours. If you are in charge of the tests, make sure that tests help you fill in gaps in your understanding, rather than satisfying some other need. If you pay for the tests, you are clearly in charge, so get the event blocks you still need.

"Creating" Events to Bridge Gaps

Often you will find that you have a gap in your understanding but you have recovered all the data you can. You do not know where to look next. At that point, you can hypothesize or "create" events *on paper* to see whether they fill the gap.

Creating events during an objective fire investigation may seem wrong, but it is not. When you test your "created" events against data the fire left and then with necessary and sufficient logic, you can do so confidently. As you formulate these ideas, try to define the events you might get before you touch, move, tear down, operate, or test anything. By doing this on paper, you often find that you do not have to do actual (and costly) tests.

Using Logic Trees or Simulations

Another "creative" investigative approach is to use logic tree analysis techniques, developed using deductive reasoning, to develop disciplined and informed guesses about what happened. Use special techniques for this purpose by using events on both sides of gaps to limit top and bottom event selection (such as backSTEP, for example, see Hendrick 1986). When you identify potential scenarios to fill a logical gap, look for data to support each scenario.

Getting Data for Events From People

To understand people as data sources, be aware of how people acquire and store data, what different categories of witnesses can tell you, and how their data can be changed before or while you access it.

People record data in the following three ways:

- Directly — they see, hear, smell, taste, and touch something, and they remember the sensory stimulus.
- As conclusions or reasoned decisions — they select data and arrive at some conclusion based on the data or decide on some action or course of action based on their conclusions.
- As personal feelings, beliefs, or cultural patterns — perceptions or truths they have adopted from an authoritative source, experience, or faith — rather than from logic.

> *Separate what people **did** or **observed** from what they **concluded** or **believed** during interviews. (Get descriptive and then interpretive data).*

Witness Categories

During a fire investigation, you will find the following witness types:

- A **victim** is hurt by fire and may be biased by self-interest in exploiting harm in litigation.
- **Participants** are not hurt, but they did something before or during the fire; for example, they may have assembled fuels, left the heater on, fled, or tried to extinguish the fire or rescue victims, etc. Involvement may limit the respondent's ability due to "focusing" phenomenon under stress, guilt feelings, and liability concerns.
- **Observer** is not involved but saw what happened; look for good overviews of actions, easy access.
- **Programmer** influenced "how *what* you *see* came to be"; may be informative but be cautious about self-interests.
- **Responders or physicians** can describe harm-producing actors, actions, and what they changed during and after the fire.
- **Firesetters/perpetrators** are a very special case; they involve complex relationships of constitutional rights, locating and accessing data. Interrogation may be necessary.

Why "People" Data Change

People may change their data because they may:

- Simply *forget* observations or conclusions
- *Rationalize* their observations to fit previous experiences
- *Deny* or dismiss observations or conclusions

- *Be influenced* by what others tell them happened
- *Distort* data to hide or obscure their role

To minimize changes in witnesses, try to keep witnesses from talking to anyone about the fire until you have talked to them. Schedule the interviews as soon as possible after your walkaround or walkthrough and identification of the fire origin.

Planning Interviews

Plan interviews to help fill in your mental movie or time/actor matrix work sheet. Your general objective is to hear from each witness the events during the fire, how these events affected the outcome, and then add or confirm these events on your work sheet or mental movie.

General interview objectives include the following:

- Gain and keep control of the interview.
- Gain and keep the witness's cooperation.
- Get all the relevant data (for events) that the witness has.
- Satisfy any legal requirements.
- Leave the door open for follow-up questions.

Identify in general terms the events or actions you need to learn about (from gaps in your mental movie or your work sheet). Plan the sequence of interviews and sequence of questions to get the data you need and the materials needed to support questions you will be asking. Decide how you will control the interview process by negotiation, assertiveness, exclusion, or other means.

Preparing for a Specific Interview

Before you start an interview, make sure that you meet in a comfortable, neutral interview setting. Base the interview on your recognition that the witness has data and that you need it. It is important to recognize that the witness does not have to give the data to you. (This helps your attitude!)

While preparing for your interview, clear your mind of similar experiences, assumptions, preconceptions, expected answers, and what should have happened. (This also helps your attitude.)

Decide how you will state your interview purpose to gain witness cooperation. (Remember, watch your attitude!)

Establish interview procedures and enforce them, especially if others will be present, and it is your interview! Find an orderly questioning sequence to ensure the witness's continued cooperation. Ask questions that allow the witness an opportunity to do most of the talking. Hear what the witness says and not what you are expecting to hear. (Attitude again.)

To build your own skills, it is a good idea after each interview to ask yourself what you might do better the next time.

Documenting Interview

During and immediately after an interview, be sure to document the data you receive from the witness.

- Document actions, decisions, conclusions, etc., as event building blocks; actor/ action columns on paper speed up note taking.
- List names and then track actions of new actors mentioned.
- Mark sketches, photos, maps, drawings, or other visual aids with data from the witness

SPECIAL FIRE INVESTIGATION CONSIDERATIONS

Handling Unknowns

After doing paper analysis, which is relatively inexpensive, it may be preferable to acknowledge unknowns before spending more money on testing or simulations to verify logical hypotheses. Evaluate value of data against cost of getting it with a test or simulation.

Watch for Biases

Everyone has biases or preconceptions about what is or what ought to be. You can minimize the influences of your own biases by using the mental movie or matrix work sheet building process to show the logic of your conclusions.

If more than one investigator is working on a case, you can minimize biases the same way — by using a method that forces all investigators to show the logic of their conclusions and judgment calls. Using "I don't understand" helps you reveal flawed or biased reasoning. Concentrate on producing an objective description of what happened with the matrix work sheet or mental movie approach

Communications

Think carefully about what you say to whom during investigations.

You should listen rather than talk during investigations. Except for raising questions and exchanging information with other investigators, you should gather data æ not disseminate it æ until you have completed your description of what happened and why it happened. Premature communication of speculation or judgments is important to avoid in any investigation.

Requests for Information

> *If asked for information by a reporter, witness, participant, owner, claimant, regulator, manager, or victim before the investigation is finished, have a response ready.*

A valid response is that you are still gathering information and trying to make sense out of it. Until you understand what happened, you do not want to run the risk of leaving something out that could change the whole focus of the investigation. Which is nice, because it is really true.

Filling in Forms

If you have to fill in forms, use the work sheet to complete the blanks to the best of your ability. Forms do not always allow for what happened in specific fires, so you may have to generalize a little to fill in a block. Most forms provide room for a narrative description of what happened, so use that space to describe what happened in the proper sequence. To write the narrative, simply state *who* did *what when*, and use "before," "after," or "at the same time as" to describe relative timing with words. If recommendations are required, the problems identified on the work sheet and the options and the rationale for selecting the recommended actions can be included in the narrative. See Appendix G, "Recommendation Development Process."

If you have to prepare a narrative report, a similar process applies. Narrative reports do not have to be works of art and are not judged on their literary merit. They should be judged by how the reader visualizes what happened and understands why it happened. The reader also should be able to visualize the predicted effects of proposed recommendations, if offered.

SUMMARY

This process seems complicated, and it may be if the fire is complicated. Remember, the complexity of the work sheet or mental movie is directly proportional to the complexity of the fire and how much of the fire process you investigate.

This investigation process is actually quite simple, fast, and efficient as you gain experience building work sheets. The hardest part is transforming observed data into events. Doing the logic checks as you add events to work sheets dramatically reduces the time spent on wasted motions. By documenting observed data on paper, you can reduce other costs too. Do not be intimidated by the process. Your work sheet has all the capacity you can use. If it gets complicated, it is because the fire was very complicated. Armed with this knowledge and some practice, you are prepared to do fire investigations.

CHAPTER 3
FIRE INVESTIGATION TASKS

Your main task is to develop a description of the fire process. It is essential for you to find the origin and cause and how the fuel, oxygen, and heat got together and what they did during that process. Assign an investigation case number to every investigation. For each fire investigation, you should use the following steps as the case develops.

Verify your investigation plan. From you preliminary knowledge of the fire, you need to ensure that your planned objectives are still valid. You can use the Investigator's Fire Process Model during discussions of any additional fire process elements that you should investigate if questions arise.

Deliverable specifications. Make sure that you know the criteria that will be used to judge the quality of your deliverables, so that you can check them yourself for quality-assurance purposes. Have some suggestions ready, if asked. (Present, with visualization aids, a complete description of what happened and why it happened, and identify uncertainties and unknowns.)

Schedules. Confirm the due date for your outputs before you start, considering your previously assigned workload. Experience enables you to recognize those cases that are likely to take longer than any established norms.

Hours to do the investigation. Ask how many days or hours the investigation is expected to take. Many fire investigations are conducted by spending a few hours at a site and doing the report in the office. Expanding the scope of an investigation will change that pattern, requiring data from more sources. Estimate your hours, and then keep track of the time you spend.

Establish your authority. If you do not already know, ask the person requesting the investigation what authority you can exercise during the investigation.

Spend money to buy something. If anything has to be bought or rented during the investigation, make sure that you know how to get reimbursed or how to authorize expenditures that will be billed to your employer.

Direct other people/take direction. Verify who directs whom at the fire scene. This will depend on the fire situation in each case. All this should be settled before you leave your office for the site.

START YOUR DATA ORGANIZATION

Often you can use your fire notification data to begin creating a mental movie of the fire. This requires transforming the information into the *who* did *what* or actor/action format to fit it into the "movie." Alternatively, you can begin to document events by starting a time/actor matrix work sheet. This gives you a framework on which you can "place" or "position" new events as you learn about them during the investigation. This "positioning" results in either a need to change previously positioned events or an incremental addition to your understanding of what happened.

CONFIRM CONTROL OF THE SITE

If you do not already know, you should determine who controls the site and their control capabilities. To determine who controls the site, ask the following questions:

Who owns the site? Whoever owns the site has many basic property rights that you are obligated to respect. The site owner may or may not be the owner of all the objects involved in the fire. Get someone to find out this information while you are on your way to the fire site.

Who has resources to control the site? For how long? Before settling on who is to control the site, make sure that the person selected for this task is capable of doing this. Do local law enforcement or emergency response organizations have the physical and communications resources needed? If so, for how long? If they do not have the resources, who does? How can those resources be engaged?

Who is in charge of the site and for how long? If something such as a hazmat spill extends the duration of a fire, make sure that changes in shifts or personnel do not leave you stranded when you need something. If arson is suspected, make sure to involve someone who has criminal investigation capability.

Position Access and Egress Controls

You should ensure adequate control of site access and egress to prevent unauthorized removal of fire-related debris, parts, or documents. You need to keep trying to determine who and what were a part of the fire process so that they can be protected until you can retrieve and document the data they hold.

The next task is to ensure that the site security boundaries are established and that the site is secure within those boundaries. The actual physical barriers and boundaries depend on the nature of the fire, what was involved, and the resources available to establish the boundaries. Barriers can be very disruptive, so the strategy is to try to put barriers around only what will be needed for the investigation and disrupt as little as you can.

Access Controls (Keep Out)

People are vulnerable to change and may need to be "protected." An instruction not to discuss what they know or saw is minimal protection. If the stakes are high, as in a fatal injury, physical separation or isolation is preferred. Fit the protection to each case.

People and objects can change the condition of what remains at the end of a fire. People can go onto a site and start touching, moving, altering, or taking objects — disturbing their distribution or changing the objects themselves. You get data from parts, positions, patterns, pieces, papers, and people — the "Six Ps" for investigators. Any of these may be present at the site, and you want a chance to look at them before they are changed. So keep people out until you have your look.

Objects can also change ending states. Rain, sleet, or snow, for example, can wash off residues, initiate oxidation in metals, dissolve chemical deposits, or melt ice. Running a bulldozer over a small object can also ruin your data. Thus you want to consider how objects might change your data and work out something that would protect the data source until you get your look.

Obviously, if the site is very small, you may want to give your walkaround look priorities and not bother setting up site barriers. This depends on your case and what you think you have to protect. Fit the barriers to each case.

If you set up access controls, you should identify who is allowed access and when and who makes sure only those people are admitted. Keep gawkers, however well-intentioned, from trampling your data sources.

Egress Controls (Keep In)

You also want to consider egress controls designed to keep fire data from disappearing. Whoever controls access can also control egress, but control does not happen automatically. Make sure that a procedure is put in place to guard against people taking objects or information out of the protected area.

Before entering a site, investigators should consider their own safety. Check with the site controller to identify any entry risks such as dangerously damaged structures, leaked chemicals, noxious gases, flammable gases, animals, hot electrical wires, blood-borne pathogens, or other energy sources. (See Appendix C, "Energy Sources," for a list of energy sources to consider).

> *No investigation data are worth an investigator's life, limb, or health.*

Work with the site controller to eliminate or control risks before entering a site to start investigating. Have an egress or escape plan and emergency equipment if it is essential to enter a hazardous site.

You need to guard against two kinds of damage at the site:

- To the people or objects containing data
- To others gathering data at the site

> *Do not damage data sources.*

Until you document the data they have stored, you should avoid damaging data sources, which are the people or objects at the site. Take photos before you start knocking down or tearing up anything.

Damage to objects can take many forms, including physical damage. With people, you do not have to be a psychologist to recognize that if people get the notion that you think they "caused" an accidental fire with fatal injury or that their "human error" "caused" the fire, the damage can be significant. Avoid threatening words, actions, or body language during interviews. Make sure that everyone you talk to understands that you are looking for understanding — not fault or blame — *unless you suspect a crime*. Then you may have to shift into an interrogation mode.

Before your investigation is completed, you may want to go back to the site to make additional observations. If feasible, negotiate call-back privileges with the owner but recognize that site cleanup will probably happen soon. Another control task is to make sure that any objects removed for testing or experimentation are returned to owners or someone designated by the owner or are at least offered to the owners. The owner should make any disposal decisions, not the investigator.

SET DATA-ACQUISITION TASK PRIORITIES AT SITE

After you make the site command connections and secure the site, you begin the data search, acquisition, documentation, testing, and refinement tasks of the investigation process. The following tasks are in the order you usually start them.

Set data search priorities. An investigator's task priorities at the site are generally to:

- ❑ Set up documentation materials.
- ❑ Start ownership data search.
- ❑ Do an external site walkaround and internal walkthrough.
- ❑ Document observed "ending" conditions at site.
- ❑ Identify or assign names to people and objects involved.
- ❑ "Read" data from objects to tell you what they did.
- ❑ Ask people to tell you what they saw and did.

Sometimes, reordering of these priorities may be necessary. When you arrive at a site while the fire is still in progress, the walkaround and walkthrough will have to be delayed. If a site is unstable after a fire, you may have to wait to document the ending condition. Reorder, but do each task.

Set up documentation materials. If not already started, you should set up chain-of-custody record keeping materials, your case notebook, a work sheet for event blocks, and your mental movies. This enables you to record and organize any new observations quickly and efficiently. If responders are still working the fire, interview the on-scene commander to get updated on what he has seen and done.

Do Site Walkaround and Walkthrough

Use the Investigator's Fire Process Model to help you recognize what to look for. By now, you should be set up to handle the events you find.

Do exterior walkaround. On arrival, do an external walkaround of the fire scene at the site as soon as feasible. During the walkaround, get generally acquainted with the location and nature of the fire and the kinds of people and objects that might have played a role in producing the outcome.

A walkaround is just that — you walk, observe, photograph, or videotape what you see. You do not touch, nudge, move, kick, or do anything that can alter what you see. Try to spot where the fire might have started if it originated outside and find out what happened. Then go back and get the details. If possible, view the site from all sides and from above. Look for areas where the most burning occurred, smoke patterns, damage to windows, contents moved outside before the fire, indications of liquids, chemicals, or runoff.

Look for fire origin. During the walkaround, be alert to indicators that indicate where the fire may have started and whether the fire started accidentally, naturally, or by someone's deliberate actions. Document what you see.

Do interior walkthrough. After completing the outside walkaround, do an interior walkthrough of the building or facility. When inside a building, look for the areas of least and most damage and possible fire origin site.

Caution: Insides of buildings can be very dangerous.

Light smoke stain usually indicates a fast moving, well-ventilated fire. Heavy smoke stain usually indicates a slow-burning or smoldering, poorly ventilated fire. Char depth also provides indications of the *type* of stressor that acted on the solid fuel.

Look for building features or objects in the facility that may have accelerated or retarded the fire growth. For example, note:

- ❑ Energy sources in the facility and the condition of their "barriers"
- ❑ Indications of the fire origin such as areas of deepest char depth, burn patterns, softening of glass, ceiling burn damage, low burn point or points, types of material ignited, heat sources that ignited the fuel, equipment that might have been a heat source, or other "pointers" toward the origin
- ❑ Indications of arson such as holes in walls, strange fire travel contrary to normal behavior, a disabled sprinkler system, residues from matches or accelerants, and characteristic unusual burn patterns produced by an accelerant
- ❑ Accelerant residues such as odors, streaks in char patterns, and cooling effects of evaporating solvents on burn patterns
- ❑ Fire loads inconsistent with the building's use such as chemicals, extra furnishings, high-value articles, and owner modifications.
- ❑ Condition of sprinkler systems and related appurtenances that might have interfered with operation or unsuccessful operation during the fire
- ❑ Condition of fire walls or doors, smoke dampers, other fire-spread safeguards
- ❑ Other features you note that acted to change the fire, smoke, and gas spreading rate

The video *Fire Investigation* describes many items to explore during your walkaround and walkthrough and during the investigation.

Document ending conditions at the site. Do not try to remember everything you see. Capture the scene with photographs or videos or add sketches, diagrams, drawings, or maps. Focus on the state of objects at the end of the incident. See

Appendix E, "Photography Support for Fire Investigators." Taking too many pictures is always better than wishing later that you had more.

> *Caution: Always include something that you can use to determine the scale of graphics.*

During your first walkaround, you probably will not have a sound idea of what is relevant and what is of no interest. Therefore, try to photograph everything at the scene that seems to have been changed, if it is safe to do so. Also get some photos of the overall scene from a sufficient distance to be able to show relative positions of changed objects. This will help you develop your mental movie.

This is a good time to start an inventory of the losses — as fatalities, injuries, property damage, damage to contents, "system" damages such as downtime, or any other damage of significance. It is a good idea to separate losses to emergency responders from other losses.

Document people and objects involved. This is also a good time to refine (or start) your mental movie of the fire. During the walkaround, you will become familiar with the "stage" on which the action occurred. To make your movie, you will need to identify and name each of the "actors" and what they did on that "stage." Record the names on Post-it™ Notes or cards for use as soon as you can get to a desk. If you do not know their official names, as often happens with objects and sometimes happens with people, use a question mark and your own temporary name until you can find out. The data source for these notes is "my walkaround."

During your "walks" and initial development of your mental movie, try to identify any people who may have "witnessed" what happened sometime before, during, or after the fire. These people may include:

- Responders
- Observers who saw what the fire or others did
- Victims that the fire injured
- People who did something before or during the fire (participants)
- "Programmers" who influenced what people or objects did during the fire

Programmers are the people that you will probably want to interview when you know enough to ask them good questions.

As you do your "walks," you will observe objects that were changed by the fire. These are also candidate witnesses —

candidate changemakers — objects that you may want to examine or "read." Other kinds of objects that you want to note are objects, such as sprinkler systems, that influenced what happened.

Identify the initial heat sources. Heat energy sources fall into one of three categories:

Category 1. Sources producing heat energy as they do planned, desired, or needed work.

- Cooking equipment
- Heating equipment
- Smoking materials

Category 2. Sources that may produce heat while doing other work include:

- Facility fuels
- Electrical power systems
- Chemicals
- Mechanical devices
- Lighting devices
- Radioactive materials

Category 3. Natural heat sources include:

- Sunshine
- Lightning
- Static electricity
- Spontaneous combustion

The previous list describes categories of sources. The video also describes examples of such sources. Appendix C, "Energy Sources," describes other potential energy sources, some of which might take the form of heat. If you do not look for the heat sources, you will not see them.

Once you identify the heat source, you need to track and describe what they did to the "receiver" into which the heat flowed before ignition. Heat sources, such as those previously listed, raise temperatures in objects or people by radiation, conduction, or convection. The sources themselves may also move, as when warmed or heated air rises, and it can suck along or entrain hot particles. Be alert to the possibility of finding one or more *"mobile"* heat sources.

GET THE REST OF DATA YOU NEED

You are rarely the first to arrive at the scene of a fire. The site has probably changed before you arrive. That creates another task — get observations from the first responders at the scene before they leave. Use their observations to identify additional people or objects at the scene, and try to capture what they did. Add those actions to your growing mental movie. The information that you get from the responders should be documented by transforming it into event blocks and adding these events to your time/actor work sheet. The source of the events should be the responder's name.

As you add the objects' names to work sheets, identify where they are now, how to access them, and what needs to be done to "read" what they have to tell about the fire. Use your mental movie or work sheet gaps to pinpoint objects or object actions you need to learn about. Focus on getting stressor actions that are related to the loss outcome.

Test events as they are documented.

- Do the events displayed on your work sheet reflect the times the events occurred relative to each other?
- Do the events displayed have cause-effect relationships to any subsequent events, and if so, are they linked to show that relationship?
- Have all the linked events been checked for the necessity and sufficiency of the cause-effect links?

Repeat the sufficient test until you have linked all and only the event blocks that had to precede the "effect" event for the incident process to continue.

Fill gaps in your work sheet. As the investigation proceeds, each event you add to your work sheet or mental movie will provide a more and more detailed understanding about what happened and why it happened. The remaining gaps drive what you do next.

To fill gaps, you may need to:

- Talk to more witnesses or go back to previous witnesses to get the additional data.
- Examine, reexamine, or test objects to find what you need.
- Guess what might have happened to bridge the gap, and look for data to support such hypotheses.
- Simulate events during part of the incident to understand what might have happened, and seek data to verify part or all of the events.

Identify witnesses. As you add people's names, you need to identify how to get in touch with them and set up an interview or perhaps request a written or oral statement from them.

Use your work sheet gaps to pinpoint people or people's actions that you still need to learn more about. Alternatively, use your mental movie to pinpoint what you still need to do.

"READ" OBJECTS

To "read" objects, use the following strategies:

- ❑ Work from the least damaged areas toward most damaged areas, if possible. (Involvement of victims may outweigh this approach when you have to act promptly to preserve things where the victim was.)
- ❑ Photograph what you move through, and use photos to document such.
- ❑ Be prepared to tell people later what you did during the investigation.

If you have not done so during the walkaround, photograph objects before disturbing them! Prepare notes describing what you photograph or videotape. Capture ending conditions of objects that are likely related to the fire.

To read data from things, start by trying to:

- Determine pre-incident states, locations, and configurations
- Observe and document post-incident states, locations, and configurations
- Visualize what people or objects had to do to produce the post-incident states, locations, or configurations that you see.

For specific objects, examine them to see data such as:

Change(s) that occurred over time. Look for signs of effects such as:

- Low energy levels applied over time
- Structural or maintenance changes
- Cigarettes or similar hidden heating
- Slow oxidation over time such as that involved in spontaneous combustion
- Low-level heat such as steam
- Degradation of wiring insulation
- Frequent overloading or overheating over time
- Chemical degradation
- Prolonged drying or dehumidification
- Worn or sagging surfaces that may have contributed to fire spread
- Changes over time in operating or maintenance procedures

Actor(s) that acted upon them (stressors). Look for energy sources or heat sources that raised temperatures of other objects and where they first appeared. See list in Appendix C. Check with organic-vapor sniffer dogs or instruments, look at wires, equipment, etc.

Action(s) that they are exposed to. Look for indications of what stressed or heated them, keeping an open mind for any energy source on the list in Appendix C.

Sequence(s) of changes that occurred. Look for indications such as:

- What came first, such as differential surface charring or surface deposits, and where smoke was first observed and where it went
- "Shadows" due to something blocking radiant energy effects
- The condition of the victim's respiratory system
- Differential melting, fusing, or oxide formation
- Direction of debris movement such as broken glass fragments or ways the objects fall

Duration of events or ***interim changes***. Look for communication data records to get event-timing data, witness recollections from interviews and walkthroughs of their experience, timing data from char depth or distribution pattern, times shown on clocks involved, and smoke dispersion, color, and production rate observations.

Exposure concentrations, duration. Look at several locations to identify exposure differentials, or do several tests.

Proposals to test objects or samples should address these needs!

Additional Observations

Keep recording additional observations and data as events on a work sheet or mental movie until you have everything you can get out of the objects you had available. Be alert to:

- Indicators pointing to area(s) of fire origin
- Actions by accelerants
- Unexpected fire loads
- Unsuccessful fire safeguard hardware operation
- Objects that accelerated or impeded the fire spread
- Other events that changed the fire process growth or decline

Add events to your mental movie or work sheet if they fit.

Test Events as They Are Documented

- For correct time and spatial sequence
- For cause-effect relationships among events
- For necessary and sufficient logic completeness or uncertainties

GET DATA FROM PEOPLE

First, establish realistic expectations of what your witnesses can give you:

- What could the witness observe?
- What did the witness do?
- Why did the witness do it?
- What did the witness think was expected?
- If indicated, explore the witness's beliefs about operation.

Scheduling Interviews

Before starting your interviews, make sure that you have built your mental movie or work sheet as much as you can from your walkaround. Begin your interviews with responders and then interview:

- Observers
- Available victims
- Participants
- Programmers

People Data Changes

You need to have a way to cross-check what one witness tells you during interviews with what others said and with your observations of the objects. The best way is to lay out next to each other the events they describe, preferably on a matrix work sheet.

Interview Procedures

Before you schedule an interview, read previous witness statements or other previous witness reports for needed data to prepare initial parts of mental movie or points to address.

> *Observe and explain the witness's legal rights as soon as you think crime may be involved.*

- Ensure that the witness is comfortable and will have adequate time to talk to you.
- Open each interview with an explanation of what you are doing (trying to understand what happened and why it happened) and why the witness should help you (to prevent future fires and reduce losses).
- Explain to the witness how he or she can help you. Have the witness describe what he or she saw other *people* and *things* do during the fire.
- Work out a way with the witness to capture accurately what the witness tells you. With a tape recorder, get the

witness's permission for recording. Written witness statements are usually very incomplete and require additional follow-up.

- Ask the witness for his or her name, address, phone number, and if appropriate for investigation purposes, his or her employer, employment date, data of birth, license number, or social security number.
- Ask the witness to describe the incident setting, witness location, and when the witness first became aware of something happening. Show the location on a sketch.
- You *and* the witness need to visualize the beginning of the witness's mental movie.
- Track the witness's observations and actions with questions such as:

  "What happened?"

  "What happened next?"

  "What did you see?"

  "What did you see next?"

  "What did you do?"

  "What did you do next?"
- Try to visualize what the witness tells you in your mental movie so that you can follow the witness from the beginning to the end of the fire and use the movie to raise questions to fill in remaining gaps in your mental movie. Account for all the time the witness was at the scene, if important.
- When you need to get your mental movie restarted, use questions such as:

  "I can't picture what you said when you said..."

  "Forgive me, but I couldn't follow what you said when you said..."
- During the entire interview, keep looking for data about changemakers that produced outcomes.
- Interview strategy is to ask "easy" questions first to finish action scenario, so if the witness ends the interview, you have as much data as you can get. Then start to explore why events happened with questions about conclusions and opinions.
- Identify witness's understanding of expected actions during the fire.
- Finish conclusions and expected actions before asking questions about responsibilities, duties, authority, contradictions, etc., which will be construed as potentially threatening by participant or programmer witnesses.

- Do not hesitate to make event blocks with the witness during personal, face-to-face interviews if a point about a fire is unclear to the witness and you.
- Close the interview with a thank-you, and ask how you can make contact again if anything else is unclear. Leave your card or other information so that the witness can contact you with more information.

Remember, focus on finding changemaker actions.

Some Interview Don'ts

It is important not to let prior incident scenarios bias your questioning during this investigation — start with a blank piece of paper, and use data you get from this case. In your questioning, do not use threatening terms such as fault, cause, fail to, failure, wrong, poorly, inadequate, mistake, or similar words reflecting your judgment of what happened. Do not talk about human error without comparing pre-fire expectations with what actually happened. Do not assume that procedures, regulations, specifications, standards, or design are correct.

Data Sources for Expected Behaviors

Do not stop with something the person did if it affected the harm or loss. Find out *who* did *what* to program the person to do it the way it was done by interviewing the following:

- Trainer and training course developer
- Supervisors and coworkers
- Equipment designers and buyers
- Managers
- Customers
- Physicians, nurses, and psychologists
- Investigators of previous fires
- Media
- Other programmers (names, actions)

Enter the data from witnesses into your mental movie or work sheet as soon as possible after each interview.

Test Events as They Are Documented

- *For sequence* — Do the events displayed on your work sheet reflect the times the events occurred relative to each other?
- *For cause-effect role* — Do the events displayed have cause-effect relationships to any subsequent events, and if so are they linked to show that relationship?
- *For necessary and sufficient logic* — Have all the linked events been checked for the necessity and sufficiency of the cause-effect links?

Cut Out Irrelevant Information and Words

As you build the work sheet and add links, you will note some events that do not play a direct cause-effect role in the process. As it becomes clear they are irrelevant, these event blocks can be removed from the work sheet. Do not discard them until you have completed the final report. Concentrate on the necessary event blocks that are needed to describe what happened and why it happened.

Quality-Check Your Description

Quality assurance checks for your description of what happened and why it happened should consist of reviewing every entry on a work sheet for their form, content, causal linkages, and completeness. *Guide 1* has a more extensive discussion of quality assurance procedures.

PREPARE INVESTIGATION WORK PRODUCTS

Know your customers and their reporting needs or demands. Your outputs may be in the form of oral or written reports. Prepare a supporting file containing documents, photos, test reports, copies of quoted rules, procedures, charts, and an index of the files.

Reports should describe at least the following:

- The scene, what happened when, and why it happened
- Where the fire started
- The ignition source
- The material that was first ignited
- The events that brought the heat and fuel together
- The fire spread and any features, conditions, or fire protection systems that limited or contributed to the fire spread and loss
- Fire suppression activities that limited or contributed to the losses, if not reported elsewhere
- The losses attributable to the fire or fire suppression activities
- The actual or estimated times of key events

Satisfy Visualization Rule

Any report or work product you produce should satisfy a general rule:

> *Make it easy for users of your work products to visualize the fire process, the points you want to make, and the arguments that support your conclusions.*

To satisfy this rule, add illustrations to any reports you submit. Your photographs, sketches, etc., help readers visualize settings for fires and fire events and help you make your points.

Do not include medical records without the "owner's" permission.

To learn from your investigations, try to document and report any investigation innovations or opportunities for improvements in procedures or tools that would help other investigators in future investigations. It is preferable to put such suggestions in a separate report for internal use.

Report Recommendations

It is better to make recommendations in a separate report, but if asked, include a discussion of the following:

- Problems disclosed by investigation in some ranked order
- Potential remedial or preventive actions in some order of preference
- Recommendations for remedial actions
- Monitoring plan to verify expected effectiveness
- Discussion of uncertainties if needed
- Observations about investigation process and possible improvements

See Appendix G, "Recommendation Development Process," for help with the development of recommendations and quality-assurance checks for recommendations. If you have prepared yourself adequately, did a thorough job of asking questions and getting data to answer them, checked the logic and quality of your work as you went along, and gave it one last quality check to make sure that it is a work product you can submit with pride, you are ready to deliver your work products to your customers.

- If you cannot look into everything, do a good job with what you do investigate.
- One key measure of your professional success as an investigator is what you have been able to change as a result of your work.

CHAPTER 4
FIRE INVESTIGATORS' TASKS

The tasks that you will have to perform during a fire investigation are listed here to help you put your investigation workload into perspective. This list describes what you have to do to conduct a fire investigation in the typical sequence in which you will do the tasks. It is designed for you to use as a checklist. The general strategy is first to identify the fire origin and then develop the rest of the fire process description. A detailed discussion of the fire and investigation processes is found in the previous chapters and additional guidance is found in the appendices.

Investigation Preparations

- ❑ Understand the investigation program mission, objectives, and policies.
- ❑ Know what you are investigating.
- ❑ Understand investigation preparation tasks.
- ❑ Have investigation supplies and kit ready.
- ❑ Practice procedures.

Upon Notification of a Specific Fire, Verify Your Plans

- ❑ Know your objective(s).
- ❑ Prepare deliverable specifications.
- ❑ Schedule completion date.
- ❑ Determine the hours to do the investigation.
- ❑ Create your mental movie or work sheet.

- ❑ Understand how to use "changes" in investigations.

ON ARRIVAL AT SITE

Confirm Control of Site

- ❑ Interview the on-scene commander about what happened, if still on site.
- ❑ Identify the site owner.
- ❑ Identify the property owner.
- ❑ Determine who has the resources to control the site. For how long?
- ❑ Know who is in charge of the site and for how long.
- ❑ Ensure access and egress controls.
- ❑ Set access controls.
- ❑ Identify people protection needs.
- ❑ Identify object protection needs.
- ❑ Set egress controls.
- ❑ Control site, safety, and data risks for investigators.

Set Data-Gathering Task Priorities

- ❑ Set data search priorities.
- ❑ Set up documentation materials.
- ❑ Acquire ownership-related data.
- ❑ Set up events handling material.
- ❑ Set up source collection file(s).

Do an External Walkaround at Site

- ❑ Use Investigator's Fire Process Model to guide search and interpretation tasks.
- ❑ Document external ending conditions by using photos, videos, sketches, maps, drawings, etc.
- ❑ Find and establish contact with potential witnesses among bystanders.
- ❑ Look for signs of origin on outside of structures.
- ❑ Identify initial heat sources, deliberate, accidental and natural.

If deliberate:

- ❑ Shift to arson investigation procedures.
- ❑ Start chain-of-custody procedures.

If accidental or natural:

- ❑ Identify and list objects involved and what they did.
- ❑ Ensure that documentation shows points that you need.

- ❑ Add events to your mental movie or work sheet.
- ❑ Document observed or estimated external losses such as fatalities, injuries, property, contents, and system.
- ❑ Document external responder losses such as fatalities, injuries, PPE, property, and other losses.

Do an Internal Walkthrough at Site

Use the Investigator's Fire Process Model to guide data search and interpretation tasks.

- ❑ Document what you walk through as you move through it.
- ❑ Document internal ending conditions by using photos, videos, sketches, maps, and drawings

Look for Signs of Origin on Inside of Structure

- ❑ Identify initial heat sources.
- ❑ Identify heat source type.

If deliberate:

- ❑ Shift to arson investigation procedures.
- ❑ Start chain-of-custody procedures.

If accidental or natural:

- ❑ Identify and list objects involved and what they did.
- ❑ Ensure documentation shows points that you need.
- ❑ Identify or assign unique names to all people and objects and document them.
- ❑ Add events to your mental movie or work sheet.
- ❑ Document observed or estimated internal losses such as fatalities, injuries, property, contents, and system.
- ❑ Document responder losses such as fatalities, injuries, PPE, and property.

Document Remaining Data and Events at Site

After locating what might be the fire origin, finish developing the description of what happened with data from objects and people. Use the Investigator's Fire Process Model to guide the search for events during the fire process stages such as:

- Pre-ignition events
- Ignition events
- Fire spread/flashover
- Fire impingement and injury
- Fire suppression and overhaul
- Loss mitigation actions

Locate and "Read" Data From Objects

- ❑ Act promptly to preserve things where a victim was found.
- ❑ Work from the least damaged areas toward the most damaged areas, if possible.
- ❑ Find energy sources in the facility and the condition of their "barriers."
- ❑ Document what you see with pictures, as you see it.
- ❑ Record description of each picture or video.
- ❑ Keep notes so that you can tell people later what you did during the investigation.

Object Data "Reading" Procedures

- ❑ Determine pre-incident states, locations, and configurations.
- ❑ Observe and document post-incident states, locations, and configurations.
- ❑ Try to visualize what people or objects had to do to produce the changes, when different.
- ❑ Add events to your mental movie or work sheet.

Examine Specific Objects to Find Data

- ❑ *Change(s)* that occurred between pre-fire and post-fire condition.
- ❑ *Actor(s)* data to tell you who or what made change occur; these include:

  Thermal
  Mechanical
  Chemical
  Electrical
  People
- ❑ *Action(s)* data so that you can describe what stressors did to stressees. Examples include:

  Heated
  Ignited
  Oxidized
  Decomposed
  Arced
- ❑ *Sequence(s)-of-changes* data to determine which changes occurred before others.
- ❑ *Duration-of-events* or *interim-changes* data to show relative event timing.
- ❑ *Exposure concentrations, duration* data to define exposure differences.
  - Add events to your mental movie or work sheet.

Additional Observations of Objects

- ❑ Indicators pointing to area(s) of fire origin
- ❑ Actions by accelerants
- ❑ Unexpected fire loads
- ❑ Unsuccessful fire safeguard hardware operation
- ❑ Objects that accelerated or impeded the fire spread
- ❑ Other events that changed the fire process growth or decline
  - Add events to your mental movie or work sheet

Test Events as They Are Documented

- ❑ For correct time and spatial sequence
- ❑ For cause-effect relationships among events
- ❑ For necessary and sufficient logic completeness or uncertainties
  - Fill gaps in work sheet with data, hypotheses, or a question mark.

Identify Interviewees

- ❑ Establish expectations of witnesses.
- ❑ What did the witness observe?
- ❑ What did the witness do?
- ❑ Why did the witness do it?
- ❑ What did the witness think was expected?
- ❑ What can your witnesses give you?

Develop Interview Plan

- ❑ Schedule your interviews (usually) with the following:
  Responders
  Observers
  Available victims
  Participants
  Programmers
- ❑ Read any statements or reports to identify needed data.
- ❑ Prepare initial mental movie to define what you want to know.
- ❑ Ensure that the witness will have adequate time to talk to you.
- ❑ Plan to ask "easy" questions first.
- ❑ Explore why events happened with questions about expectations and opinions.

Conduct Interviews

- ❑ Open each interview with explanation of who you are, what you are doing, and why the witness should help you.

- ❑ Explain how the witness can help you by describing what he or she saw other *people* and *things* doing during the fire and what the witness did.
- ❑ Ask the witness for his or her name, address, phone number, and if appropriate for investigation purposes, employer, employment date, data of birth, license number, or social security number.
- ❑ Work out with the witness a way to document the interview.
- ❑ Ask the witness to describe the incident setting, witness location, and when the witness first became aware of something happening. Show the location on a sketch.
- ❑ Try to visualize what the witness tells you, and add it to your mental movie.
- ❑ Track the witness' s observations and actions with questions such as:

  What happened?

  What did you see?

  What did you see next?

  What did you do?

  What did you do next?
- ❑ When you need to get your mental movie restarted, use questions such as the following:

  "I can't picture what you said when you said...."

  "Forgive me, but I couldn't follow what you meant when you said...."
- ❑ Keep looking for data about changemakers that produced outcome.
- ❑ Identify the witness's understanding of expected actions before or during fire, if applicable.
- ❑ Finish questions before potentially threatening any witnesses with responsibility questions.
- ❑ Do not hesitate to make event blocks with the witness during personal, face-to-face interviews if a point in a fire is unclear to the witness and you.
- ❑ Close the interview with a thank-you and phone number exchange.

Interview Programmers

- ❑ Ask *who* did *what* to program the person to do it the way it was done.

  To determine expected behavior programming, check with:
- ❑ Trainer and training course developer
- ❑ Supervisors and coworkers

- ❑ Equipment designers and buyers
- ❑ Managers
- ❑ Customers
- ❑ Physicians, nurses, and psychologists
- ❑ Investigators of previous fires
- ❑ Media
- ❑ Other programmers
    - Add events to your mental movie or work sheet.

Interrogations differ from interviews; a trained criminal investigator should do interrogations.

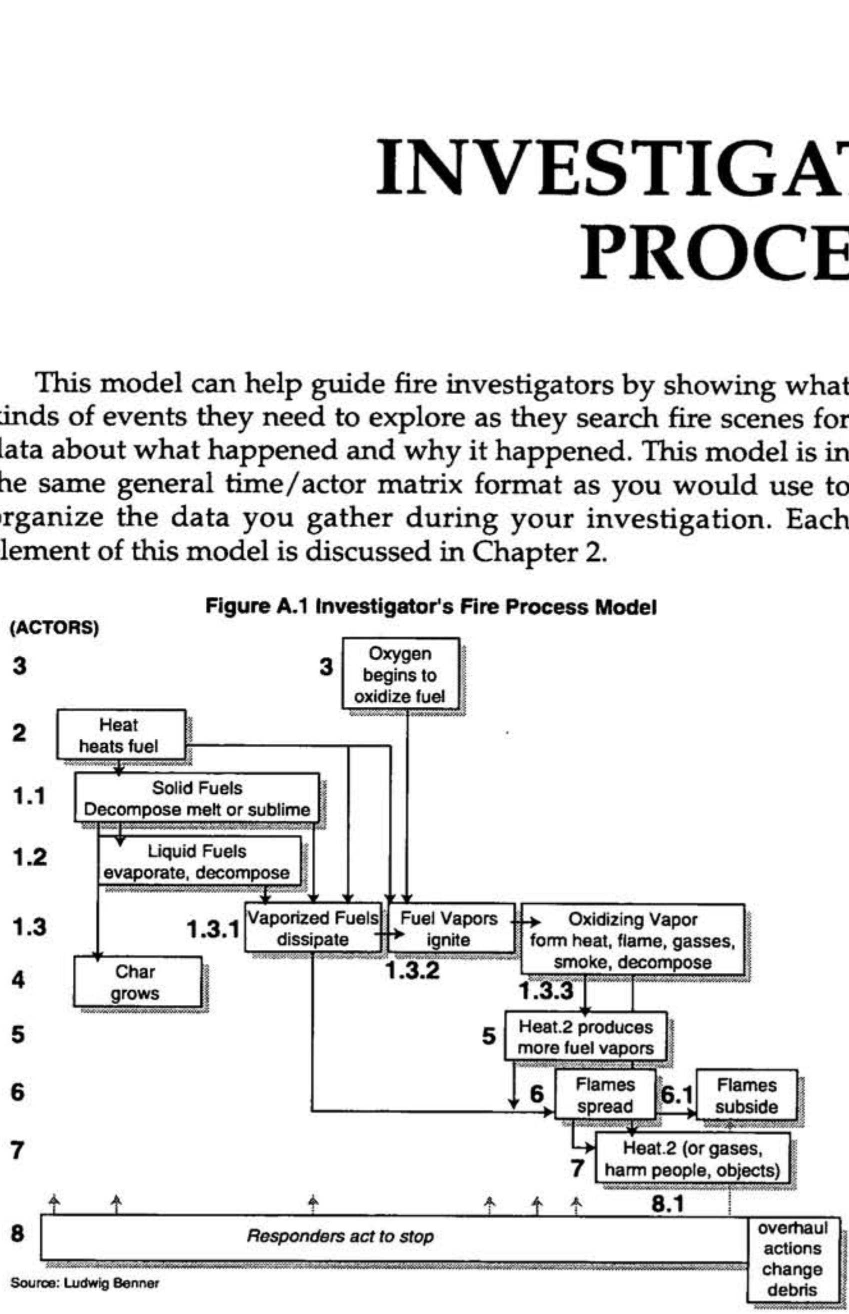
Prepare Report

- ❑ Test events as they are documented.
- ❑ Cut out irrelevant information and words.
- ❑ Quality-check your description.
    - Prepare reports from the work sheet or mental movie and sources, describing:
        - ❑ The scene, what happened when, and why it happened
        - ❑ Where the fire started
        - ❑ The ignition source
        - ❑ The material that was first ignited
        - ❑ The events that brought the heat and fuel together
        - ❑ The fire spread and any features, conditions, or fire protection systems that limited or contributed to the fire spread and loss
        - ❑ The losses attributable to the fire or fire suppression activities
        - ❑ The actual or estimated times of key events
        - ❑ If fire suppression activities limited or contributed to the losses, describe those actions, if not reported elsewhere.
- ❑ Support report with visualization aids.

APPENDIX A
INVESTIGATOR'S FIRE PROCESS MODEL

This model can help guide fire investigators by showing what kinds of events they need to explore as they search fire scenes for data about what happened and why it happened. This model is in the same general time/actor matrix format as you would use to organize the data you gather during your investigation. Each element of this model is discussed in Chapter 2.

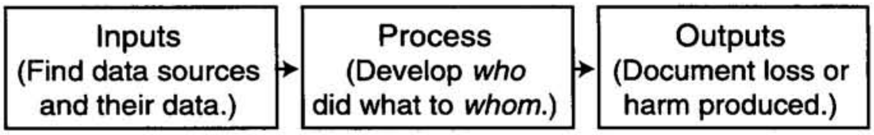
Figure A.1 Investigator's Fire Process Model



Source: Ludwig Benner

A second model that you can use to help you think about the *investigation process* is derived from the general systems model:

Figure A.2

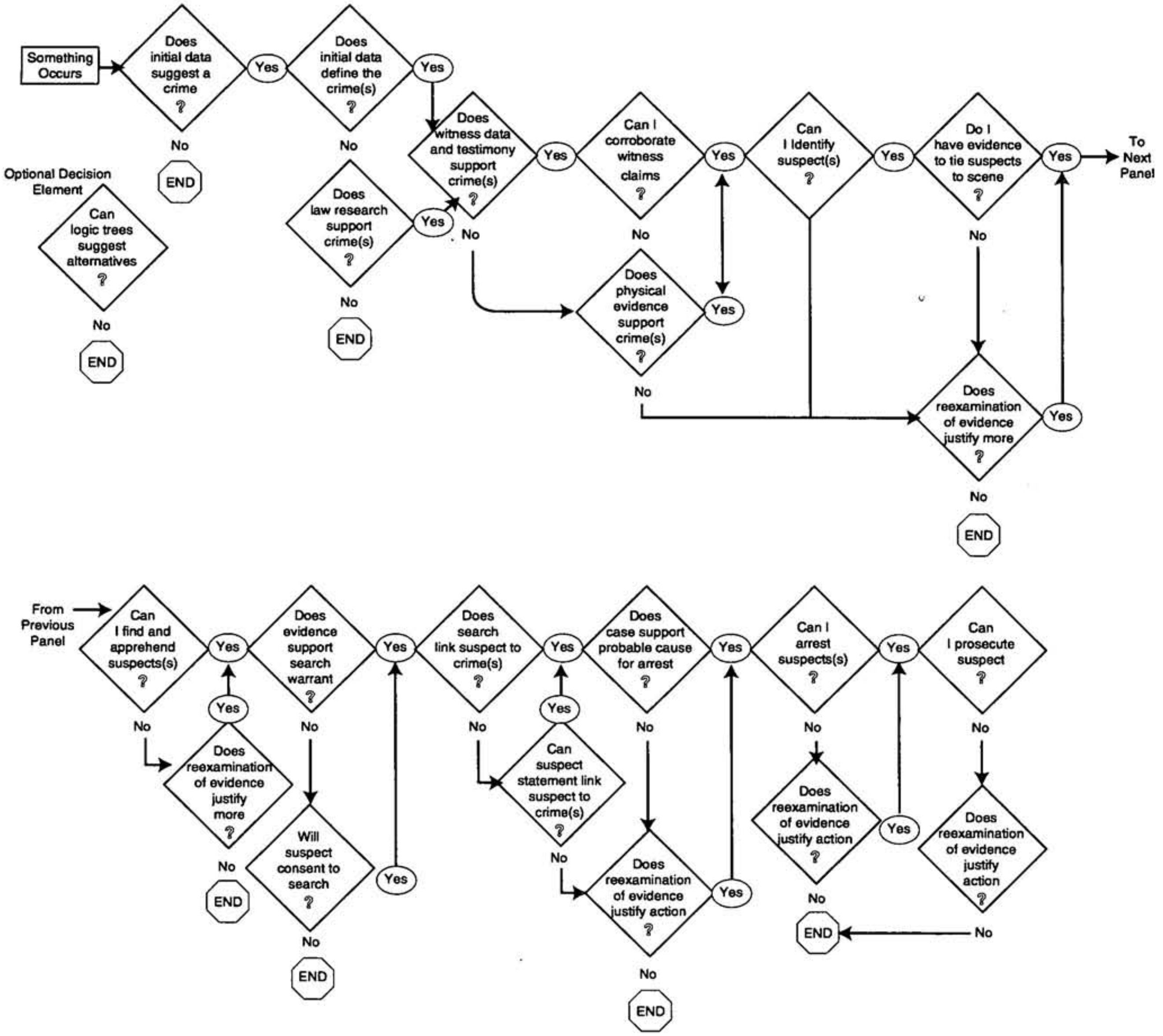


1. *Inputs* for your investigation are the data from data sources that you find and use to identify the fire process.
2. The *process* is what you do to develop a timely, valid description of what people or objects did during the fire to produce the outputs.
3. *Outputs* are your descriptions of the fire and all the harm or losses the fire and responses produced.

APPENDIX B
CRIMINAL INVESTIGATION DECISION MODEL

The following Criminal Investigation Decision Model is provided to give fire investigators an insight into the kinds of decisions associated with the investigation of a crime such as might occur when arson is suspected. The process varies from jurisdiction to jurisdiction, so this model should be viewed only as general information.

Figure B.1
CRIMINAL INVESTIGATORS' DECISION MODEL



APPENDIX C
ENERGY SOURCES

Energy produces changes in objects. This appendix provides a list of energy types for investigators to use as they examine changes in objects during investigations. Energy produces useful work and occasionally harm or loss. To do work, energy typically must be confined and directed by barriers to the point where the work is to be done. For example, such work takes various forms such as deformation, deposits, chemical reactions, motion, or heating. Work generally produces some change in the prior state of the target object on which the energy works. Investigators need to know that energy leaves tracks when it does unintended work in incidents. Those tracks may be in the barriers that were intended to control the energies or the tracks may be outside the barriers. When looking at changed objects, investigators can use these tables as a checklist to look for energy sources that might have produced the changes.

Table C.1 describes natural energy sources. Table C.2 describes energy flow change questions to ask. Table C.3 describes strategies for controlling hazards associated with energies to help with development of performance improvement recommendations. Table C.4 describes managed energy sources.

The symbols ❍ = input energy and ❑ = output energy.

Table C.1
Natural Energy Sources

[ ]Terrestrial	[ ]Atmospheric
❍ Earthquake	❍ Wind velocity, density, direction
❍ Floods/drowning	❍ Rain (warm/cold/freezing)
❍ Landslide/avalanche	❍ Snow/hail/sleet
❍ Subsidence	❍ Lightning/electrostatic
❍ Compaction	❍ Particulates/dust/aerosols/powders
❍ Cave-ins	❍ Sunshine/solar
❍ Underground water flows	❍ Acid rain, vapor/gas clouds
❍ Glacial	❍ Air (warm/cold/freezing, inversion)
❍Volcanic	

Table C.2
ETBA Change Analysis Checklist

Energy Flow Changes	Changes in Barriers
1. Flow too much/too little/none at all	7. Barrier too strong/too weak
2. Flow too soon/too late/not at all	8. Barrier designed wrong
3. Flow too fast/too slowly	9. Barrier too soon/too late
4. Flow blocked/built up/released	10. Barrier degraded/failed completely
5. Wrong form/wrong type input or flow	11. Barrier impeded flow/enhanced flow
6. Cascading effects of release	12. Wrong barrier type selected

Table C.3
Haddon's Ten Strategies For The Control Of Energy Hazards

1. Prevent creation in first place.	6. Separate hazard from exposure by a barrier.
2. Reduce amount brought into being.	7. Modify basic attributes of hazard released.
3. Prevent release of what exists.	8. Make exposures more resistant to damage from hazard.
4. Modify rate/distribution of release.	9. Counter damage already done by hazard.
5. Separate hazard from exposure in time/space.	10. Rehabilitate object harmed.

Table C.4
Managed Energy Sources Checklist

(1) **[ ] Electrical**
- ❍ ☐ AC or DC current flows
- ❍ ☐ stored electrical energy/discharges
- ❍ ☐ electromagnetic emissions/RF pulses
- ❍ ☐ induced voltages/currents
- ❍ ☐ control voltages/currents

(2) **[ ] Mass/Gravity/Height (MGH)**
- ❍ ☐ trips and falls
- ❍ ☐ falling/dropped objects
- ❍ ☐ suspended objects

(3) **[ ] Rotational Kinetic**
- ❍ ☐ rotating machinery/gears/wheels
- ❍ ☐ moving fan/propeller blades

(4) **[ ] Pressure/Volume/Kinetic Displacement (P/V/KD)**
- ❍ ☐ overpressure ruptures/explosions
- ❍ ☐ vacuum
- ❍ ☐ growth
- ❍ ☐ liquid spill/flood/buoyancy
- ❍ ☐ expanding fluids/fluid jets
- ❍ ☐ uncoiling object
- ❍ ☐ ventilating air movement
- ❍ ☐ trenching/digging/earth moving

(5) **[ ] Linear Kinetic**
- ❍ ☐ projectiles, missiles/aircraft in flight
- ❍ ☐ rams, belts, moving parts
- ❍ ☐ shears, presses
- ❍ ☐ vehicle/equipment/movement
- ❍ ☐ springs, stressed members

(6) **[ ] Noise/Vibration**
- ❍ ☐ noise
- ❍ ☐ vibration

(7) **[ ] Dust**
- ❍ ☐ mineral
- ❍ ☐ organic
- ❍ ☐ metallic

(8) **[ ] Chemical (acute & chronic sources)**
- ❍ ☐ anesthetic/asphyxiant
- ❍ ☐ corrosive
- ❍ ☐ dissolving/solvent/lubricating
- ❍ ☐ decomposable/degradable
- ❍ ☐ deposited materials/residues
- ❍ ☐ detonable
- ❍ ☐ oxidizing/combustible/pyrophoric
- ❍ ☐ monomer/polymerizable
- ❍ ☐ chemical toxin/embryotoxin
- ❍ ☐ waste/mixture
- ❍ ☐ water reactive

(9) **[ ] Thermal**
- ❍ ☐ radiant/burning/molten
- ❍ ☐ conductive
- ❍ ☐ convective/turbulent
- ❍ ☐ evaporative/expansive heating/cooling
- ❍ ☐ thermal cycling
- ❍ ☐ cryogenic

(10) **[ ] Etiologic Agents**
- ❍ ☐ viral
- ❍ ☐ bacterial
- ❍ ☐ fungal
- ❍ ☐ parasitic
- ❍ ☐ biological toxins

(11) **[ ] Radiation**
- ❍ ☐ ionizing
- ❍ ☐ nonionizing/laser

(12) ❍ ☐ **Magnetic Fields**

(13) **[ ] Living Creatures or Things**
- ❍ ☐ actions/interactions by people
- ❍ ☐ actions by animals, other species
- ❍ ☐ actions by trees, shrubs, etc.

(14) ❍ ☐ **Moisture/Humidity**

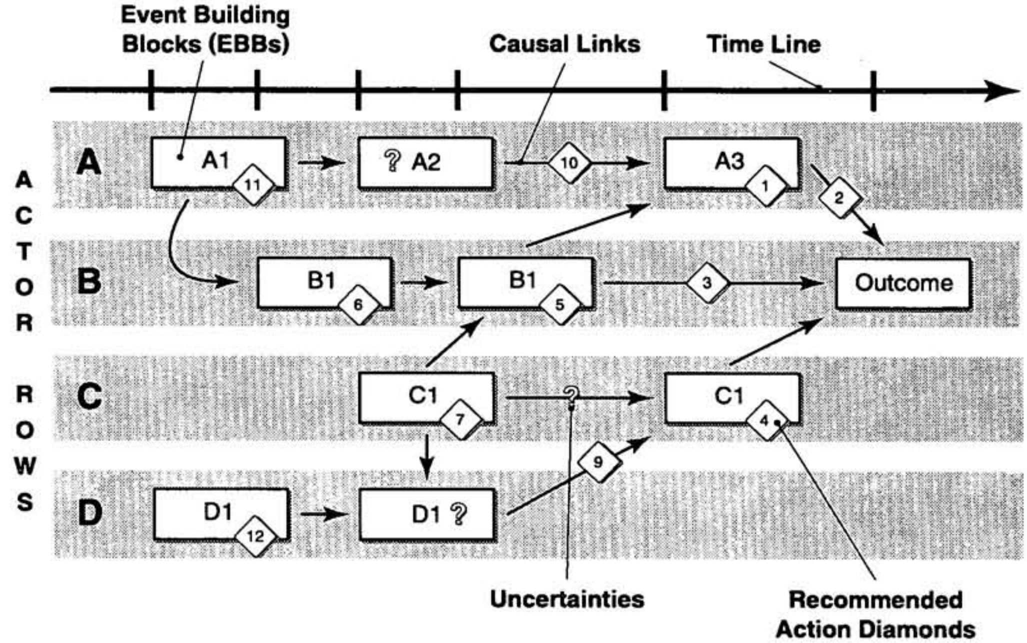
APPENDIX D
INVESTIGATION DATA ORGANIZATION

This appendix provides a simple example of the general elements found in a time/actor matrix work sheet after it has been completed by an investigator. It includes both the description and explanation elements and the problem and recommendation elements of the investigation task.

Time scales are flexible. The number of actor rows may be increased as needed. The links represent relationships that have been tested with sequential, cause-effect, and necessary and sufficient logic. Uncertainty or unknowns are shown by question marks.

Note that all events are linked on the completed work sheet. Narrative reports can be written from the work sheet, using the sequenced events. The numbers in the diamonds represent candidate problems identified and addressed by the recommendation development process.

Figure D.1 Time/Matrix Work Sheet Elements



Source: 10 MES Investigation Guides, Ludwig Benner & Associates, Oakton, VA

APPENDIX E
PHOTOGRAPHY SUPPORT FOR FIRE INVESTIGATIONS

WHY TAKE PICTURES DURING AN INVESTIGATION?

People tend to focus on what attracts their attention in a scene. Photos record everything within camera sights. Photos provide visual documentation that will not change. Photos quickly show the "stage" on which the actions occurred.

Preplan

- Arrange for a camera with auto exposure, zoom, flash, and date/time stamp features.
- Practice with the camera you will use so that you can use it properly.
- Arrange for local photographers who will know what is needed in advance.
- Give someone authority to hire and direct photographers.
- Make sure that everyone knows investigation policy — too many photos are always better than not enough photos.

RULES FOR ACCIDENT INVESTIGATION PHOTOGRAPHY

Rule 1. Photos should provide an accurate record of the scene; you are not seeking an artistic or sensational prize-winning creation. The scene, especially in fires, should include not only the object but also the bystanders.

Rule 2. Make sure that the photos are not reversed, cropped, or off-color. If more detail is needed, changing contrast can help. Use color referent if accuracy is important.

Rule 3. Ensure correct perspectives. Use appropriate focal length and lens angle. Grids may work on flat surfaces. Have horizontal lines to aid perspectives.

Rule 4. Use camera settings needed for the situation. To cope with lighting differences, take photos with different light sources and angles. Check shutter speed versus film speed. Use meters, extra lighting, etc.

Rule 5. Provide accurate size reference. Use people, coins, ruler, etc. Sometimes it is okay to show your hand in the picture.

Rule 6. Use color for maximum information content. Record data in colors. If exact color is important (as it is with fires), use color bar and charts to help developers and investigators.

Rule 7. Always identify each photo (OSHA has a nice form). Documentation should include: date and time, film type, lighting and exposure, location, subject/purpose of view, photographer's name, and witness (if litigation is involved).

Rule 8. Show enough of the scene to provide good orientation. Go from long shots to close-ups of detail. Cover from different angles. Aerial is invaluable for outside accidents, fires, and explosions. Aerial may be available as baseline for before and after information (check U.S. Geological Service or available photo sources).

Rule 9. Do not skimp on film — film is relatively cheap. You may not have to print everything by the time you understand what happened. On the other hand, look at shots to see what you might be missing.

Rule 10. Do not overlook other options, such as multispectral, stereo, thermal, motion pictures, and videotapes, to capture data visually.

SUMMARY

1. Think of visual records as documentation of incident witness plates.
2. Get as much as you can before it changes.
3. Better too much than too little.
4. Watch for tricks and distortions with photography.

(Adapted from DOE MORT training.)

APPENDIX F
TIME/LOSS ANALYSIS FOR INVESTIGATORS

Fires pass through several stages. People or things may intervene to try to reduce loss at any stage. It is important to determine whether the intervention actions were satisfactory, or could they have been changed to produce better outcomes? Time/Loss Analysis (T/LA) was developed to analyze intervention performance. T/LA displays provide a measure of intervention effectiveness and insights into effectiveness of underlying intervention strategies.

T/LA uses estimates of:

1. The time when the occurrence began
2. The time when each loss type began and when it reached its ultimate severity in the occurrence
3. The loss levels at various times during the occurrence
4. The loss levels over time without intervention
5. The times specific intervention actions were taken during the response
6. The expected effects of each intervention action taken, at the time they were taken

The intervention actions should be described in event block (actor/action) format.

Data sources vary with each incident.

1. Witnesses and debris can indicate when specific loss events occurred within workable tolerances. They usually can

provide sufficiently accurate information about the times when an occurrence began to affect them and when the effects reached certain stages of harm.

2. Property damage data are usually less precise, but a consensus can be reached among well-informed individuals such as the fire marshal, insurance appraisers, property owner, designers, or maintenance personnel. "Best estimates" and consensus opinions are acceptable for most purposes. A helpful technique is to develop a total-loss value and then work with increments of that total to develop losses over time.

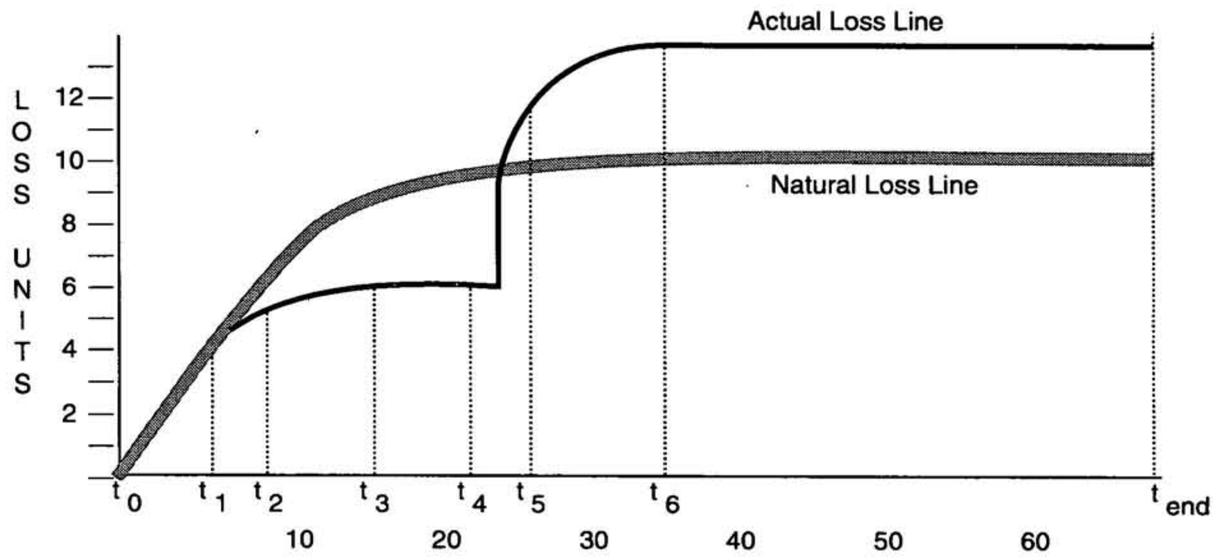
3. After an incident scenario is understood, estimates should be taken of the loss line, if no intervention had been attempted (natural loss line). One approach is to track the potential energy exchanges between sources and exposed targets and project the likely harm that would reasonably have been expected to occur. Consensus-building can be helpful if the experts are willing to help.

4. If disagreement exists, high/low loss estimates at successive times are acceptable and can be displayed on the T/LA charts as high-curve/ low-curve formats.

Data are arranged in a plot showing changes in cumulative loss vs. elapsed time during the response to a fire with notations showing responder arrival time and other action times.

Figure F.1 shows the general format of a plot.

Figure F.1 Example of T/LA Data Plot



T/LA Plotting Procedure

1. *Prepare a set of plotting coordinates.* The horizontal axis along the bottom margin is labeled "time." The scale begins at the moment of the first loss and ends at the time of the last loss. Divide the scale into equal increments, and do not change it. The vertical axis is labeled the "loss." Show scales for fatalities, injuries, and property damage separately along the left margin. Scales are numbered from 0 to the value of the maximum loss or the total elapsed time of the incident.
2. *Plot a line for each type of loss,* showing the estimated loss, accumulated as time elapsed during the mishap.
3. *Plot the estimated natural loss line*(s) if no intervention had been attempted in the occurrence.
4. *Plot the time each person arrived at the emergency* after all the loss lines are in place and then draw a vertical line upward from that time coordinate to the loss lines plotted in 2 and 3.
5. *Label all the data points* and add Chart Title Block describing the occurrence being analyzed.

Comments

T/LA plots indicate performance. Any time that the actual loss line with intervention is higher than the natural loss line, intervention increased loss and is judged unsatisfactory. The further the actual loss line is below the natural loss line, the better the performance. A steeply sloping loss line *after* the arrival of intervenors suggests that either the system was uncontrollable or the response action was ineffective. Losses before response teams intervene must be controlled by objects in place before a fire occurs.

For more information and examples describing the preparation and interpretation of Time/Loss Analysis plots, see Benner (1994) or for more general guidance, DOE SSDC 37 (1987).

APPENDIX G
RECOMMENDATION DEVELOPMENT PROCESS

Fire investigators may or may not be required to prepare performance improvement recommendations. When recommendations are required, fire investigators have to shift mental gears to think about and improve future performance. To do this, they need to know how to discover, define, and assess problems and needs; identify, define, and assess options for reducing future risks; and develop a plan to determine whether the changes implemented are producing the predicted effects.

Take great care to ensure that all recommendations you propose:

- Are based on a valid description and explanation of the fire that will support the action(s) you propose
- Will, if implemented, resolve the problems you have discovered, *for the life of the system*
- Provide for real-time monitoring to verify predicted effectiveness

> *To develop recommendations, you must understand clearly what happened and why it happened, and you need to develop additional and different data to predict the effects of future actions you might propose.*

To develop recommended actions, an investigator needs to:

- Define candidate problems, in terms of *who* did *what when* and with what effects (causal links) and restate them as a need.

- Determine which problems need to be fixed.
- Select the best technical strategy, and identify candidate controls to fix those problems in terms of *who* should do *what* and *when*.
- Predict "benefit" and "cost" tradeoffs of each option, and balance them against each other to rank order "best" candidate recommendations.
- Do a QA check of your selected recommendations.

> *The most efficient way to do these tasks is to use the time/actor events sets on the matrix work sheets showing the fire process. If you are required to define a "cause," make sure that you have a recommendation that fixes each "cause."*

Define Candidate Problems

Use the description and explanation of the fire to discover, define, and assess problems disclosed by your investigation. The fire description on the completed time/actor matrix work sheet identifies all relevant events that need to be examined to discover, define, and assess problems. It, therefore, facilitates innovative thinking regardless of your experience.

Mental movies can provide detailed explanations of what happened, but you will have difficulty finding and defining problems. You will also tend to overlook many problems that are poorly defined, but mental movies are better than nothing.

General Approach to Problem Definition Task

When you use a work sheet, you start by looking for candidate problems by examining one linked event pair or set at a time, until all have been studied. Start anywhere, but cover every pair or set on your work sheet. For *each event pair, set, or link,* ask yourself questions to determine if the event or relationship may be a problem.

"Was this event or relationship expected to happen...

- ❑ At all?
- ❑ The way it did?
- ❑ Where it did?
- ❑ When it did?
- ❑ Why it did?
- ❑ To whom it did?

"Can this event or relationship indicate a need for action and if so, why?"

The answer to each question may suggest a problem event or relationship and helps you define the problem definition in terms of the acronym MOTEL, or

- MAGNITUDE — the strength of the influence on the next event
- ORIGIN — should that relationship have occurred at all
- TIMING — how fast or when it happens or how long it lasts
- EFFECTS — who or what it affects and how or when
- LOCATION — where it starts or happens in relation to exposures at risk

When you identify a problem, restate it in terms of what needs to get done to eliminate or control it. The wording establishes the objective for any action.

Does Problem Need Fixing?

After identifying all the candidate problems, you need to decide which problem or deficiency is worth fixing. The recommendation development process should separate those worth fixing from those you can afford to live with. Focus on the problems you select to fix. Usually this decision is most heavily influenced by the extent of the likely future harm if the problem is not fixed.

Document Problems

Record your description of what the problem is and what need that poses. Keep track of your efforts by marking each event or link you defined as a problem on the work sheet.

Fix Problems

> *Control strategies consist of changing people behaviors or object behaviors.*

As you look at the LINKS, consider introducing changes to achieve control strategies.

- ADDITION of other events or relationships between events
- ELIMINATION of events or the relationship between events
- MODIFICATION of observed events, links or energy exchanges

Any possible change that would favorably change the course of future events indicates a possible recommendation. At this point in the search for options, do not rule out any possibilities based on your past experiences. Experience usually recycles previous problems and imposes restrictive limits on your creativity.

Predict Effects and "Costs" of Each Candidate Option

This task requires knowledge of how things work and how any changes are likely to affect future performance if implemented. You usually need help with this part of the investigation from "experts" who can help you predict whether it would affect:

- Only one event or link
- Only this specific kind of occurrence
- Several kinds of occurrences in this operation
- Several kinds of occurrences in this organization
- Several kinds of occurrences throughout the area or industry

These effects give you a way to state your improvement goal for your recommendation later.

Identify Trade-Offs to Rank Order Candidates

If you find more than one fix, rank order them to reflect their relative desirability. You must weigh and balance other considerations such as:

- Trade-offs with overlapping priorities such as schedule, quality, cost, motivation, and public opinion
- Credibility of the problem and need to whoever has to pay for fix
- Any external or internal pressures for change
- Who creates, bears, and accepts the risks of NOT acting
- Acceptance of the need for and feasibility for implementing the preferred corrective actions
- The effectiveness of the proposed action as perceived by those at risk.

As you go through the various steps, you will recognize the differing trade-offs among the various options. The most cost-effective action will probably be worth selecting.

Do QA of Best Recommendations

You have to decide whether or not to make any recommendations at all from each fire that you investigate. If you identified action(s) that would truly improve future performance and that seem necessary, feasible, and credible, check their quality before forwarding them.

THE BOTTOM LINE:
Will your recommendation achieve your performance improvement objectives, and will you get convincing proof over time that they did?

This summary was a synopsis from Benner (1994). For more detailed guidance, see Benner (1994) or Hendrick (1986)

APPENDIX H
GLOSSARY OF INVESTIGATION TERMS FOR FIRE INVESTIGATORS

Actor
A person or object that does something to influence the progression of the fire process to its loss outcome.

Change
A transition from one steady or dynamic condition to another; may occur quickly or gradually.

Conclusion
A decision or judgment reached after a logical reasoning process.

Data Source
Any person or object that has and can make available information about a fire that will help an investigator understand what happened and why it happened.

Deviation
An action that differs from what was planned, intended, or expected and known before the fire began.

Event
The investigators' basic investigative and analytical building block; what someone or something did — technically, one actor plus one action.

Fire
A rapid, persistent reaction process that produces heat, light, and reaction products; usually the exothermic combining of oxygen with a combustible substance.

An *accidental fire* is a fire process that begins unintentionally and grows unexpectedly or produces unwanted loss. An *incendiary fire* is a fire process resulting from one or more persons deliberately placing combustible materials and their ignition with the intent to do harm. A *natural fire* is a fire process resulting from some action by natural energy sources such as lightning, volcanic action, and ambient outdoor static electrical discharges.

Incident
An aborted fire process; an incipient fire process that was prevented from igniting or reaching a significant loss level by successful intervention actions by some person(s) or object(s).

Intervention
Actions by people or objects to change the course of events constituting the fire process.

Investigate
To observe and inquire into what happened and why it happened; examine systematically. (Informal: How did what you see come to be?)

Objective
The desired accomplishment for which a task is undertaken.

Observation
A noting and recording of an action, condition, or state by an observer.

Opinion
A belief held confidently but reached without positive proof.

Process
A system of interacting components producing changes in people and things for the production or achievement of some output.

Systematic
A set of orderly, structurally interrelated steps based on a coherent network of concepts, principles, and rules.

Witness Plate
Something on or in which is implanted a partial or complete record of events to which it was exposed.

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