Guide 3

HAZMAT INVESTIGATION

This Book was originally created in 1996-97 to provide basic Hazmat accident and incident investigation knowledge, skills and practices for investigation programs, 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 second of four such guides created by and containing material copyrighted by Ludwig Benner Jr.

It is posted here for reference by Hazmat accident and incident investigators who are interested in improving their Hazmat accident investigation knowledge and skills by exploring and applying alternative methods for investigations and investigation quality assurance processes

Guide 3

HAZMAT INVESTIGATION

To complement the Emergency Film Group's
Hazmat Investigation video

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PREFACE

Guide 3, **Hazmat Investigation**, is the third in a series of four investigation guides. It complements the Emergency Film Group's **Hazmat Investigation** video, produced in cooperation with IFSTA. Guide 3 highlights and supplements the information found in the video.

Other Guides and videos in the Emergency Film Group 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.

Fire Investigation covers comprehensive investigations of fires.

These videos and guides are available from IFSTA.

INTRODUCTION TO HAZMAT INVESTIGATION

Hazardous materials (referred to as "hazmat" in this Guide) are a category of materials and substances that because of their form or inherent properties have the potential to do many kinds of useful work, or harm. Properly controlled, they pose modest risks. When subjected to certain kinds of stress, they can produce harm ranging from discomfort to death and from transient environmental harm to permanent environmental destruction or damage to vulnerable species. Because they pose risks, hazardous materials are regulated extensively by national, state, and local authorities and by industry codes and standards.

Hazardous materials can be involved in incidents involving potential releases and actual releases. Both types of incidents are worth investigation. Actual releases that produce harm are usually investigated. Governmental agencies usually become very interested when a large loss occurs. Public interest in investigations usually is proportional to the size of the loss or potential loss.

Unfortunately, large losses are more difficult to investigate than incidents where the potential losses were averted by successful intervention. Large losses are more difficult to investigate because the people or objects that can help investigators understand what happened are usually impaired or lost during the incident. Second, the scope of some large-loss incidents may be so great as to overwhelm investigations, preventing a full investigation of the complete loss-producing process.

For many years, hazmat investigations focused on hazmat release origins and causes to prevent similar future hazmat incidents. For the past twenty-five years, this strategy has been expanded to look at what happened both before and after the release. This expanded investigation strategy produced significant reductions in hazmat risks during that period. Changes have included use of alternative lower risk materials, improved system control designs, changed training strategies and materials for operators and response personnel, emergency response strategies and procedures, information campaigns, improved facility or hazmat handling procedures, and cooperation among all parties interested in reducing risks.

These experiences help and challenge hazmat incident investigators. They help by providing investigators hazmat spill process models. Also, behavior of most hazardous materials during releases is now reasonably predictable. They challenge investigators to gain new insights into remaining problems and to discover the problems associated with new systems. These challenges are addressed in this Guide.

The video **Hazmat Investigation** provides many useful techniques and tips to help hazmat investigators. This Guide is designed to highlight and supplement that information by providing investigators an overview of the essential hazmat investigation process and investigation and analysis tasks needed to produce worthwhile results — efficiently and quickly.

WHO CAN USE THIS GUIDE?

- *Hazmat investigators* can use this Guide to prepare for hazmat investigations and to check off things to do during their investigations.
- *Managers* responsible for establishing hazmat investigation programs can use the Guide to establish investigation specifications and establish an investigation program and judge its quality and value over time.
- *Hazmat investigation supervisors* can use the Guide to help them complete specific investigations on budget and on schedule and to control testing expenses.
- *Industry safety personnel* can use this Guide to help them prepare for and do hazmat investigations.
- *Training or seminar leaders* can use this Guide to help trainees build their general hazmat investigation knowledge and skills.
- *Data analysts* can use this Guide to help analyze episodic hazmat reports and other information to identify problems disclosed by others' experiences.
- *Expert hazmat investigators* can use this Guide to improve their efficiency and effectiveness and to evaluate their own performance.

- *Designers* can use the Guide to identify the kinds of problems they need to design out of their work products.
- *Regulatory investigators* and codes and standards technical staffers can use the Guide to investigate the effectiveness of their regulations, codes, or standards scheme.

CHAPTER 1
GENERAL PREPARATIONS FOR HAZMAT INVESTIGATIONS

For detailed discussion of preparations for investigations, please refer to Guide 1, **Introduction to Investigation**. Key preparation steps for investigating hazardous materials releases are presented in this section.

To prepare for hazmat investigations, you should:

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

Hazmat investigations share one common objective with all investigations — to determine *what* happened and *why* it happened to reduce future risks. A second objective is to try to understand what intervention actions limited the harm so that you can determine what might be changed to reduce future losses.

Hazmat releases are a special category of investigations because of the risks involved. Hazmat investigations differ from other investigations because of the nature of the materials and systems involved, their inherent dangers, the length of the incident, and the nature of the involvement of emergency responders. In these circumstances, it is particularly important to establish clear objectives for the investigation of specific incidents and pay attention to issues of scope, interim recommendations, and report content.

INVESTIGATION SCOPE

The best place to state your objectives is in your organization's Investigation Policy statement. Establish the scope of the investigation before you actually start the investigation. Questions that you may need to ask to start the investigation include the following:

- Should you prepare only a description of what happened, or should you also develop recommendations?
- Should you get into the vehicle aspect of the incident or just the hazmat aspects if you are investigating a truck or rail spill?
- Should you be looking for violations of regulations, standards, or procedures; or should you also be looking for the effectiveness of those regulations, standards, or procedures?
- How far should you delve into the decision making that resulted in the interactions you find?
- What actions are needed to reopen a major chemical plant, refinery, or other facility involved in an incident as quickly as possible without introducing unreasonable risks? Often, these decisions depend on your understanding of what happened.

REPORTING OBJECTIVE

Before you submit your report, determine the expected format, scope, content, and delivery demands by answering the following questions:

- Who will use the report and for what purpose?
- What is the format of your expected report — verbal, completed form(s), written narrative, flowchart, or some other format?
- What is the scope of the findings you are expected to report?
- Should you limit the report to a summary of findings or "causes," or should you include any deficiencies you observe, even if not related to the incident?
- Should you report problems or needs and propose recommendations?

- If you are to report "cause," what are the criteria for selecting one or more causes?
- Should the content include a summary or complete description of what happened?
- How can you best serve the needs of anyone who must act on the information you provide, and to what degree should you report the rationale and trade-offs supporting any recommendations?
- Should the content be only factual, or are you expected to offer your opinions and beliefs?

The degree of detail to which you are to report the behavior of the released hazardous material also requires a decision. For example, if a gas cloud forms and covers a large area, do the reporting objectives include:

- A description of all injuries and why they occurred
- Categories of injuries and why they occurred
- A full or partial dispersion map
- Discussion of regulation effectiveness
- Emergency response analysis and critique

KNOWING YOUR LIMITATIONS

Hazmat investigations have special limitations. First, if the release is large, it is likely that the harm will be great. Unlike an automobile collision, which happens quickly, a hazmat release may last days or possibly even years if serious groundwater contamination occurs, for example. Ensure that time limits do not limit the achievement of your investigation.

A second limitation may be the kind of investigation you conduct. For example, you may wish to let specialized investigators from agencies such as the Nuclear Regulatory Commission do investigations of large radioactive materials incidents. Large explosions are better left to Federal Treasury Department investigators. Try to define the categories of materials you will NOT investigate. Work out arrangements either to participate in investigations with others as the primary investigation organization or simply to get their reports.

Another limitation on your investigation is the personal risks that are posed to you by the hazardous materials. In some cases, such risks may be very significant, as with an infectious agent or a radioactive material release. In such incidents, the investigation may be delayed because of delays in accessing the site. It also may require a different set of witnesses who worked during the release to stabilize the site and make it safe.

When you observe indications or suspect that the release or spill resulted from deliberate actions, such as a possible crime, you may need to turn over the investigation and any objects or witness data you have collected to a criminal investigator. Criminal investigations are broader in scope than are incident investigations. They involve defining the crime; identifying suspects; determining motive, means, and opportunity for the suspect; chain-of-custody requirements during evidence gathering; and witness interrogation rights and procedures. That process is well-defined by law and must be observed faithfully to achieve successful prosecution of the perpetrator. This is not intended to suggest that your incident investigation should be any less rigorous and careful in determining what happened and why it happened but only to caution that requirements of law play a larger role in criminal investigations.

RECOGNIZING OTHERS' INTERESTS

Sometimes the scope of a hazmat release involves a large number of bystanders, unlike other kinds of incidents. For example, the number of interested parties increases dramatically when a widespread gas cloud spreads or threatens to spread into a community. A hazmat tanker truck incident on a major urban traffic artery results in major disruptions of many lives in a community — whether or not a release occurred. This means more people (including those in public safety, political figures, and the media) may express interest in your investigation or may conduct their own inquiry with different agendas and objectives. Other concurrent investigations may affect the course of your investigation. Unless the investigation results are consistent, controversy will inevitably result. You need to prepare to deal with others' interests and investigations.

> *Always expect others to act in what they perceive to be their best interests, and you will never be disappointed.*

KNOWING YOUR INVESTIGATION PROCEDURES

General investigation procedures are described in Guide 1, *Introduction to Investigation*. During investigations, be prepared to:

- Formulate questions quickly and efficiently.
- Find, observe, and record data to answer those questions.
- Organize your information, and test it to enable you to understand what happened and why it happened.
- Report to others a description and explanation of what happened.

Special Data-Gathering Procedures

When working on hazmat incidents, you will face specific data-gathering procedures that differ from one hazmat incident to another. For example, gathering data about a radioactive release differs from gathering data about a gasoline spill or gaseous product release or an explosion. You need to be aware of the potential differences and prepare for them. Part of the preparation involves getting acquainted with different kinds of hazmat behaviors you might encounter. You can do this by looking over emergency response guides such as the U.S. Department of Transportation's *Emergency Response Guide* for categories of materials, Sax and Lewis's *Hazardous Chemicals Desk Reference*, or hazmat Material Safety Data Sheets (MSDS) available on the Internet for specific materials. Reports of past incidents can provide models of hazmat release behaviors. Hazmat owners should be able to furnish you with this kind of information.

Your main goal is to get a working knowledge of the various kinds of incidents and behaviors you may encounter. Get acquainted with the hazmat "classes" and "divisions" from sources such as the *Emergency Response Guide*. If you do hazmat transportation investigations, you may encounter any one of these materials in an incident. If you work in a facility or investigate incidents in the facility, get the local Material Safety Data Sheets (MSDS) to help you develop knowledge of the materials present.

PRACTICING INVESTIGATION PROCEDURES

Your preparations must include *practicing* the investigation process steps to build your investigation skills. Practice should include the following:

- Thinking about what is being investigated as a process so that you get used to basing your actions on that perspective
- Tracking the changemakers that produced the outcome to help you formulate questions and recognize answers you need
- Transforming observations into consistent, documented, and analytical event-building blocks so that you can analyze your data as your investigation proceeds
- Focusing quickly on what you still need to find out; organizing events by building time/actor matrix work sheets, or by creating mental movies of what happened
- Identifying and documenting causal relationships among interactions that determine how the incident progresses toward its outcome

- Structuring and confirming or discarding guesses to bridge any gaps in your understanding of what happened
- Doing a quality assurance check of your work products; producing a satisfactory report of your work

If your objectives include developing recommendations, you should practice

- Discovering, defining, and assessing problems and needs
- Formulating effective action recommendations to reduce future risks or improve operations
- Doing a quality assurance check of your completed recommendations and follow-up plan

Hazmat incidents do not happen very frequently. Practice is needed to help you maintain and improve your proficiency. As part of your skill growth for investigations, you can practice using these procedures whenever you are trying to understand something that has happened. You will also see the value of the thought processes.

Another practical way to do this is to take reports of hazmat releases — either current or recent cases — and apply the event flowcharting methods to those cases. This enables you to enhance your skill levels, learn about ways releases can occur, perhaps see ways to improve the investigation or problems with what was done, and see examples of useful lessons you can learn from the investigations.

PREPARING THE EQUIPMENT YOU WILL NEED

Hazmat incident investigators may face risks posed by residual hazardous materials at the incident site, resulting in a need for personal protective equipment (PPE) during your investigation. The equipment you need depends on the nature, quantity, and form of particular hazardous material you will face and the stage and size of the release. For example, corrosives require the investigator to wear special protective clothing, but toxic, infectious, and radioactive materials require the investigator to take other protective actions.

If you MUST do any investigation tasks in "live" spills, make sure that you have the proper PPE, proper training in its use and decontamination, and proper certification in its use in hazardous situations.

Residual hazardous materials may also affect other devices or equipment you may need. For example, a radioactive material release requires different measuring instruments than does a flammable material spill. If you carry any special hazmat equipment, make sure that you are trained in its use.

Your investigation policy should determine the contents of your investigation kit. Your investigation kit should not tempt or require you to violate a key investigation policy:

> *Collecting hazmat incident data is not worth risking an investigator's life, limb, or health.*

In addition to tools customarily carried on your job and personal protective equipment, consider including the following in your "go-kit":

- A bound notepad (to keep together any notes you make) and pens
- Several 3- x 3-inch Post-It™ notepads to record data
- 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
- This Guide as a reminder checklist and "how-to" resource

Your "go-kit" contents will depend on the kinds of hazardous materials incidents you expect to investigate.

KNOWING WORK PRODUCT QUALITY ASSURANCE PROCEDURES

This Guide assumes that you want to do high-quality hazmat investigations. The investigation process relies heavily on you to check your own work as you proceed. As the investigation proceeds, you can measure your work against your quality assurance standards. The procedures in this Guide can help you do this quickly and efficiently as each new piece of data is acquired.

Before you can do a quality assurance check of your work, you need to know the criteria for assessing your work. The key yardsticks for any investigation are the objectives specified. Build quality assurance into your work throughout the investigation process. The procedures describe how you can do this with logic tests as you add data. By doing this, you will be able to do a better investigation in less time than if you leave your quality assurance action to the last minute or skip it.

KNOWING SOURCES FOR HELP

You will furnish *investigation* process knowledge and skills to an investigation. Other expertise may be required to help you understand how controls or other hazmat handling systems work or were intended to work. At other times, you may need special help to "read" objects so that you can access the data they hold about interactions during the incident. That expertise may be found locally, at a university, at some industry source, in a governmental agency, or in the safety community.

Some experts are very knowledgeable about the inherent properties of hazardous materials or metals, but they are *not* expert in hazmat release processes or their investigation. You need to prepare to direct effectively the work of experts so that they deliver the help you need to describe what happened. Inadequate or weak direction and supervision of experts can be costly and frustrating. A good way to prepare for this task is to review the test plan discussion in Appendix E, "Basic Hazmat Incident Test Plan Elements," and always insist on test plans.

In large releases, help is usually needed to acquire data and document the scene. This help may come from other agencies charged by law with investigating the incident, but that raises other problems as you will see. Be prepared to explain what data and format you need to ensure that you receive the technical expertise to complete your understanding of what happened.

Do not overlook possible help from an increasingly available source — predictive hazard analyses. Such analyses are sometimes prepared for changes to existing hazmat activities and new activities. These analyses are system reviews performed by "investigators" to identify safety risks before incidents occur and are usually well documented. Be aware that these analyses are, in effect, predicted "incident scripts" that describe how incidents might happen. They can help you understand the systems involved in the incident, and how they function. Their review during hazmat investigations provides insights into their completeness and validity. If you note problems, this provides you another opportunity to improve expectations for hazmat risk reduction.

KNOWING CONTENTS OF THIS GUIDE

Your preparations should include viewing the videos and being able to find and use the tools in this Guide. The appendices contain additional guidance for specific tasks. The hazmat behavior model and its application are presented in this Guide to help you work your way through the incident in an orderly way. This guidance will not help if you do not use it.

KNOWING WHAT TO DO IF CRIME IS SUSPECTED

As with any investigation, you need to know what to do the instant you begin to suspect that an incident was not accidental but the result of deliberate or willful action. This suspicion immediately changes requirements for investigation procedures.

Criminal investigations are governed by very specific, judicially imposed restraints to make a case to support prosecution. Note that a violation of a safety regulation is usually resolved by civil action after the "facts" are known. Only very rarely have criminal actions been initiated for knowing and willful violations of hazmat regulations. For these reasons, you should always be meticulous about documenting the sources of the events you use in your incident description.

CHAPTER 2
KNOWLEDGE FOR HAZMAT INVESTIGATIONS

This chapter describes what you need to know about a hazardous material (hazmat) incident and how to do an investigation. You have to know what hazardous materials were involved and what the hazardous materials did. Thus, knowledge of hazardous materials and their behavior is an essential investigation starting point.

HAZARDOUS MATERIALS

A hazardous material or substance may be a liquid, a solid, or a gas that can do harm if it escapes in an uncontrolled manner from its container. Hazmat releases can have a wide range of results, ranging from major catastrophes to incidents that were controlled by emergency response efforts. Hazmat incidents can occur in many different circumstances such as in a large industrial facility, in a room in a home, or at a street corner.

Behavior

Categories of hazardous materials are defined largely by a regulatory scheme devised for transportation or other federal agencies for safety purposes. These categories reflect, with a few exceptions, the inherent properties, quantity, and form of hazardous materials or substances. Those properties result in characteristic behaviors when they react or escape. This behavior includes the reactivity, dispersion, and effects of the material when released, as well as effects of container behavior in incidents. General hazmat and container behaviors in incidents are represented by elements in the model shown in Appendix A, "Hazmat Incident Process Model for Investigators."

Classification Vs. Name

Current regulatory schemes provide a hazmat classification system for all regulated hazardous materials. Materials in one class or class division can behave a lot like materials in other classes. For example, materials from six regulatory classes have been known to detonate in past incidents. Therefore, investigators should recognize that the *name* of any hazardous material involved in an incident, rather than just its *class*, must be the focus of their initial hazmat incident investigation efforts. Do not settle for what are sometimes called **NOS** or "not otherwise specified" generic descriptions of hazardous materials in shipping documents! **Hazmat behavior cannot be predicted unless the name, form, and quantity of the material are known.**

> *Knowing the chemical or trade name of the materials or substances involved will help you identify the hazards and risks. This is for your safety as well as to help you understand what happened.*

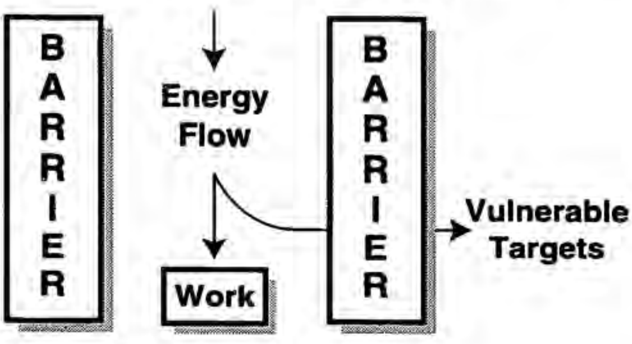
Energy Sources

Hazardous materials are considered hazardous because they are energy sources that can do desirable and undesirable work. For example, when controlled, chlorine gas can kill bacteria in water, turn paper white, keep swimming pools attractive for recreation, or bleach stains out of clothing — all desirable work. When these energy sources are not controlled, they can do undesirable work. Chlorine has the potential to fatally injure people when it is not controlled, as in an accidental release in a railroad incident. *Control* makes the difference in hazardous materials energy sources.

Energy Barrier Concept

Control is achieved with barriers. You need to understand the energy control model. It helps you to formulate good questions during investigations. The Energy Barrier Target Model describes how energy is controlled and what happens when energy is not controlled (Figure 2.1).

Figure 2.1
Energy Barrier Target Model



Barriers take many forms, depending on the inherent nature and energy content of the energy source to be controlled. Investigators need to view barriers, in the broad sense, as controls put into place to control the behavior of the hazardous materials capable of doing harm. Barriers can be physical, such as pressurized containers, or they can be procedural, such as quantity limits on the amount of material placed in a container during loading. See Appendix C, "The Control of Energy Hazards."

Containers

The most prevalent barrier is a *container*. Containers are typically selected based on the nature, form, and quantity of the energy they must control. Hazmat containers can range in size from small vials to huge supertankers. Examples of containers include the following:

- A cylinder or piping is a common container for high-pressure gases.
- Insulated wire is an electrical energy container for carrying the electricity.
- Very large lead-lined casks are barriers for high-level radioactive materials.
- Bags are barriers around powders and pellets that may be irritating.
- Spray cans are barriers controlling pressurized propellants and hazardous insecticides.

Space

Another form of physical barrier is *space* or *distance*. For example, the idea of separating potential targets from the energy source is used for warning signs to "keep away" from electrical switch gear boxes.

Procedural Controls

Procedural controls are another form of barrier. For example, some procedures specify separation of incompatible materials in storage, which places reliance on the actions of people to control risks. Procedures may be implemented in other ways such as placing a placard with a warning symbol and number on a hazmat transport vehicle.

Quantity Limits

Another form of barrier for control purposes is quantity limits. For example, a fraction of an ounce of an explosive material provides us with the pleasure of fireworks displays, while pound quantities pose a lethal threat if they detonate. The potential for harm associated with hazardous materials is typically dependent on the quantity and form involved.

Regulations Regarding the Handling of Hazardous Materials

Hazardous materials are regulated by various federal, state, and local regulatory bodies. The regulatory system in the United States is very comprehensive and complex. You need to be aware of the regulatory agencies involved because investigators from one or more of these agencies might appear at an incident.

For general guidance, if the incident occurs during transportation, the Department of Transportation regulations probably govern the transportation. Intermodal containers or vessels may involve the U.S. Coast Guard. Air transportation may involve the Federal Aviation Administration regulations or its investigators. Sometimes the National Transportation Safety Board may get involved.

If the incident occurs on private property at an industrial or commercial facility, the U. S. Department of Labor's Occupational Safety and Health Administration or state equivalents are probably applicable, and their investigators may conduct either an independent or cooperative investigation with environmental protection agencies. Other agencies may get involved in other kinds of incidents such as military, mining, or incidents regarding off-shore oil platforms, public lands, hospitals, or agricultural incidents.

Some regulations depend on the nature of the materials. For example, radioactive materials may involve U.S. Nuclear Regulatory rules and investigators. Biological hazardous materials may involve other rules and Center for Disease Control inquiries. In addition to federal and state governmental regulations, numerous local codes and industry or professional organization standards address hazmat investigations.

The regulations establish the minimum standards for hazmat safety and what people handling them are expected to do. If there is any uncertainty, a place to start tracking down the applicable regulations is in the *U.S. Code of Federal Regulations*, Title 49, Part 173. If you have access to the Internet, it may prove helpful to access the U.S. Department of Transportation's hazmat information system at its current Internet site:

hmix.dis.anl.gov (146.137.100.54)

You might network with experts knowledgeable in the regulation system such as a safety representative of a trucking company that hauls packaged hazardous materials or a local hazmat incident response team member. Material Safety Data Sheets (MSDS) for specific products are also useful references to get acquainted with hazmat safety precautions.

Containment System Design

Generally, the philosophy for containing hazardous materials during transportation is to design the "packaging" (or containment system) to withstand conditions "normally incident to transportation," including "normal accidents." In facilities, the codes, standards, and margins of safety govern the design philosophy for a containment system. However, few standards govern the selection of hazardous materials that are used in processes or systems, which is one of the key factors in eventual hazmat incidents. Because most packaged and many bulk hazardous materials are transported at some time, most hazmat packaging is determined by transportation regulations.

In industrial settings, "packaging" takes on a different meaning when large bulk quantities of hazardous materials are processed. For example, the hazardous materials in an oil refinery or chemical plant are contained in a variety of "containment systems" ranging from chemical reactors to huge storage tanks. The designs conform to various professional society codes (for example, the American Society of Mechanical Engineers, or ASME) or industry standards (such as the American Petroleum Institute, or API). Sometimes transportation containers governed by transportation requirements are used for short-term storage in or near industrial facilities.

Identifying Hazardous Materials

Identify hazardous materials in transportation by required warning signs or labels and shipment documentation. You usually will know whether the incident you are investigating involves hazardous materials. If not warned, you must recognize and view any hazmat warning signs as "flags" to tell you that hazardous materials are present in an incident. The name of the material may be more difficult to find, and finding it may require assistance from emergency response personnel who usually would have identified it by the time you arrive at the site. Reference documents (with the material description) accompany a shipment and provide phone numbers to call for help and should be used if other material is not already available on site. A hazmat transport container is generally fully loaded and placarded or labeled, or it is "empty." Empty does not really mean that there is nothing in the container because some residual hazardous material usually remains after unloading most transport "containers."

In industrial facilities, materials usually are identified in emergency preplans, but the quantities may or may not be readily identifiable by external inspection. Levels in storage tanks may vary depending on supply and demand in the marketplace or plant outages.

HAZARDOUS MATERIALS INCIDENTS

A hazmat incident is a process that produces undesired outputs. Hazardous materials involved in incidents behave according to natural laws and thus act relatively predictably. Past investigations using the methods described in these Guides have resulted in a general understanding of the incident process and models describing that process. Therefore, a hazmat incident investigator has available a general incident process model (see Appendix A, "Hazmat Incident Process Model for Investigators") to guide the following investigation tasks:

- The definition of the scope of an incident and what to investigate
- The orderly formulation of questions to determine what happened and why it happened
- The organization of data needed to understand and explain what happened efficiently, consistently, and promptly
- Assessment of the quality of the investigation and description of what happened

To explain why something happened, deviations from codes, standards, regulations, or procedures are involved in over half of the hazmat incidents that you may investigate. Your challenge is to consider both whether a hazmat incident involved a deviation from a code, standard, regulation, or if the code standards or regulations may need attention.

NOTE: The Model is applicable to *explosive* reactions during hazmat incidents. The **Hazmat Investigation** video provides much helpful guidance (which is not repeated in this Guide) for investigating explosions. It is supplemented by using the Model elements and investigation procedures described in Appendix A.

Stressors Stresses Hazmat Container

Hazmat containment systems are built to accommodate "normal" handling or reaction stresses such as internal operating pressures, stacking or movement during storage or transportation, and ambient temperature changes. Over time, these normal stresses have been defined and translated into specifications for:

- Containers
- Production process components
- Reuse limitations
- Handling procedures
- Warning markings
- Storage requirements

When stressors on a container system exceed the system's accepted or "design basis" limits on which its design is based, the risks of adverse behavior by the containment system or its contents increase. The effects of such stressors acting on containment systems produce three kinds of potential harm:

- The container itself may come apart or fragment and do harm.
- The hazardous material may escape and cause harm.
- If the hazardous material reacts, the reaction products may be released and cause harm.

Sometimes more than one of these effects are present in an incident. A specific hazmat release begins with the unintended stressing of the hazmat or its containment system, or both simultaneously.

Your task is to observe, define, and document the state of the hazardous material and containment system when the stressor began to stress the system. Then you must identify and document the stressor(s) and what it or they did to start the incident.

The task varies with the nature of the material, the incident, and the stressor. Stressors may be internal or external to the system. A stressor can be a person or an object. For example, when a storage tank operator overloads a storage tank, stresses are placed on the tank and contents that are different from the stresses produced by corrosive hazardous materials impinging externally on the same tank.

From past incidents, investigators have learned that the most common stressors of containment systems and hazardous materials in those systems fall into one of several categories — thermal, radioactive, ambient, chemical, electrical, and mechanical. You can use the acronym TRACEM to help guide your search for stressors if they are not obvious.

STRESSOR STRESSES

HAZMAT CONTAINER

Stressors:
Thermal
Radioactive
Ambient
Chemical
Electrical
Mechanical

Thermal

The following kinds of actions produce temperature differences in objects that result in stresses in those objects. These thermal stressors are:

- Actors that heat objects
- Chemicals that react
- Mechanical objects heating other objects by friction
- Self-refrigerated liquids chilling objects
- Volatile liquids evaporating
- Gases expanding through small openings.

Because heat tends to dissipate as soon as the heat-generating source is exhausted or removed, the thermal stressor may have disappeared by the time the investigation begins. This means that the investigator may have to learn of thermal stressors indirectly through testing or examination of objects, residues, or observed hazmat behaviors during the incident. Observations of the environment for indications of overheating (charring and discoloration) or freezing (distortion and shrinkage) may be useful.

Radioactive

Radiation from radioactive materials can induce other forms of stress, ranging from small disturbances in electronic or chemical objects that might affect controls to induced personnel disability. Radioactive materials stay at the site unless transported by other propellants; therefore, they are readily identifiable with radiation counters.

Ambient

Ambient stressors may include weather-related events such as sunshine, ambient temperature changes that freeze moisture-stressing adjacent objects, and winds or wind-borne atmospheric precipitation. Earthquakes can induce stresses in containment systems. Subsidence can do the same.

For investigators, atmospheric stressors are most readily identified by external effects on containment systems. For example, freezing soil can lift foundations, stressing any structures on the foundation such as tanks, piping, and control systems. Effects of windblown debris can be observed on the outside of whatever was struck.

Chemical

Chemical reactions produce reaction products that can create expanding gases, corrosive reaction products, or heat. Each has the potential to produce stresses in hazardous materials and containment systems. For example, an explosive material reaction produces rapidly expanding gases and heat. If the gases expand at speeds greater than the speed of sound, the reaction is called a "detonation."

Investigators can find data about a chemical reaction by examining "witness plates" of the reaction. Data to help investigators identify chemical reactions include:

- Bulging or distortion of the containment system or attachments
- Residues on debris
- Indications of temperature differentials on objects
- Eroded surfaces due to corrosive effects

Electrical or Electromagnetic

Electricity may produce several kinds of stressors. Static electricity can provide the energy to ignite an oxygen and flammable liquid mixture. Lightning can ignite a hazardous material in an oil storage tank or knock out process controls. Continued electricity flow in a heater led to an oxygen tank explosion on Apollo 13. Interruption of electricity flow to a control valve can leave a cooling water valve closed.

Electromagnetic effects may induce electrical flows in conducting objects within the electromagnetic fields. Concern about this energy source is significant in the explosives field, where protection against induced currents is one key safety precaution.

Identification of electrical energy flow in hazardous materials or containment systems may be difficult for investigators. It is dependent on some conductor, electrical potential in or around the conductor, and how barriers might have been breached to permit the flow or interruption of the flow. The electrical flow may leave tracks, identified by work it did on the containment system or components such as arcing or indications of overheating of conductors. Arcing in flammable environments requires determination of the "hot" spot location.

Mechanical

Mechanical impacts, gravity, and momentum in transportation or parts in reciprocating compressors or pumps are examples of mechanical stressors. Such stressors can introduce changes in the containment systems or affect the hazardous materials in those containers. An auto colliding with a tanker carrying gasoline can overstress the tank and breach it. A backhoe can dig into a pipeline carrying hazardous materials.

You can usually identify mechanical stresses by the changes in the containment system such as gouges, dents, tears, distortion, and similar displacement of material. Your observations of damage often indicate the direction (vector) of the mechanical stressor, its intensity, or its shape or configuration before the impact or collision.

Another type of hazardous material that might be encountered rarely is etiologic agents or viral and bacterial infectious materials in some laboratories, medical facilities, or in transportation. At the first indication of the presence of such agents, call in expert medical assistance if that has not been done by the responders. Use Appendix B, "Energy Sources " Table B.2 to help you identify stressors.

CONTAINER SYSTEM BREACHES

Breach types:
crack
puncture
split
tear
separation
fragment
disintegration

Your challenge is to observe, identify, and describe the initial pre-incident containment system state, any stressor(s) that acted on the containment system or contents, and what it or they did prior to the containment system breach or hazmat reaction.

Container System Breaches

A *breach* is a gap, rift, or an opening in a containment system or one of its components. Breach types include cracks, punctures, splits, tears, separation, fragmentation, and disintegration. For example, a bag may tear; a pipe may split; a drum seam may separate; a tank may crack; and a pipe flange may separate.

Stressors can breach containers. Determination of what the containment system did when stressed is essential to understand what followed. Your focus here is the behavior of the stressed containment system until the breach process ends.

A reacting hazardous material can produce energy levels inside a container that result in the containment system breaching, giving the contained hazardous material a way to escape from the container. The manner in which the container breaches depends on the hazmat behavior induced by the stressors and the reaction of the container to such stressors.

The size and nature of the breach and the speed at which it occurs are of interest to the investigators. Document any breach, beginning with the actions by stressors and hazardous materials on the container and how the container responded to those actions. The aim is to be able to describe what the container or components did and why they did it.

Container breaches take various forms, depending on the container. They can range from a tiny pinhole to a complete circumferential crack allowing one section of a tank to separate from the other section. The nature of the stressor producing a puncture differs from the stressors producing the disintegration and fragmentation of the container (wrapper) around a stick of dynamite.

If hazardous materials do not react, most forms of nonpressurized hazmat solids such as "frozen" solids, powders, pellets, flakes, chips, blocks, vitrified substances, or similar forms will not exert unusual stresses on the bags, bottles, drums, cartons, or boxes used to hold them. Containers holding pressurized materials are under constant internal stress and will behave differently when they are stressed.

Your challenge is to make observations, identify, and document the behavior of the containment system from the time of the initial stressor action until the containment system breach process has ended.

Container Disperses

When a container fails, it may turn into one or more "missiles." These missiles can fly through the air or penetrate objects and are capable of producing harm. For example, a detonation fragments an explosives containment system and drives the pieces in all directions. A loaded high-pressure gas cylinder may become a projectile when its valve breaks off.

The investigator can usually trace the dispersion of a container or container parts by examining the effects on the environment. The pattern of effects formed on other objects by the dispersing objects provide "vectors" indicating the direction from which the object was coming as it did its damage. Using the vectors, investigators can then work backward to discover where the container was located before the breach.

From past accidents, we know that breached containers may disperse in a limited number of patterns. These patterns are linear, spherical, hemispherical, and ambiguous.

Linear Trajectory

A cylinder with a valve broken off will be propelled by the contents like a skyrocket. It will travel along a linear trajectory much like an artillery shell, subject to the pull of gravity downward, until it strikes some object that stops it or redirects its path. Any pressurized hazardous materials container can disperse that way. The velocity and distance are dependent on the pressure and quantity of the contents.

You can track these actions by identifying marks or traces left on either the container or anything the container may have encountered en route to its final destination. From those marks, you can identify "vectors" to indicate the pathway of the moving container or parts. If it is important, you can measure the debris weight and distance traveled, adjust for energy lost to struck objects, and estimate within reasonable bounds how much energy it took to launch a specific "missile."

Spherical

A breached container may disperse in a spherical pattern, as when a stick of dynamite detonates and blows container fragments in all directions with relatively similar forces behind them. This kind of pattern is indicative of an explosion. A typical characteristic indicating a detonation, rather than an explosion, is the relatively uniform graying of small steel fragments of the container and characteristic hot tearing of the edges of such container fragments. Cratering will occur.

This pattern can help you because a detonation will drive any object under a detonating hazardous material downward into the earth where it can be retrieved by digging it out of the crater. The digging must be done cautiously to capture the most data possible from the work.

CONTAINER "DISPERSES"

Container dispersion paths:

linear
spherical
hemispherical
stream
ambiguous

Hemispherical

A nondetonating explosion of combustible gas that blows the roof and sidewalls of a building outward is an example of a breached container dispersing in a hemispherical pattern. Because the resistance downward is greater than up or sideways, the pattern of the debris usually will be hemispherical and smaller than a detonation pattern.

During this part of the investigation, try to visualize the movement of the dispersed container parts away from the container breakup to the ending location of each piece of debris. The number of pieces of debris may be large; therefore, it is not always necessary to trace each piece for its origin to its final resting place, unless for some reason this is an objective of the investigation.

Ambiguous

A breached container may disperse, for example, like a paper bag blown empty by the wind or floated away from its origin by rainwater or fire hose water runoff. While most prevalent when bags or plastic containers are used, any container that lands in water follows ambiguous dispersion patterns.

> *Your challenge is to observe, identify, and describe the container dispersion events or what went where, when, and why.*

CONTAINER IMPINGES ON EXPOSURE

Container Impinges on Exposure(s)

Once container fragments are launched, natural forces such as air resistance and gravity tend to bring them back to earth. En route to their destination, they may drop on, collide with, or strike people or objects — called "exposures" — in their pathway. Exposures may be people, systems, property, or the environment. For this to happen, the exposures must be in the pathway of the dispersing container or parts. This part of the incident process description can lead to novel control actions

What was the size, shape, mass and velocity of containment system parts that impinged on the vulnerable (struck) objects?

- How did they come to be where they could be impinged on by the parts?
- Why were they struck?
- Why didn't they act to avoid the flying object?
- If they avoided impingement, *who* did *what* to accomplish that?

> *Your challenge is to observe, identify, and describe the container system impingement events.*

Container Harms Exposure(s)

The motion of "dispersing" containers, parts, or fragments is stopped when they fall to the ground because of gravity or when they strike something in their path. The harm they produce when they impinge upon a person or object depends on the kinetic energy or energy of motion they contain. Usually the speed at which they are traveling and their weight are enough for them to do some damage if they impinge upon something.

Objects in motion tend to keep moving in a straight line until acted on by other forces. The motion defines an "arrow" or vector that can represent the object's movement. You can use observed harm to develop vectors that point to where the object started to move to its final observed resting place. The vectors can be shown on sketches or diagrams to show the "flight path" of a flying cylinder, explosive debris, or any physical object, including gases.

The harm you observe provides one potential starting point for data gathering. It can help you identify the actions of the striking object by "reading" backwards from the harm. For example, the direction glass fragments fall from a smashed window (stressee) indicates the direction in which the stressor moved. The direction of bending of a metal object indicates the direction from which the bending force came, and if the mass or speed of the stressor is known, it indicates the forces that did the harm.

Your challenge is to read harmed objects or injuries to people to identify and describe the container or parts vectors and impingement actions — in terms of the harm produced by the objects, what it or they did, and where and when they did it.

CONTAINER HARMS EXPOSURE

Hazardous Materials React

After you track the container movements (if any), focus on the hazardous material in the container. The hazardous material either did or did not react to the stressor. To *react* means that the hazardous material changed because of the stressor. The hazardous material may change its *form* or *composition*. For example, the hazardous material changes its form when it melts, freezes, boils, condenses, crystallizes, or expands. It is also important to recognize that oxidation, polymerization, or decomposition can change the composition of the hazardous material.

Before exploring hazmat reactions in containers, it is important to understand what it means to you. During production, hazardous materials pass through stages where their composition and form must be controlled carefully to prevent an unwanted reaction such as decomposition or polymerization. Finished hazardous materials are either very stable or controlled

HAZMAT REACTS

Sample reactions:

melts
freezes
boils
condenses
crystallizes
expands

In composition:

oxidizes
polymerizes
decomposes

by the containment system design so that they are unlikely to react until used for their intended purpose. When the controls are not successful, the hazardous material can react.

Hazardous materials around a container may lead pressurized liquefied gaseous contents to physically expand or boil in the container and increase the internal pressure to the point that it ruptures the container. The initial external stressor may initiate a chemical change in the hazardous material. Some hazardous materials, such as an explosive or oxidizing material, can react by decomposing at an explosive rate or detonating when an external stress, such as heat or impact energy, stresses the container.

Introduction of a new incompatible chemical stressor into the container may also produce a vigorous reaction and generate a lot of heat or pressure. Other kinds of reactions include corrosion reactions with the container.

Heat stress may induce a chemical monomer to polymerize with similar effects. Physical motion can lead to initiation of an internal oxygen reaction with the container material of construction when impurities are present.

Each kind of hazmat reaction leaves different "tracks" on the containment system components or elsewhere. Corrosion changes the surface appearance at the interface by removing base material or depositing corrosion products on the surface. Pressure increases (for example, when refrigerated gases warm) can change the shape of components by stretching them or displacing gaskets or seals at fittings or pipe joints. Heat may change the physical failure characteristics of metals.

Over time, some chemicals in storage change from safe liquid to shock-sensitive crystals. Reasons for the change have to be identified in each case. The change may be due to partial evaporation, variations in external temperatures, presence of certain trace impurities, or perhaps just continuous but very slow phase-change activity in the liquid phase.

Always consider the possibility of a new hazmat behavior. Observed data in individual cases should govern any conclusions about what the hazardous material did because behavior not previously seen may be involved. For example, boxcar fragments at a railroad accident showed evidence of a detonation reaction by a material that had not been observed to detonate in past incidents. Perhaps the hazardous material contains traces of incompatible contaminants or constituents in quantities greater than the limits for that hazardous material.

Investigations of hazmat reactions can be very challenging, requiring logical thinking to figure out where to find the required data.

- For example, data might be found in preserved samples of the material that reacted — if they are available in sufficient quantity to analyze.
- The data might also be found in residues left by the reaction — if they survived the reaction and you can find them.
- The data can be inferred from observed or measured changes in the container, process vessel, or instrumentation during a reaction.

> *Your challenge is to observe and describe what the stressors made the hazardous material do in each specific incident. Look for changes in form or composition. Track the energy source and what it did to the hazardous material or containment system, and document those actions.*

Hazardous Materials Escape

When a container breach occurs, hazardous materials can escape through the breach. How much material gets out and how fast it gets out varies with the nature of the hazardous material and the containment system breach process. For example, when a container holds a liquid at ambient pressure, the material escaping through a displaced gasket on a pipe flange will be entirely different than if it held a high-pressure gas. The quantity of material escaping through a ruptured pressure-relief device will be different than the material escaping through a spring-loaded pressure-relief device that can reseal.

If a hazmat reaction occurs inside the containment system, you also need to address what the products of the reaction were, their form and quantity, and what they did during the incident. The nature, form, and state-of-the-reaction products determine how they escape. Those behaviors are reasonably predictable. If the reaction products are solids and essentially under no pressure, they may be pulled by gravity through the breach in the container and flow downward onto the ground or whatever the container was resting on. Liquid reaction products behave similarly, except they may also wet the surfaces surrounding the breach. Pressurized liquids may escape as both liquids and some gas because some of the pressurized liquid may vaporize if it escapes through a small opening. Pressurized liquefied gasses may turn almost entirely to gas after they pass through a breach because it is the pressure that keeps them in the liquid state in the container. However, when the pressure is gone, they turn back to a gas. Gases will flow in any direction influenced by the breach size and shape, as well as the orientation of the breach relative to the horizon.

HAZMAT ESCAPE

Escape:
name(s)
form/state
quantity
route(s)
behavior

Your challenge is to observe, identify, define, and document the actions of the hazardous materials and reaction products as they pass through the containment system breach. If they did not act in an expected way, determine why they did not.

HAZMAT DISPERSE

Dispersion mechanisms:

pop
puff
plume
puddle
BLEVE
linear vector
air transport
personal transport
stream transport
vehicle transport
underground

Hazardous Materials Dispersion

This stage of the hazmat incident investigation process addresses where and how the hazardous materials get into position to do the observed harm. Your task is to trace and document where the hazardous materials or any reaction products went after escaping from the containment system and why they went there. The focus is on the spreading of hazardous materials or reaction products.

Each release is unique as to the nature and quantity of the released material(s), the containment system configuration, the surroundings at the time of the release, and the reasons for the specific hazmat dissemination. The nature and form of the hazardous material determines, in part, how and where it will go. The nature of the ambient surroundings at that time may affect the hazmat dispersion process. If involved, the actions of response personnel may also affect the process.

Dispersion patterns common to different types of releases have been documented from past incidents and provide guidance to help investigators formulate questions to ask. These dispersion mechanisms include:

Pop. The form of dispersion during a detonation or explosion, for example. The dispersion is propelled initially by the expansion of the reaction products and heat of the explosion itself. It travels, initially, in a spherical pattern from the explosion source outward in all directions. As the dispersion slows down, ambient weather conditions take effect, transporting the reaction products and heat into the atmosphere where they dissipate eventually.

Puff. The form of a short-duration cloud released quickly from a hazmat container. The dispersion is propelled by the pressure pad on the liquid hazardous material that boils above ambient temperature and continues to flow only until the pressure pad dissipates.

Plume. A pressurized liquefied gas from which pressure is bled off the container over a period of time. A cloud, holding a liquid that boils at a temperature below ambient, emanating from a hazmat container.

Puddle. The form of a slowly evaporating liquid dripping or spilling from a container onto the ground surface. If the contour of the surface below the leak leads to the formation of a puddle, the dispersion through evaporation is gradual. When this happens, look for underground dispersion.

BLEVE (Boiling liquid expanding vapor explosion). The violent dispersion of the reaction products over a short period of time. Considered a special form of a puff and usually followed by a hazardous material of some duration.

Linear vector. A radiant form of energy, such as gamma radiation, thermal radiation, or electromagnetic waves or pulses, traveling in a straight line. Explosion debris also follows a modified linear vector called a *trajectory*.

Air transport. After the hazardous material no longer propels itself, air may carry or entrain the hazardous material where it disperses. This is a typical dispersion mechanism for dust, smoke, and other light materials. Air drops the particles when they are no longer buoyant in the airstream.

Personal transport. Hazardous material carried on personal protective equipment or on persons; this is the reason that decontamination is sometimes needed. Consider this to include animal transport to undesired exposures.

Steam transport. The movement of hazardous materials by moving water, such as runoff during a rain, or hazardous materials that spilled into a stream. Can include contaminated surface water dispersion into ground or groundwater.

Vehicle transport. Vehicles carrying hazardous materials to new places, as when a rescue vehicle drives through a hazardous material spill.

Underground dispersion. This is when a hazardous material spills onto the ground and the ground absorbs the spill. This may also include transport into growing flora and fauna and into the food chain by those objects, if environmental harm may have occurred.

> *Your challenge is to observe, identify, define, and document a description of what the hazardous material did during this stage of the incident, including the nature, pathway(s), and boundaries of the release. Then you need to sort out what or who did what to produce the dispersion.*

HAZMAT IMPINGES ON EXPOSURE

Impingement process:
surface deposit
inhalation
ingestion
contamination

Impingement intensity:
concentration
duration
velocity

Hazardous Materials Impinge on Exposure(s)

During the dispersion of hazardous materials, they may contact or impinge on people and various kinds of exposed objects. Such contact depends on the nature, form, and concentration of the dispersing hazardous material; the location and behavior of the people impinged; the location of objects impinged; and in some cases, actions by emergency response personnel. For example, the impingement process for a liquid hazardous material will be quite different from the impingement process for a gaseous material, a radioactive material, and a bacteriological or viral agent. The location of the people or objects plays a greater role in the impingement by a fast-moving gas cloud than a slow-moving liquid spill. Evacuation of people by emergency response personnel may also affect the impingement process.

The impingement process can occur through surface deposit, inhalation, ingestion, and contamination. For example, it can contact the skin or organs of people or the surface of objects. The hazardous material may also impinge on people by inhalation or ingestion.

> *Your challenge is to observe, identify, and document the people and objects impinged by the dispersing hazardous materials and when, where, why, and how long that contact occurred.*

HAZMAT ACTS ON EXPOSURE

Reaction effects:
impingement attributes
exposure attributes
exposure actions

Hazardous Material Acts on Exposure(s)

This is the harm mechanism identification task. Some hazardous materials may impinge on people or objects without any reaction. For example, released compressed gases may dilute quickly enough to become harmless. However, other hazardous materials may act on people or objects. For example, toxic corrosive vapors can act on both people and objects when they come into contact with them. The investigator's task for this stage of the incident process is to observe, identify, and document the action of the hazardous material on people and objects, from the time of the first impingement until the action on the exposure begins.

This action is influenced not only by the nature, form, and duration of the impingement by the hazardous material but also by the attributes and actions of the people and objects impinged. Hazardous materials are not likely to act on people in personal protective equipment (PPE), but they may act on the PPE. Etiologic agents are less likely to make a person ill if they impinge clothing rather than skin or orifices or if people were inoculated against the organism. A corrosive acts more slowly on exposures than will hot, burning fuel oil. This aspect of the model is particularly sensitive to the properties of the hazardous material, the impingement duration, and the vulnerability of the object.

> *Your challenge is to observe, define, and describe the actions of the hazardous material and the results of the impingement on the people or objects.*

Hazardous Materials Harm Exposure

This is the loss documentation task. The harm that hazardous materials produce on exposures depends on the duration of the harmful action on the exposure and the nature of the hazardous material and the exposure. Some hazardous materials produce lingering effects and others produce short-term effects. Hazardous materials produce harm to:

People. To document the effects or losses to people, you have to know the physiological consequences.

Systems. If the loss is a system disruption, system incapacitation, or loss of production, identify and describe that harm.

Environment. For environmental loss, describe the consequences of the hazmat action on the exposed flora and fauna and natural resources.

Objects. For harm to objects, describe the changes in the objects resulting from the hazmat action.

> *Your challenge is to identify and describe the losses that are caused by hazardous material actions on exposures.*

HAZMAT HARMS EXPOSURE

Loss to
people
systems
environment
objects

Reaction Products Breach Container

Changes in hazmat form or composition can produce additional stress on the container system. Sample stressors are pressure rise, acid corrosion, stress corrosion, pressure pulse, and thermal. What reacts and the nature of the reaction products determine the stressing energy imposed on the inside of the container. For example, an explosive mixture reacts explosively, producing gases so quickly that they impose explosive pressures on the inside of the container. When a corrosive acid leaks through a liner in a tank or pipe, it can begin to eat a hole through the tank material.

> *Your challenge is twofold: Determine what the stressed hazardous material did after it started to react and what its reaction products did to create a breach in the container. In many cases, develop the timing of the reaction and subsequent breaching of the container, if possible.*

REACTION PRODUCTS BREACH CONTAINER

Sample stressors:
pressure rise
acid corrosion
stress corrosion
pressure pulse
thermal

Reaction Products Escape

When hazardous materials react and breach a container, these events pose a special challenge to you. First, you do not know what the reaction products are until you can identify them — the warning label on the vessel or container will not indicate them. Second, until you find out what the reaction products are, you do not know what they can do to disperse, impinge exposures, or act on and harm exposures. These are difficult challenges for you to overcome.

You will have to "read" the answers to these types of questions from whatever data sources survived the incident. Fortunately, most of these reactions leave some kind of tracks for you to

REACTION PRODUCTS ESCAPE

Escape:
name(s)
form/state
quantity
route(s)
behavior

pursue. If you look for changes on objects or observations by or on people, you can often develop your answers from the data they offer. Look at the effects, and try to determine the nature and name of the changemakers that brought about those effects. Work backwards from the outcome. If more than one possibility exists, figure out what evidence would best support one or another theory, and test your data against that theory. Usually, you will want to adopt the theory that the data support most persuasively.

> *Your challenge is to observe when a hazmat reaction occurred and breached the container and to identify and describe reaction products that escaped and what they did as they escaped.*

REACTIONS PRODUCTS DISPERSE

Reaction Products Disperse

When hazardous materials react, the dispersion of the reaction products may be different from the unreacted hazardous material.

> *Your challenge is to observe, identify, define, and document a description of what each hazmat reaction product did during this stage of the incident, including the nature, pathway(s), and boundaries of the release.*

REACTION PRODUCTS IMPINGE ON EXPOSURE

Reaction Products Impinge on Exposure(s)

Dispersing hazmat reaction products can impinge on exposures as previously described. The main difference in this event is that the impingement of more than one reaction product probably must be traced. After you identify the reaction products, you can determine the form of the impingement.

> *Your challenge is to observe, identify, and document the dispersing hazmat reaction products impinged on people and objects and determine when, where, and why that contact occurred.*

REACTION PRODUCTS ACT ON EXPOSURE

Reaction Products Act on Exposure(s)

Look for reaction mechanisms that affect exposures. It may be complicated in unusual circumstances when the reaction products interact before acting on the exposure or, by interacting, are neutralized after impinging on the exposure.

> *Your challenge is to observe and describe the actions of the hazmat reaction products on the people or objects.*

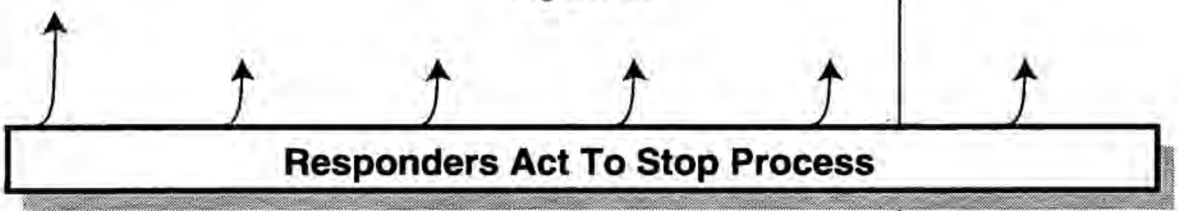
REACTION PRODUCTS HARM EXPOSURE

Reaction Products Harm Exposure(s)

This is the loss documentation task for the hazmat reaction products. You may have to look at harm produced by more than one material or substance. You are still interested in the loss that was produced in the incident.

Your challenge is to observe and describe what harm followed the action of the hazmat reaction products on the people or objects, without consideration of ameliorating actions by others to lessen the harm.

Figure 2.2



Responders Act to Stop Process

This is the responder identification and action documentation task . This element of the model illustrates the potential range of responder intervention actions that you should look for during your investigation. Responders might intervene at any stage of the incident process (as indicated by the arrows in Figure 2.2) and affect the outcome. You should think of both people and objects as responders. For example, a plant hazmat brigade, a local hazmat incident response team, an operator, or possibly one of the victims might be a responder to track because they did something during the incident to stop the incident process or retard its progress.

Examples of responders.
people
active safety devices
passive safety devices
warnings

The action by an object such as a pressure relief device, an audible warning device, or a chemical shower might be the responder to explore. Document any actions by the responder to control or limit the incident process in terms of who did what, when, and why. The *how* may become important if the response played any role in improving or worsening the outcome or had no effect when it was intended to achieve some effect.

Your challenge is to observe, identify, define, and describe any people or objects that acted to control the hazmat incident process, what they did, and what effects their actions had on the outcome.

If you are tasked to develop recommendations, the intervention events will probably be helpful to you in your problem definition procedures.

Responders Ameliorate Harm

Responders Ameliorate Harm

This task identifies and documents what actions were taken to ameliorate or treat the harm done by the hazmat or container behaviors. The event may or may not be a part of the incident process, depending on where and when it occurred. If it occurred at a hospital, for example, you may not want to address it unless it is your charter. This event may begin as early as immediately following the beginning of the action on exposed people or objects and end with the residual harm produced by the incident. The scope of this event depends on your organization's mission and your own marching orders.

One aspect of this harm is the amelioration efforts that took place to limit the harm before the incident began. The investigator should describe these actions where they actually limited the harm the impinged exposure experienced or when they did not perform as intended.

The more widespread the dispersion pattern produced by the release is, the larger the investigation workload for this task. In such cases, it may be adequate to identify and document an example of each *kind* of harm-reducing interaction rather than every such action for every harmed person or object. This is an investigation management decision involving trade-offs between the value of the additional data and the cost of acquiring it.

Your challenge is to observe, identify, and document any actions to ameliorate the harm produced by the containment system, the hazmat or hazmat reaction products, and the effects they produced.

CHAPTER 3
HAZMAT INCIDENT INVESTIGATION PROCESS

This chapter describes what you need to know about the investigation process. Trained hazmat investigators use an orderly, logical investigation process and tools. A preferred investigation process helps you identify and define the questions you need to ask and the answers you need. It enables you to organize, analyze, and assess your information as soon as you acquire it. It 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 *Introduction to Investigations*. Specific hazmat investigation tasks are described in the following material.

You need to expect training in a preferred investigation process to provide you with:

- Unifying principles for thinking about hazmat incident processes
- Guidance to help turn your observations into consistent, efficient, and timely descriptions and explanations of what happened
- Ways to apply effective, quality assurance tests to your data as you acquire the information
- Ways to discover and define problems and find options for improving performance
- Ways to monitor changes to ensure they produced the desired results

PRINCIPLES FOR INVESTIGATORS

A key principle for investigators is "change." Investigators look for changes to objects in hazmat incidents. To identify change, you must identify what changed. You identify change by identifying what something was and comparing it to what you observe now. During an incident, the outcome is produced by people or objects that change other objects or people. Thus, identifying changes and deriving an understanding of what happened from those changes is your continuing challenge.

A hazmat incident is a loss-producing process. To understand that process, you investigate it. When you finish investigating the process, you should be able to flow-chart what happened and why it happened. A *flowchart* is a schematic representation of interactions among process components to show how they produced the outcome. To flow-chart what happened, you need to think about what you are investigating as a process that produced a loss outcome.

> *If you cannot flow-chart the hazmat incident process, you do not understand it. You know that you understand the process if you can make it happen again the same way.*

OBSERVATION TASKS

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

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

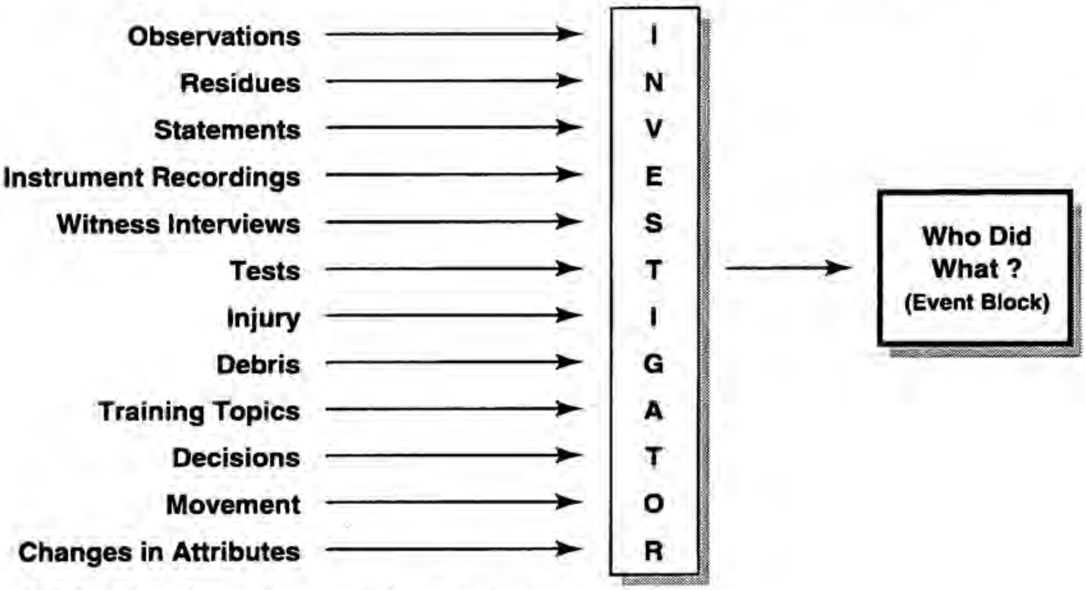
You must be able to take observations of anything and transform them into descriptions of actions as shown in Figure 3.1. This is a continuing challenge for you during every investigation.

A format that works well is the "*who* did *what, when,* and *where*" format (Kipling's "faithful servants") shown in Figure 3.2 (called "events" for convenience from now on).

To transform and document data into events, use the following procedure:

- Identify and record the name of the person or object (actor) that did something, preferably on 3- x 3-inch Post-It™ notes. Every event describes *one actor and one action by that actor.*
- Record what that person or object (actor) did and any additional descriptive words needed to help you visualize that action later.

Figure 3.1 Investigators Data Transformation Challenge



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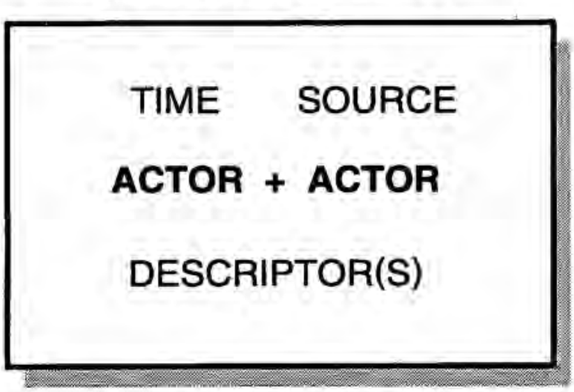
- Enter the time, if you know it, or indications of *relative* times such as before, after, or at same time as other events, for example.
- Enter the source of the data you used to create the event block.

This procedure may seem tedious, but it really pays off throughout the entire investigation. It also helps you recognize and define an event when you see one. It also helps you use the term "event" consistently (one actor plus one action).

Figure 3.2 Event Blocks



© Source: Benner, L., 4 Accident Investigation Games,,Events Analysis, Inc., Oakton, VA

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 you do not know yet what someone did, use a question mark (?) or a tentative name plus a question mark to indicate what you do not know.

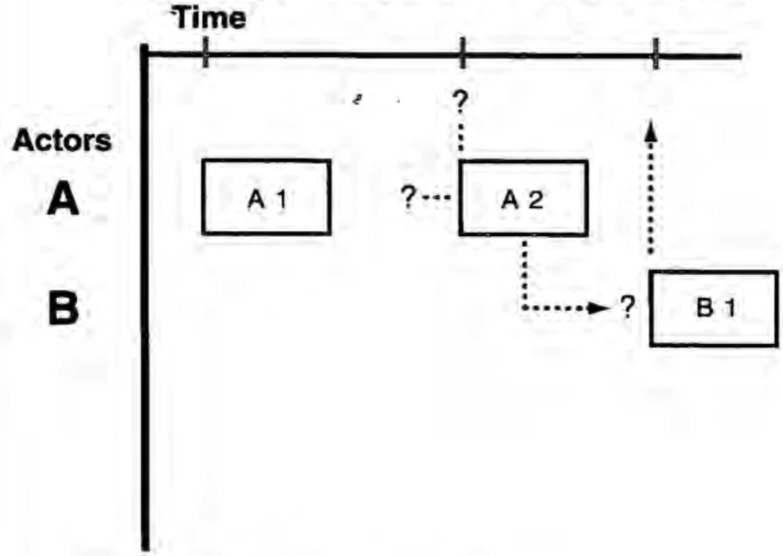
DATA ORGANIZING TASKS

> *It is imperative for all investigators to organize new information as it becomes available during the investigation.*

You should not go out with just a big net and grab everything you can, hoping you have what you need when you start to analyze it. As you identify new actions by people, objects, or events, you *must* have some way to keep track of them and organize them so that they help you figure out what you know and what you need to find out next.

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 3.3. Event work sheets enable 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 3.3 Placing Events On Work Sheet



This increases your work efficiency. If you do this, you can significantly reduce the total investigation time required to produce better results in less time.

As soon as you record your first observation as an event, you can start making your matrix or events work sheet. The work sheet uses one row to hold each actor's actions, or events. The events are spread out along the row in the sequence in which they happened. Follow the example in Figure 3.3 to see how you build your work sheet to develop a description of what happened.

You have learned about actor A and event A1. You placed A1 on your work sheet along 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, below (or to the right of) A1. Next you found out about another action by A, described as 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 of A2 shown in Figure 3.3 shows that you found it occurred after A1 and before B1. Use the left edge of your event block to indicate its relative time for positioning purposes. The question marks indicate the before/after questions you ask before placing the event on your work sheet.

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

LOGICAL REASONING TASKS

By handling events this way, you can quickly and efficiently put your events in the order in which you think they happened. To do this, you apply *logical reasoning tasks* to your events. You will use three types of reasoning: sequential reasoning, cause-effect reasoning, and necessary and sufficient reasoning. You must use these tests if you want to achieve valid and complete descriptions of what happened and why it happened.

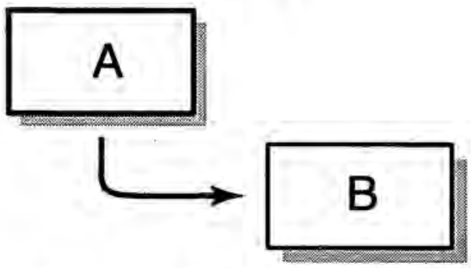
Sequential Logic

Sequential logic is the reasoning process applied to events to put them into the proper time sequence. To understand *who* did *what* when, investigators have to put the events they acquire into sequential order or in parallel on the matrix if they occurred at the same time. This logic involves visualizing *who* or *what* did *what* and to arrange them in the right sequence. For example, by reasoning about which event occurred first, you will state that event A had to happen before event B.

Cause-Effect Logic

Cause-effect logic is the reasoning process used to determine whether one event led to another event. You do this to establish relevance and relationships among events you identify. For example, when 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 3.4). If you think that there may be a causal relationship but need more data, add an arrow with a question mark on it.

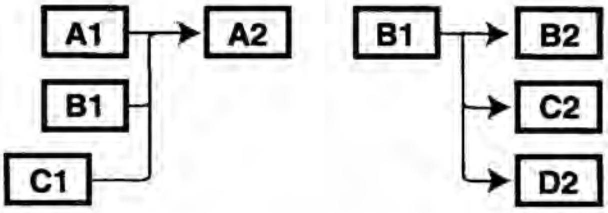
Figure 3.4



Necessary and Sufficient Logic

Necessary and *sufficient logic* is the reasoning process applied to pairs of events or events sets with identified cause-effect relationships to determine the validity and completeness of the description of the hazmat incident. For example, looking at events with necessary and sufficient tests may disclose that A1, B1, and C3 are all necessary (have to happen every time) for B to occur. You may find that only B1 is necessary and sufficient for B2, C2, and D2 to occur every time A occurs (Figure 3.5).

Figure 3.5



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 hazmat incident process. As new data become available, they fill in the missing frames in their movie. Their mental movie helps them to put all the events they find out about into sequential order, using time and spatially sequenced reasoning. When they think their movie is finished, they start writing the narrative description of what happened from their "mental movie."

It is okay to use mental movies for simple hazmat incidents such as a drum falling off the back of a truck or if you are interested in only putting the events that you collect in the right sequence. In more complicated hazmat incidents, or in hazmat incidents with high loss potentials, the movie can get so complicated that your memory begins to lapse or get confused. Sequencing the data tells you what happened, but other people cannot see the mental movie in your head; therefore, 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 tell what happened solely with only 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.

Properly sequencing the events usually will satisfy the need to determine the hazmat incident cause. If you want to learn more from a hazmat incident or assess performance, you will not want to stop with the simple sequencing.

> *To understand why a hazmat incident occurred, you need to apply cause-effect and necessary and sufficient logic tests. This is when your documented events and matrix really start to reward your efforts rapidly.*

CAUSE-EFFECT LINKING TASKS

You may have noticed when working with Figure 3.3 that you looked at two events together to apply sequential logic tests when adding a new event to the matrix.

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

By recording and organizing your observed data this way, you are able to analyze all your information each time you add an event to your work sheets. As you place new events onto a work sheet, you also can look for cause-effect relationships between events and show links where justified by your logic.

For example, after placing A2 onto the work sheet in the position shown in Figure 3.3, you can ask yourself whether A1 caused A2. If it did, then you can link A1 to A2 with a linking arrow to show that relationship. Similarly, looking at A2 and B1, did A2 lead to B1? If so, link the events. By examining events in pairs (event pairs) on your work sheet, you can add links as your work sheet develops.

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

After a few links are added, you will begin to see events you recognize as part of the incident process, but they are not linked to anything yet. This is one type of gap. You will see a second type of gap when you do the necessary and sufficient logic test and find that one or more additional causal events had to occur before the effect event could occur. The gaps point you to specific information you need and help you define questions you need to ask. 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 know.

GAP-HANDLING TASKS

When you see gaps during your description development efforts, do one of the following:

- Get more observations about the actor for which data are missing to fill in the holes.
- Identify the other actor(s) that probably did something during the gap and get more observations about those actors to fill the holes (or "decompose" or break down events into two or more actors or actions).
- Apply deductive logical reasoning to build logic trees to describe what you think might reasonably have occurred. After you have some realistic hypothetical scenarios, go out and 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.

> *Each way focuses your investigation energies to increase your investigation efficiency.*

Additional Workload Approvals

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

FINISHING YOUR INVESTIGATION TASKS

When you investigate a hazmat incident, 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 if 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. This is extremely difficult to do with mental movies and usually not considered if you are only looking for a simple cause, unsafe acts, or standard injury form entries in an incident report form.

EXPLAINING WHY IT HAPPENED TASK

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 successive event during the incident.

> *Use a question mark to indicate uncertainties and unknowns.*

Before you turn in your work, check to see if you have a gap regarding:

- What happened
- Who did something or *what* they did
- When or what effect it had on other events
- What had to happen to make something else happen

Show a question mark on your work sheet at any uncertain actors, actions, events, times or links, where the work sheet is incomplete, or where uncertainty remains. A question mark indicates an open investigation work item.

Necessary and Sufficient Logic Procedure

This is the task that separates average investigators from pros.

> *The necessary and sufficient testing task is where most new learning occurs.*

This logic-testing procedure involves examining each linked event pair and asking yourself several questions. When you link the events, you know the causing event was probably necessary to produce the effect event. For this test, review your logic to verify that the effect event could *not* have occurred unless the causing event occurred.

Then ask if the causal 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 and determine what else people or objects had to do to make the effect event *result every time* all the causal events occurred. The aim is to define all the actions that had to occur, and their timing, to produce the next event *every time they occur that way*. If you understand ALL the necessary and sufficient actions, you can make the hazmat incident happen again or duplicate the hazmat incident. This is your real test of your understanding of the incident.

VISUALIZATION TASKS

Documented visualization aids help you and your customers "see" what happened. Your documentation task is to prepare graphic records of observations at the site or elsewhere. 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 create their mental movie of the hazmat incident from your work.

NOTE: 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 that it is an estimate.

Photographs. See Appendix F, "Photography Support for Hazmat Investigations," for specific guidance. Your objective is to record what you see in a way that lets you use it later to provide an overview or close-ups to help you 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. Sketches can focus on those aspects of a scene that you want to emphasize. Using marked up photos might satisfy this need too.

Label all objects shown in a sketch with the same name used elsewhere in reports. A title block should show the sketch topic such as "Container Breach." You should also include a case identifier and other data to define the sketch and the data on the sketch. See Table 3.1 for a list of the items to show when you prepare a sketch, diagram, drawing, or map.

Diagrams. Diagrams are generally line drawings with symbols, designed to demonstrate, explain something, or clarify

Table 3.1
Sketch Data Checklist

❑ A Title Block showing name and location of the hazmat
❑ A legend showing what any of symbols represent
❑ A "NORTH" indicator to orient the user, if relevant
❑ The case identifier
❑ Page numbers if more than one page is used
❑ The hazmat incident date
❑ The topic or main subject of the sketch or diagram
❑ Relative or actual dimensions of objects or components
❑ Distances between objects or a scale that can be used to measure them
❑ The preparer's name
❑ The revision number and the date it was last revised

relationships existing relative to the parts of a whole. For investigations, diagrams should contain the information shown in Table 3.1.

When you make sketches or diagrams, remember that they will probably be reduced to standard letter size paper, so print with large letters that can stand reduction for reproduction. Graph paper can be very useful for diagrams or sketches.

Drawings. Drawings generally are considered to be something like a blueprint or plan, formally prepared by a designer or professional staff member and properly referenced and described. Building, equipment, and process drawings — to name a few examples — 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 as designed.

Drawings can be used to help users visualize pre-incident conditions, what happened, or the progression of a hazmat incident through a facility. However, drawings, as well as sketches, are usually too cluttered to serve that purpose; sketches can be edited and highlighted to emphasize specific points.

Maps. Maps with topographic features as well as facility locations are helpful when the scope of a hazmat incident covers a relatively large area. Examples include a hazmat spill with a dispersing gas cloud, large hazmat explosion with extensive debris patterns, or blast damages; or whenever you want to show where anything went or dispersed. They are also useful for depicting where objects were located in large facilities showing emergency response or evacuation routes and similar purposes. Directional orientation is also aided with maps.

On a smaller scale, maps with dimensions can be used to show residues and deposits, although sketches are usually as informative. Watch that you or your mapmaker do not get carried away with clever detail at the expense of basic data. Map preparation costs can rise quickly.

COMPLETING YOUR INVESTIGATION TASKS

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 G, "Investigation Data Organization," for an illustration of how you can show your data on a completed work sheet.

Remove Unlinked Events

Remove events without links from your work sheet after you have exhausted your logic testing and possible hypotheses to establish links. Events with no links to the flowchart are probably irrelevant and are almost guaranteed to raise unnecessary questions from your customers.

> *After you finish your investigation, check the quality of your work one last time.*

When you have entered your last possible events on your work sheet and removed irrelevant (unlinked) events, 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 mark one last time to ensure that the logic is valid and as complete as data permit (Table 3.2).

When your quality assurance check is complete, you are ready to produce your deliverables from your worksheet. What you deliver, of course, depends on your customers.

If you can use a neat copy of your finished 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, diagrams, drawings, or maps to enable any users to visualize what happened and why it happened. Your completed work sheet with supporting visual aids approaches the ideal of producing one work product to serve all users.

Table 3.2 Work Sheet Quality Assurance Checklist
❑ Each actor name checked
❑ Each action description checked
❑ Each event format and source checked
❑ Each event pair and set checked for sequence
❑ Each event block checked for sufficient logic
❑ A question mark to show all your uncertainties and unknowns
❑ Each link checked for necessary logic
❑ Unlinked events are removed or properly noted

SUMMARY

You need to recognize that the hazmat investigation process differs from other investigation processes. When you arrive on the scene:

- ☐ Identify and define the residual hazmat risks present and the precautionary measures you may need to take to protect yourself.
- ☐ Have knowledge of the specific hazardous material and its behavior.
- ☐ Know the general hazmat behaviors during the harm-producing process and the challenges these behaviors pose.
- ☐ Know the procedures required to manage data gathering over a wide geographic area if the released hazardous material dispersed widely or over a lengthy period of time or if cleanup is delayed
- ☐ Be aware of the potential for a large number of casualties during the incident, including environmental losses and the need for specialized training of responding personnel.

CHAPTER 4
INVESTIGATION DATA SOURCES

This chapter describes what you need to know to get data during investigations. You 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, that is, if you know how to "read" objects. People think about and sometimes change their memories about what they did or saw. Objects react without thinking, resulting in predictable outcomes.

In setting your data-gathering priorities, generally you will want to look over the available objects before you talk to people. However, if responders are still on scene, 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 hazardous materials incident data. As energy impinges on an object, the object changes in some way. For example, a container dent is a change that is easy to recognize. Objects are trustworthy witnesses. But, you have to know how to read what they have to say. Things will not "talk" to you; therefore, you have to be able to "read" all the information that the things "recorded." Data that you can get from objects depend on your "reading" skills. This is an area where you may need expert help.

Think Stressors and Stressees

To read data from things, think in terms of "stressor" and "stressee." External heat can be a stressor — the energy source that introduced a change into a container. The container was the stressee, or stressed object. Sometimes a stressee becomes the stressor, as when an exposed flammable hazardous material ignites to produce more heat energy.

What this means for you is that interactions among objects are likely to be recorded by changes to both stressing and stressed objects in many cases. Objects with such recorded changes become "witness plates." Your challenge is to read and time the changes so that the initial stressor actor can be distinguished from the initial stressee. Use your sequential logical reasoning skills for this task.

You also read "things" data to verify or supplement what people say. However, you may be unable to do this if people were not around to see anything or if there were no survivors from the hazmat incident. The basic approach is the same. Track the actions of people or things on other things from tracks left on "witness plates" left during the incident.

Before disturbing things, photograph or videotape them! See Appendix F, "Photography Support for Hazmat Investigations." Either write or tape-record notes of what you photographed and why. If you take videos, talk while you are making your video. Capture ending states as you find them on arrival or on your walkaround.

Acquiring Events From Objects

To get "things" data about events, try to:

- Track successive changes of conditions required to produce the outcome, using the investigator's Six Ps.
- Use the energy trace and barrier analyses technique to track energy flows into and out of "objects." See Appendix B, "Energy Sources."

You can extract data from objects by working backwards from observed ending or intermediate conditions. Techniques include:

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

Stressors = The actors for your object events

In hazmat incidents, stressors come and go so often that only stressees may be available for you to "read." Stressors can become stressees during interactions with stressees (for example, an operator who opens a valve releasing a hazardous material can become a victim in the ensuing events). This is why sequencing and timing require your special care.

In hazmat incidents, you can use the TRACEM tool to look for stressing energies (See Chapter 2) *plus people actions*. See Appendix B, "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":

- *Paper* may help determine beginning or intermediate states. Papers examined might include shipping papers, hazmat facility inspection records, predictive hazard or risk analyses, purchase orders, material safety data sheets, instrument charts, and standard procedures.
- *People* — ask others what they saw the hazardous materials or objects do before or during the hazmat incident as well as:
  - How they operated objects
  - How they were trained or instructed to operate the process or object
  - How the process or object behaved in various known circumstances
  - Conditions they observed while the process or object was operating
  - Any actions they took in response to what they saw process or object doing
- *Parts* define stressor actions from observed effects. The changes to parts during the incident may indicate exposure to hazmat impingement such as changed surface characteristics, deformation, overheating, corrosion, heating, chemical composition, and residual data computer memories.
- *Positions* define the effects of stressor actions. This is the position in which objects came to rest during or at the end of a hazmat incident. Discovers if and how positions changed from pre-hazmat incident positions.
- *Patterns* infer or define stressor behaviors, intensities, exposure duration, and velocities, for example. Notice patterns in hazmat actions on exposures, differences in

patterns on exposures, unexpected chemical deposits, deformation or residue patterns inside container, and cracking patterns in high-pressure hazmat equipment.

- *Properties* determine events from data about their effects on objects. Examine materials of construction of containers for changes in inherent properties of objects such as metallurgical properties of fittings, resiliency of gaskets, and changes in spring-resistance attributes on spring-loaded pressure-relief devices, for example.

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

Testing Objects to Get Data

Your general approach to reading events is to get all the information you can before you do anything to change, damage, or destroy what is available. Sequence of testing objects is to:

- Look
- Dismantle
- Operate
- Destroy by testing

As you learn about what things did and put them into your mental movie or onto your work sheet, you may find that you have trouble getting 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 unintentional damage to your data:

- 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 whatever experts give you must fit into your mental movie or your work sheet. Settle any test plan *before* you sample, change, dismantle, try to operate, or test anything! (See Appendix E, "Basic Hazmat Incident Test Plan Elements," for hazmat incident test planning guidance.)

> *One indispensable rule to remember is: NO PLAN, NO TESTS!*

Then, stick to your plan. Experts from other fields and laboratories may not be used to satisfying your need, which is to get events to finish off your scenario. 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 events you still need. If not, the work sheets have been used successfully to persuade whoever is paying the bills to get what you need.

PEOPLE DATA SOURCES

To understand people as data sources, you need to recognize 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. You also need to be able to plan for and acquire the data you need from people by asking the right questions.

How People Record Data

People record data directly. They may see, hear, smell, taste, touch something, and remember the sensory stimulus. Actions and observations are often stored as visualizations — or mental movie clips. People also record data 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. They may remember the input and process leading to conclusions, or they may not. Some may record data as personal feelings and beliefs or cultural patterns. Their perceptions or truths have been adopted from an authoritative source, experience, or faith rather than logic.

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

Recognize Witness Types

During a hazmat incident investigation, you may find the following witness types:

- *Victim* — Hurt by hazmat incident; may be biased by revenge or self-interest in exploiting harm in litigation.
- *Participant* — Not hurt but did something before or during the incident. "Focusing" phenomenon during stress, guilt feelings, or liability concerns may limit or bias responses.
- *Observer* — Not involved but saw what happened. Look for good overviews of actions, easy access.
- *Programmer* —Influenced "how *what* you see came to be"; informative, but be cautions about self-interests.
- *Responder or physician* — Can describe harm-producing actors and actions and what they changed during and after hazmat incident.

Know Why "People Data" Changes

Data about hazmat incidents stored in people's memory may change because people 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 incident until you have talked to them, and schedule the interview as quickly as possible after your walkaround.

Plan Interviews

Plan interviews to fill in your mental movie or time/actor matrix work sheet. Your general objective is to hear the witness's entire "mental movie" of events during the hazmat incident and add or confirm events on your work sheet or your own mental movie.

Set your interview objectives. These should 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 open the door for follow-up questions.
- Identify events or actions, in general terms, that 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 arrange for materials needed to support questions you will be asking.
- Decide how you will control the interview process by either negotiation, assertiveness, exclusion, or other means.

Prepare for a Specific Interview

Before you start an interview, make sure that you:

- Meet in a nonthreatening, private, and neutral interview setting.
- Base the interview on your recognition that the witness has the data that you need and that the witness does not have to give it to you. (This helps your attitude!)

- Clear you mind of your similar experiences, your assumptions, preconceptions, expected answers, and what should have happened. (This also helps your attitude.)
- Decide how you will state the 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.
- Give the witness an opportunity to do most of the talking (more than 95%) by the questions you ask
- Hear what the witness says, not what you are expecting to hear. (Attitude again!)

95% Rule: Run interview so that the witness talks 95% of the time to maximize the information acquired.

Document Your Interview

During or immediately after an interview, document the interview data.

- Document actions, decisions, conclusions, etc., as events. The actor/action columns on paper speed up note taking and help you concentrate on listening for events.
- List names and then track actions of new actors mentioned.
- Have the witness make or mark sketches, photos, maps, drawings, or other visual aids with data from the witness.

After you have the data, record the actions described to you in the event format, resolve differences among the actors, and cite the witness as the source on each event.

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

HYPOTHESIZING

Often you will find that you have a gap in your understanding but that you have wrung out all the data you can from what survived the incident. You do not know where to look next. At that point, a conscientious investigator can end the investigation and live with the gaps. An alternative is to legitimately hypothesize or "create" events *on paper* to see if they can fill the gap.

Creating events during an objective hazmat incident investigation may sound wrong, but it is not. Your insights grow as you "create" events, and you define the data you need to compare with other hazmat incident events. You will also test any proposed scenario with necessary and sufficient logic. If it survives, you can offer your theory with reasonable confidence.

As you formulate these ideas, try to define the events that 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) lab tests, tear-downs, or simulations.

The most useful investigative data "creation" approach is to use *logic tree analysis* techniques, 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 a potential scenario to fill a gap, look for data to support the scenario.

After doing a 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 the value of data against the cost of getting it with a test or simulation.

SPECIAL HAZMAT INCIDENT INVESTIGATION CONSIDERATIONS

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 work sheet 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 motivates all investigators to show the logic of their conclusions and judgment calls. Concentrate on producing an objective description of what happened.

Communications

Think carefully about what you say to whom during investigations.

You should listen a lot and talk little during investigations. Except for raising questions and exchanging information with other investigators, you should gather data — not disseminate it — until you have completed your description of what happened and why it happened. It is okay to share information with someone whom you are asking for help, but otherwise avoid premature communication of speculation or judgments.

Requests for Information

Have a response ready when a reporter, witness, participant, owner, claimant, regulator, manager, victim, or other third party asks for information during a case.

A valid and truthful 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.

Filling in Forms

If you are expected to fill in forms, use the work sheet to provide information and to write the narrative description of what happened in the space usually provided in forms. To write the narrative, simply state *who* did *what when* and what happened. Use the words "before," "after," or "at the same time" to describe relative timing. If recommendations are required, the problems identified on the work sheet and the options as well as the rationale for selecting the recommended actions can be described in the narrative.

If you have to prepare a narrative report, the same guidance applies. Narrative reports do not have to be works of art and should be judged on their technical merit rather than their literary merit or political correctness. They should be judged by how well you enable the reader to visualize what happened and understand why it happened. The reader should also be able to visualize the predicted effects of proposed recommendations.

The information gathering and documentation process may sound complicated. It takes longer to describe than it does to use it. Remember, the complexity of the work sheet or mental movie reflects directly the complexity of the hazmat incident and how much of the hazmat incident process you investigate.

These procedures are actually quite simple, fast, and efficient as you gain experience. The hardest part is transforming the information you get into events. Doing the logic checks as you add events to work sheets cuts down the time wasted on blind alleys. By documenting observed data this way, you also can reduce other costs, too, such as extra paperwork, filing, testing, review, approvals, and potential litigation.

Do not be intimidated by the process. Your work sheet has all the capacity you can use, and if the incident was complicated, the work sheet helps you keep in command of your information.

Armed with this knowledge, good observation and logic skills, and some practice, you are ready to do good hazmat investigations and to keep your experience from getting in your way.

CHAPTER 5 HAZMAT INVESTIGATION TASKS

This chapter describes in a brief format what you need to do during investigations. Your tasks require planning, data gathering, analysis, and reporting. Before departing for a site, you should complete a number of common investigation tasks. This should all be done before you leave your office for the site.

- Verify the ground rules for investigation.
- Verify the investigation objective(s). Determine what happened and what should be the principal objective in all investigations. If you do not do this, you probably will be gathering data and not conducting an investigation.
- Strive for results that enable you to visualize what happened and why it happened from your description and accompanying pictures, sketches, diagrams, or maps.
- Verify specifications for what you must deliver. Ensure that you know the criteria that will be used to judge your deliverables for quality-assurance purposes, and work toward them as you investigate.
- Determine cause(s). If you are asked to find the cause or causal factors, this is an objective someone wants you to accomplish. If you have criteria for "cause," pick them off your work sheets. Otherwise, do the best you can with what you get.
- Verify authority and constraints. Whoever tells you to investigate should also be able to tell you what investigation authority you have. Find out:

  –How much time and money you have.

–When your deliverables are due.

–How to handle the situation if you need more hours or money. Do not overspend your allotted hours without asking for more time. If you pinpoint the remaining uncertainties and do not get the time to resolve them, the supervisor will explain why the remaining uncertainties were not pursued.

- Leave some slack time for delays you cannot control such as witness access, parts removal and testing, and review for legal comments, if applicable.
- Verify who takes your directions or gives you direction.
- Establish who directs whom at the incident site. You need authority to request and get access to the site, witnesses, debris, or records. A brief letter of introduction stating your task and authority is always useful, if properly written. The other side of the coin is that you should not abuse such power — you want cooperation on future investigations.
- Clarify the chain of command if more than one investigator will be investigating. Governmental investigators' authority usually takes precedence over any private sector authority.
- Verify who resolves disputes. Clarify who resolves disagreements or disputes if they arise while you are investigating. It is important to know where to turn when someone is walking away with your property and you do not like what they are going to do with it.

START DATA ORGANIZATION

After you get notification of a hazmat incident to investigate, start organizing newly acquired data as soon as you get any events. Usually you learn about an occurrence by telephone or in person. What happened is sketchy, incomplete, and inconsistent. Transform what you learn into tentative events to add to your mental movie.

Alternatively, you can begin to document events by starting an actor/time matrix work sheet. This provides a framework on which you can "place" or "position" each new event as it is acquired during the course of your investigation. You "position" each new event relative to previously acquired events. This results in an incremental addition to your understanding of what happened or recognition of what to get next.

Establish Control of the Investigation Site

While en route to the site or upon arrival at the site, you or someone helping you should identify site control needs, capabilities, and authorities for investigation purposes. Talk to the emergency response site commander, if he or she is still available. Identify the following as soon as possible:

- Site owners
- Hazardous materials and facility or vehicle owners

Hazmat incidents happen on private or public property, but they can and often do spread beyond the initial property boundaries. Identification of the hazardous materials and property owners involved may be important because of access, object removal, and interests in the investigation. 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 incident.

Governmental authorities have the power under many laws to establish control of the hazmat incident investigation site, regardless of who owns it. This control is authorized to prevent harm from being inflicted on what remains or to cover up what happened. This Guide assumes that a hazmat release does not involve any criminal activity. If there is something that looks willful, consult with law enforcement personnel immediately.

On government property, follow the ownership too. For example, highways are government owned, and the owner's representative is the local law enforcement agency, state police, or the fire and rescue organization.

> *If you are the investigator in charge, make sure that the person selected for the site control task is able to complete it.*

An explosion, for example, may involve large areas and many people. Does your organization have the physical and communications resources to adequately control access to and egress from the site? If not, who does, and how can those resources become engaged in your project for the duration of the investigation?

Determine who is in charge of the site. Make sure that changes in shifts or personnel do not leave you stranded when you need something. If an incident like a hazmat spill, for example, extends the duration of an incident, you need to find out the name(s) and access information for contact(s) to get something done at the site.

Access and Egress Controls

Hazardous materials can pose lingering risks at the site of a release, necessitating site control before and possibly during investigations. Site control requires control of individual access onto and egress from the site. Be a party to defining who will be granted access to the site and for what specific investigation purpose they are admitted. Clearly establish control of egress to prevent unauthorized removal of incident-related debris, parts, or documents.

Before entering a site, consider your own safety. Check with the site controller to identify any entry risks, such as dangerously damaged structures, leaked chemicals, noxious gases, unignited flammable gases, exposed animals, charged electrical wires, blood-borne pathogens, or other energy sources. (See Appendix B, "Energy Sources," for 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 available 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, avoid damaging data sources — people or objects at the site. Damage can take many forms including physical damage and psychological damage.

In addition to being exposed to physical harm, people at a site are vulnerable to change and may need to be "protected." This is why it is important to protect people from outside influences until they have given their data to you. An instruction not to discuss their observations is minimal protection. If the stakes are high, as in a fatal injury, physical separation or isolation is preferred. Fit the protection to the case.

Avoid psychological damage; recognize that if people get the idea that you think their inattention "caused" a fatal injury incident or that their "human error" "caused" the incident, the damage can be significant. Hammering on a witness to admit or agree to something can be equally threatening.

Avoid using threatening words, actions, or body language. Make sure that everyone you talk to understands that you are looking for understanding — not cause, fault, or blame.

Protect objects from investigators and other people who go onto a site and start touching, moving, altering, taking objects, disturbing their distribution, or changing the objects themselves. Because you rely on objects for your data, you do not want them changed until you see them. You will need 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 examine them before they are changed.

Nature can change objects too. Rain, for example, can wash off residues, initiate oxidation in metals, or dissolve chemical deposits. Sunshine or rain can melt ice. Running a bulldozer over a small object can also ruin your data. Therefore, you want to consider how objects might change and work out something that would protect them until you get your look.

If the site is very small, you may want to give your walkaround look priority and not bother setting up site barriers. What you do depends on the incident and what you have to protect.

Set Security Boundaries

Your next task is to set up site security boundaries and secure the area within those boundaries. In hazmat releases, the boundaries for investigators are going to be smaller than the boundaries established by emergency responders dealing with a gas cloud, for example. The actual physical barriers and boundaries depend on the nature of the incident, what was involved, and the resources available to establish the boundaries. Barriers, such as highway barriers, can be very disruptive; therefore, the strategy is to try to put barriers around only what will be needed for the investigation and then restore the activity as quickly as possible.

Disrupt as little as you can and for as short a time as possible. During this task, you continually keep trying to figure out who and what were a part of the incident process so that the data they hold can be protected until it can be acquired, documented, analyzed, and tested.

After you make the site command connections and secure the site, continue the data search, acquisition, documentation, testing, and refinement stages of the investigation.

Find Out Who "Owns" Debris and Can Authorize Tests

Site ownership and debris ownership are often different. For example, when a private vehicle crashes on a government highway, the ownership is different. Whoever owns the hazmat debris should have a voice in its removal for testing and analysis — before any debris is changed or destroyed at the site or in a laboratory.

However, in hazmat releases, the site may have to be disturbed significantly to control losses, as when water is applied to extinguish hazmat fires or cool exposed containers. In some incidents, such as airplane crashes, government investigators have the authority under laws to commandeer debris for investigation purposes. In these types of cases, determining ownership is not a priority.

Media Contact Procedures

Hazmat incidents, especially in urban or suburban areas, seem to attract more media attention than other types of incidents. If the media are interested in your incident, someone will contact you. The media have a different agenda than do investigators. The media use controversy and accusations of wrongdoing to sell newspapers or TV time. Investigators try to gain understanding that can be used to fix things. If the media ask questions during an investigation that you are not prepared for, tell the reporter that you are trying to find out what happened and until you understand, it would be unfair to discuss any findings to this point.

Avoid offering the media subjective judgment calls or speculations. During this task, you continually keep trying to figure out who and what were a part of the incident process so that the data they hold can be protected until it can be acquired, documented, analyzed, and tested.

The site control task is finished when the site managers have been contacted and site control materials and procedures have been negotiated, implemented, completed, and removed.

Set Data Acquisition Task Priorities at Site

Your task priorities at the site, generally, are to:

- Set up documentation materials.
- Start data search, including hazmat name and properties.
- Do site walkaround.
- Document ending states at site.
- Identify people and objects involved.
- Acquire data to tell you what they did during the incident.

Some reordering of priorities may be necessary. For example when you arrive at a site while the incident is still in progress, the walkaround may have to be delayed. If a site is unstable, as during a fire, the ending state documentation may have to wait. General priorities may have to be reordered, but each task still will have to be done.

Set Up Documentation Materials

Organize your data as you get it. If not already initiated, set up the work sheets for events, or at least set up your mental movies. Have some place to document and put any new observations quickly and efficiently.

Start Data Search

Your data search and data gathering actually begins with the first verbal notification of the incident. Your first direct observations for data begin on arrival at the site of the incident.

Do Site Walkaround

You need to get familiar with the incident setting as soon as possible. On arrival at the site, do a walkaround of the incident scene as soon as feasible to get generally acquainted with the location, nature, and scope of the incident and the kinds of people and objects that might have played a role in producing the outcome. Depending on the size of the incident, a walkaround may involve a "drive-around" or a flyover to get acquainted with the incident.

Use Appendix A, "Hazmat Incident Process Model For Investigators," as guidance to help focus what you look for as you proceed. Take lots of photos and notes. At large releases, get help to cover the full perimeter around the site adequately. Make sure that you identify the hazardous material and the containment system(s); they rarely disappear except, possibly in explosions or large loss incidents, and even then you will find at least some bits and pieces.

A walkaround is just that — you walk, ride, or fly, observe, and start to document and organize your observations. You do not touch, nudge, move, kick, or do anything that can alter what you see.

Document Ending State of Site Objects

During the walkaround, you can start to document the objects at the scene. This means that you should try to see and record the ending state of objects affected by the incident process so that you will have a faithful record of their states throughout the investigation. During your first walkaround, you probably will not have a sound idea of what is relevant and what is not. Therefore, try to photograph or video everything at the scene that seems to have been changed, if it is safe to do so.

Capture the scene with photographs, videos, sketches, diagrams, drawings, or maps. Do not try to remember everything you see. (**CAUTION**: Always include something you can use to determine the scale in the graphics.)

Get Specific Hazardous Materials Data

Your first data requirement is to determine what hazardous materials may be present in the incident. You can determine this from many sources such as markings or placards on containment systems, process documents, transportation shipping papers, or labels on packages if visible, or from the nature of the effects of the hazardous material if you have nothing else.

The second initial data requirement is to identify and document the containment system from which the hazardous material escaped. Each release involves the escape of a material from its containment system. Containment systems handling hazardous materials usually are marked with some identification labels, plates, or markings. To determine what happened, you need to identify and document the normal state of the hazardous material and the containment system before the incident process began.

You may see two basic types of containment systems: pressurized and nonpressurized. Each type includes several categories. Pressurized containers include cylinders, spheres, casks, and tanks that may have rounded ends or tops, piping, and process vessels. Nonpressurized containers include tanks that may have flat ends or heads, tote bins, drums, jugs, bags, and cartons or boxes. Look for specification markings or identifiers and other required data on the outside of the container.

Document Other Hazardous Materials Involved

You must recognize that in transportation, hazardous materials may be carried in bulk transport vehicles. Bulk vehicles include pressurized rail tank cars, highway tank trucks, barges or ships, pipelines, and intermodal tank containers. Some vehicles may have rounded ends, but do not count on finding that clue. Van-type vehicles, including boxcars, trucks, and seagoing containers, may be carrying a mixture of pressurized and nonpressurized hazardous materials.

GET SPECIFIC INCIDENT DATA

Find Container Stressor(s)

To describe and explain what the container, hazardous material, and possible reaction products did during the incident, you need to look at all three as potential sources of any harm you observe.

Apply Hazmat Incident Model to Guide Data Search

You can use the Investigator's Hazmat Incident Process Model in Appendix A, "Hazmat Incident Process Model for Investigators," to guide your data search and collection during the walkaround and afterward.

In specific incidents, you may not be able to track the release process in the sequence shown because of the extent of the damages. In explosions, for example, the heat created by the chemical reaction of the explosive material and the forces of the explosion reactions either destroy or disperse the objects involved over a wide area. This may require you to work backward from the ending state. This is a perfectly acceptable and orderly way to proceed, as long as you organize the data to help you determine what is needed next to identify earlier events.

Identify Energy Barriers

Be alert to the barriers involved in the incident. Consider any control device or procedure a barrier. Watch for barriers that did and did not work. Describe their condition before and after the incident if possible.

Barriers take many forms, depending on the inherent nature and energy content of the hazardous materials. Haddon's strategies (see Appendix C, "The Control of Energy Hazards") illustrate the many kinds of barriers used. Consider both primary barriers such as tanks or piping and secondary barriers such as safety devices, insulation, process controls, warning devices, procedures, standards, and periodic maintenance programs.

Physical Barriers

Identify the physical barriers involved in the hazmat incident control system. Physical barriers are typically dependent on the nature of the energy. For example, a common electrical energy barrier is insulation around a wire carrying electricity. Cylinders are barriers to control the compressed gasses inside. Insulation is a barrier to fire. Dikes are barriers to hazmat spill dispersion.

Space Barriers

Watch for space or distance barriers. For example, look at the dispersion of fuel storage tanks in a tank farm. Cargo separation in storage areas is another example.

Quantity Limits

Watch for quantity-limit barriers. For example, a fraction of an ounce of an explosive material provides us with the pleasure of fireworks displays, while pound quantities of explosives pose a lethal threat if they detonate.

Procedural Controls

Watch for procedural barriers. For example, a placard with a warning symbol and a number on a hazmat transport vehicle is a form of procedural control — in that its intent is to result in certain actions by the observer.

Summary of Barriers

When investigating a hazmat release, you need to be aware of and be able to document and describe the containers and barriers used to control the hazardous material as they existed before the incident started and their role in the incident.

Organize Information

Add new information to your work sheets, mental movies, note cards, or whatever system you elect to use, but document and organize the information as you get it. This is the only way you will know what you have and what you still need. If you do not do this, you will have no realistic basis to get at the unknowns that you do not even know about or the unknown unknowns sometimes called "unk-unks."

Document People and Objects Involved

This is also a good time to refine your work sheet or your growing mental movie of the incident. 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 and organize them promptly. If early in your investigation you do not know their official names, use a question mark and your own name until you can find out. The data source for these notes is "my walkaround."

Identify People Witnesses

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

- Responders
- Observers who saw what the hazardous material, container, or other people did
- Victims injured in the incident
- People who did something before or during the incident (participants)
- "Programmers" who influenced what people or objects did during the incident

These are the people you will probably want to interview after you know enough to ask them good questions.

Identify Object Witnesses

As you do your "walks," you will observe objects that were changed by the incident. These are also candidate witnesses too - candidate changemakers or objects that you may want to examine or "read." Other kinds of objects you want to note are anything that influenced what happened such as safety systems, signs, procedures, manuals, or guides.

Get the Data You Need

You are rarely the first to arrive at the scene of an incident. The site has probably changed before you arrive. This creates another task — getting observations from first responders at the scene before they leave. Use their observations to identify additional people or objects at the scene, and try to learn what they saw and did. Add those actions to your growing mental movie or work sheet. Document the information that you get from responders by transforming it into events and adding these events to your work sheet. The source of the events should be the responder's name.

Test Events as They Are Documented

Do the events displayed on your work sheet represent the sequence in which 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 the event blocks required to produce 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, why it happened, and what you still need to understand. 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.

Read Objects

The next set of tasks is to "read" data from objects to learn what they can tell you about events that happened or why they happened. The following are useful strategies to help you read data:

- Use the six Ps to locate and describe objects to read.
- Read the container or remaining parts and components.
- Read hazardous material effects or residues on objects.
- Talk to people about what objects did.

Procedures for Reading Objects

> *If you have not done so during the walkaround, photograph objects before disturbing them!*

Prepare notes describing what you photograph or videotape. Use close-up photos to capture details about ending conditions of objects likely to be causally related to the incident.

To read data from things, start by trying to:

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

Examine specific objects to get data for events, such as:

- **Change(s)** that occurred and times involved
- **Actor(s)** that acted upon them (stressors)
- **Action(s)** in which they are exposed
- **Sequence(s) of changes** that occurred
- **Duration** of events or interim changes
- **Exposure** concentrations, duration

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 of:

- Area(s) of stress origins
- Actions by reaction products
- Unexpected behaviors
- Hardware safeguard operation
- Objects that accelerated or impeded the incident growth
- Other events that changed the course of the incident process

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

Test events as they are documented for:

- Correct time and spatial sequence
- Cause-effect relationships among events
- Necessary and sufficient logic completeness or uncertainties

Get Data From People

Objects are your most reliable data sources and behave predictably if you know how to read them. People are less reliable and predictable but can be helpful and should be used as data sources. Get data you need from people after you have some idea about what to look for.

Establish realistic expectations of what information your witnesses can give you:

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

Interview Preparations

Before starting your interviews, make sure that you have built your mental movie or work sheet as much as you can. Sequence your interviews in the following preferred order:

1. Responders
2. Observers
3. Available victims
4. Participants
5. Programmers

Watch for the changes in data that people offer. Cross-check what one witness tells you during interviews with what others said and against what your observations of objects tell you. The best way to do this is to lay out the events next to each other on an event work sheet or at least a mental movie.

Interview Procedures

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

Conducting your interview:

- Ensure that the witness will have adequate time to talk with you.
- Open the interview with an explanation of what you are doing and why the witness should help you.
- Work out with the witness a way to document (preferably with your tape recorder) what the witness tells you.
- 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 or anything else you need to fill in a form.
- Ask the witness to describe the incident setting, witness's location, and when the witness first became aware of something happening. Show this location on the sketch.

- Visualize with the witness the beginning of the witness's mental movie.
- Have the witness describe what he or she saw other *people* and *things* do and what the witness did during the time interval you describe.
- Track the witness's observations and actions with questions such as:

  –What happened?

  –Then what happened?

  –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 beginning to end of the incident and use the movie to raise questions to fill in the remaining gaps in your mental movie. Account for all the time the witness was at the scene, if you need the data.
- To restart your mental movie, use questions such as "I can't picture what you said when you said..." or "Forgive me, but I couldn't follow what you said when you said..."
- During the entire interview, keep looking for information about changemakers that produced outcomes.
- Ask "easy" or "what happened" kinds of questions first to finish action scenario so that if the witness ends the interview, you have as much data as you can get.
- Identify the victim's, participant's, programmer's, and witness's understanding of expected actions during the incident; then start to explore why events happened with questions about conclusions and opinions.
- Finish conclusions and expected actions before asking questions about responsibilities, duties, authority, contradictions, etc., which will be construed as potentially threatening by the victim, participant, or programmer witnesses.
- Do not hesitate to make event blocks with the witness during personal face-to-face interviews if a point in an incident 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 note so that the witness can contact you with more information.

Remember, focus on finding changemaker actions.

Some Interview Don'ts:

- 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-incident expectations with what actually happened.
- Do not assume that procedures, regulations, specifications, standards, and design are correct.
- Do not let prior incident scenario bias your questioning during this investigation — start with a blank piece of paper, and use data you get from this case.

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 trainer or training course developer
- Supervisors and co-workers
- Equipment designers, buyers, and managers
- Customers
- Media
- Other programmers (names, actions)

Enter data from witnesses into your mental movie or work sheet as soon as possible after each interview and preferably before you start the next interview. It's worth the time.

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?

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.

You need an event work sheet for objective 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.

Your reports should satisfy your specifications but also include:

- The scene, what happened when, and why it happened
- What started the incident
- The hazardous material(s) that played a role in the outcome
- The events that brought the stressor and hazmat system together
- The hazmat dispersion and any features, conditions, or safety systems that limited or contributed to the loss
- If not reported elsewhere, response activities that limited or contributed to the losses
- The losses attributable to the hazardous materials, container, or response activities
- The actual or estimated times of key loss or response events

Any report or work product you produce should be easy for your reader to visualize the hazmat incident process, the points you want to make, and arguments that support your conclusions. To accomplish this, add illustrations to any reports you submit. Your photographs, sketches, etc., help readers visualize settings for events constituting the hazmat incident and help you make your points.

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

Learning From Investigations

To learn from your investigations, 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.

DEVELOP RECOMMENDED PERFORMANCE IMPROVEMENT ACTIONS

You may or may not be required to prepare performance improvement recommendations. When recommendations are required, you have to shift mental gears to think about and improve *future* performance — or look *forward in time*. To do this, you need to know how to discover, define, and assess problems and needs; identify, define, and assess options for improving future performance; and develop a plan to show whether the changes implemented are producing the predicted effects.

Take great care to ensure that all the recommendations you propose are based on a valid description and explanation of the hazmat incident that will support the action(s) you propose. If implemented, make sure that the recommendations will resolve the problems you want to fix, *for the life of the system*. Also ensure that the recommendations will provide for real-time monitoring to verify predicted effects.

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

To develop recommended actions:

- Define candidate problems, in terms of who did what, when, and with what effects (causal links), and why it is a problem.
- Determine which problems need to be fixed, and restate each problem as a need to be satisfied.
- Select the best 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 quality assurance check of your selected recommendations.

> *The most efficient way to do these tasks is to use the time/actor event sets on the events work sheets showing the hazmat incident 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 hazmat incident to discover, define, and assess problems disclosed by your investigation. A hazmat incident description on the time/actor matrix work sheet identifies all relevant events that need to be examined to discover, define, and assess problems. The procedure facilitates innovative thinking, regardless of your experiences.

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.

When you use a work sheet, start by looking for candidate problems by examining one linked event pair or set at a time, until all pairs 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 whether 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 its:

- Magnitude — the strength of the influence on the next event
- Origin — should that relationship have occurred at all
- Timing — how fast, when it happens, or how long it lasts
- Effect — 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 needs statement establishes the objective for any action.

Determine Which Problem Needs 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 future harm likely if the problem is not fixed. Sometimes, other circumstances may affect your decision.

Record your description of what the problem is and what need that creates. Keep track of your efforts by marking each event or link you defined as a problem on the work sheet. Using numbered diamonds helps keep track of the problems.

Find Candidate Changes

As you look at the links and events, consider introducing changes to achieve different results. For additional control strategies, see also Appendix B, "Energy Sources," and Appendix C, "The Control of Energy Hazards."

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 needs statements as seen by the person who pays for the 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 of 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 Quality Assurance of Best Recommendations

You have to decide whether or not to make any recommendations at all from each hazmat incident. 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:*
>
> *When implemented, will your recommendation achieve your predicted performance improvement objectives, and will you get convincing proof over time that it did?*

CHAPTER 6
HAZMAT INVESTIGATOR'S TASK LIST

The main tasks you will have to perform during a hazmat incident investigation are listed below. This list describes what you have to do in the typical sequence you will do the tasks. It is designed so that you can use it as a checklist if you wish. Remember, the general strategy is to first identify the material(s) involved and then to develop the rest of the hazmat incident process description.

Investigation Preparations

- ☐ Understand the investigation mission, objectives, and policies.
- ☐ Know what you are investigating.
- ☐ Understand investigation preparation tasks.
- ☐ Ensure investigation supplies and kit readiness.
- ☐ Practice procedures.
- ☐ Understand how to use "changes" in investigations.

Upon Notification of a Specific Case
Verify:

- ☐ Objective(s)
- ☐ Deliverable specifications
- ☐ Scheduled completion date
- ☐ Hours to do the investigation
- ☐ Your authority

On Arrival at Site

- ☐ Start data organization.
- ☐ Confirm control of site.
- ☐ Interview on-scene commander about what happened.
- ☐ Identify the hazardous materials involved and present.
- ☐ Identify hazardous materials owner.
- ☐ Acquire other ownership-related data.
- ☐ Determine who is in charge of the site and for how long.
- ☐ Ensure access and egress controls.
- ☐ Control site safety risks.
- ☐ Control site data risks.
- ☐ Find out who "owns" debris and can authorize tests.
- ☐ Set security boundaries.
- ☐ Obey "do no harm" rule.
- ☐ Protect people from change.
- ☐ Protect objects from change.
- ☐ Set site data-gathering priorities.
- ☐ Set up documentation materials.
- ☐ Start data search.
- ☐ Do site walkaround.
- ☐ Document ending state of site objects.

Get Specific Hazmat Data

- ☐ What hazardous material was involved?
- ☐ What containment system was involved?
- ☐ Was there more than one hazardous material in an incident?

Get Specific Incident Data

- ☐ Find container stressor(s).
- ☐ Search for data using Hazmat Incident Model.
- ☐ Identify energy barriers.
- ☐ Organize information.

Read "Objects"

- ☐ Select strategies.
- ☐ Read data from objects.
- ☐ Make additional observations.
- ☐ Add and test events as they are documented.

Get Data From People

- ☐ Establish expectations of witness.
- ☐ Make interview preparations.
- ☐ Watch for changed people data.
- ☐ Conduct interviews.
- ☐ Document interviews.
- ☐ Test events as they are documented.
- ☐ Fill gaps in understanding.
- ☐ Delete irrelevant information and words.
- ☐ Quality-check your description and explanation.
- ☐ Report what happened and why.

Develop Recommendations

- ☐ Define candidate problems.
- ☐ Determine if problem needs fixing.
- ☐ Document problems.
- ☐ Find options to fix.
- ☐ Predict effects and costs of options.
- ☐ Identify trade-offs and rank options.
- ☐ Satisfy visualization needs.
- ☐ Select recommendations.
- ☐ Do QA of best recommendations.
- ☐ Prepare report.

APPENDIX A
HAZMAT INCIDENT PROCESS MODEL FOR INVESTIGATORS

The Hazmat Incident Process Model for Investigators is a general description of the hazmat incident process. The model begins when the first stressor acts on the hazmat system. It progresses through the steps required to produce harm. It ends with harm amelioration actions. It displays actions in a flowchart or multilinear events sequence format. Events are shown in the usual sequence they occur, and the arrows indicate how they relate to each other. Timing among events will, of course, vary from incident to incident.

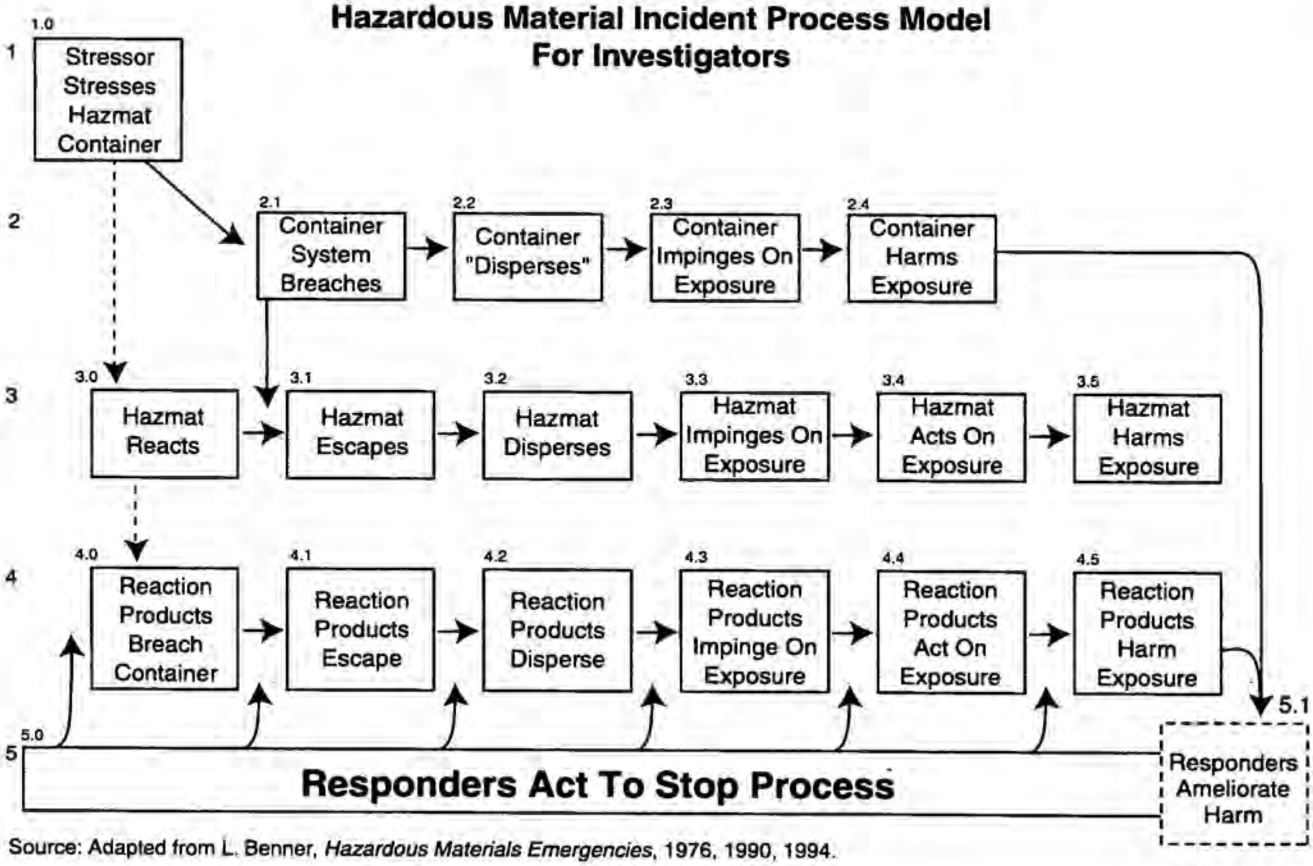
This model is provided to help you do an orderly and comprehensive investigation of a hazmat spill, release, or incident. Because it is a general model, you will have to "decompose" or break down actions to understand and be able to describe what happened in specific incidents. Depending on the nature of the incident and your objectives, you may want to focus more intently on one element of the model than others.

During investigations, use the model to guide the development of questions to raise and the areas of inquiry to pursue.

This model represents the physical processes involved in incidents and shows five general actors (1-5 along the left margin).

- Actor 1 is the initial stressor.
- Actor 2 is the container system.
- Actor 3 is the hazardous material.
- Actor 4 is the reaction products, which you may want to decompose into the specific reaction products that advanced the process.

Figure A.1
Hazardous Material Incident Process Model For Investigators



Source: Adapted from L. Benner, *Hazardous Materials Emergencies*, 1976, 1990, 1994.

- Actor 5 represents the people or objects that acted to change the normal course of events to reduce the size of the losses.

When you do your logic testing, you usually find other actors had to do something to advance the process, and you will probably want to describe them. If so, just add more rows and events. For example, if the exposures are people, and they did something to reduce or increase the harm that occurred, you may want to describe those actions. You may want to add designers and regulatory personnel as actors if they designed some feature into the system to reduce the size of the loss to meet regulations and if it did not work. These are the kinds of unique incident circumstances that require decisions by the investigator as information about the incident evolves.

APPENDIX B
ENERGY SOURCES

Energy produces changes in objects and people by doing work. Typically, energy must be confined and directed by barriers to get it to the point where the work is to be done. Hazmat containers are barrier systems that confine the hazardous materials until they can do the desired work.

Energy also produces harm to the hazmat containment systems as well as to the hazardous materials. Such work takes various forms, such as deformation, deposits, chemical reactions, motion, or heating. Work applied to hazmat containment systems generally produces some change to the prior state of the container or hazardous materials. The energy leaves tracks in the form of work performed. Those tracks may be in the barriers that were intended to control the energy flows or may be outside the barriers. Energy flows can also be inferred by what the hazardous material does.

Table B.1 describes natural energy sources. Table B.2 describes energy flow control problems. Table B.3 describes managed energy sources.

The symbols ○ = input energy and □ = output energy.

Table B.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 B.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 B.3
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 C
THE CONTROL OF ENERGY HAZARDS

Hazardous materials are energy substances considered hazardous because of their potential to do harm if they are not properly controlled. Physician William Haddon was a pioneer in the battle to reduce the carnage produced by automobile accidents in the '60s. One of his contributions was the development of strategies for the control of energy that produced harm (Figure C.1).

Haddon's strategies are offered here as thought-starters for two purposes:

1. For use during investigations to identify actions that might be needed to complete the necessary and sufficient testing of the investigator's understanding of incident process relationships
2. For use during the development of a full description and explanation of the incident and for use during the development of recommended actions to reduce future risks

Note how the strategies parallel the hazmat harm-producing process sequence in Appendix A.

Table C.1
Haddon's Ten Strategies For The Control Of Energy Hazards

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

Source: *Hazard Prevention* 16:11, p. 8.

APPENDIX D
TIME/LOSS ANALYSIS OF HAZMAT RESPONSE

Hazardous materials pass through several stages during their release. People or things may intervene to try to stop the advance of the loss process during any stage of the process. It is important to ask whether the intervention actions were successful or whether they should be changed to produce better outcomes. Did the loss occur too fast to do much or anything to reduce the losses?

Time/loss analysis (T/LA) was developed to analyze intervention performance by people and things. Your T/LA displays provide an approximated and unscientific but useful measure of intervention effectiveness, which leads to insights into effectiveness of underlying intervention strategies, tactics, procedures, and hardware.

DATA REQUIREMENTS

Knowledgeable hazmat officials or investigators use the following information to plot time/loss analysis:

- The estimated time when the occurrence began
- The estimated time when each loss began and when it reached its ultimate severity in the incident
- Loss levels at various times during the incident
- Loss levels over time without outside intervention
- Times any specific intervention actions were initiated during the response
- The expected effects of each intervention action taken — *at the time each was taken*

Describe the intervention actions in an event block (*who* did *what* to *whom* or actor/action) format.

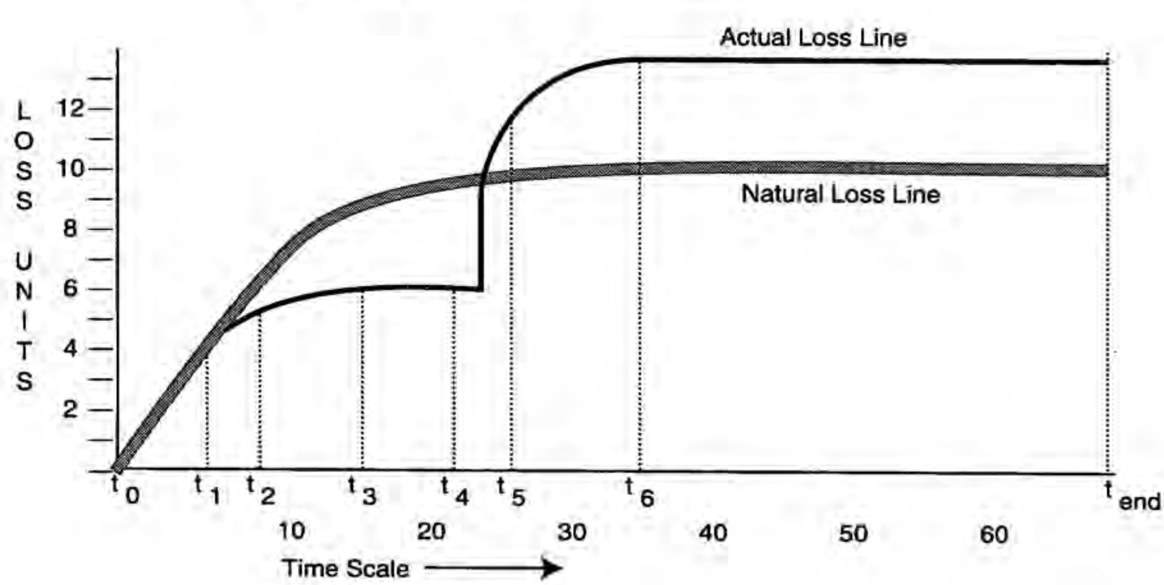
Data Sources Vary With Each Incident

- Witnesses and debris can indicate when specific loss events occurred, within workable tolerances. They usually can provide accurate information about the times when an occurrence began to affect them and when the effects reached certain stages of harm.
- Property damage data usually are less precise, but a consensus can be reached among well-informed individuals such as the hazmat incident commander, 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.
- After an incident scenario is understood, get estimates 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 to project the likely harm that reasonably would have been expected to occur. Consensus-building can be helpful if the experts are willing to help.
- 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.

Arrange the data in a plot showing changes in cumulative loss vs. elapsed time during the response to a hazmat incident, including notations showing responder arrival time and other action times.

Look at the following example, reproduced from an actual incident, for the general format of a plot.

Figure D.1 Example of T/LA Data Plot



T/LA Plotting Procedure

Prepare a set of plotting coordinates. The horizontal axis along the bottom margin is labeled "time." The time scale begins 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 "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 to the total elapsed time of the incident.

Plot a line for each type of loss, showing the estimated loss, accumulated as time elapsed during the mishap.

Plot the estimated natural loss line(s) if no intervention had been attempted in the occurrence.

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 previously plotted.

Label all the data points, and add chart title block describing the occurrence being analyzed.

COMMENTS

- T/LA plots indicate performance. Any time the actual loss line with intervention is higher than the natural loss line, intervention increased loss and is judged unsatisfactory.
- The farther 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 hazmat incident occurs.

For more information and examples describing the preparation and interpretation of time/loss analysis plots, see Benner (1994) or for additional general guidance, see DOE SSDC 37 (1987).

APPENDIX E
BASIC HAZMAT INCIDENT TEST PLAN ELEMENTS

In hazmat incidents, you may need to examine something to find out what happened. Examinations may address:

- Chemical residues from reactions on a wide range of objects
- Debris formed during reactions
- Damaged or impaired parts or components
- Subsystems such as hazmat containers
- Process control systems or "safety" devices

To ensure that you get what you need from any testing work, you should insist on a test plan that describes what will be done and what the work is expected to produce. Elements of such a test plan are indicted in this appendix. Tailor them to develop any test plans you need.

> ***Caution:*** *Get all the data from observing objects before you agree to their destruction by testing.*

TEST PLAN ELEMENTS

Test/Examination Objectives

Why do you want to do a test on something? Either to *verify* that what you think happened actually did happen or to *discover* what did happen. Focus on gaps in incident description you want to have addressed or the hypothesis for which validating data are being sought. If more than one party is involved, objectives desired by each of the parties may have to be documented. *Your* deliverables should be events to add to your hazmat incident description and documentation of the source data used to define them.

Physical Objects to be Examined

Describe the object(s) being tested or examined, and document them with photos to ensure tests are performed on parts everyone expects to be examined. State any protective measures for the objects to preserve them for more tests or for chain-of-custody needs.

General Test Approaches

Use this section to record any general principles to be followed by the testers, any assumptions that need to be documented before the test begins, and how the objects and tests will be documented. This is where any differences in the approach must be identified and resolved. For example, should a device be operated before it is dismantled, or should the dismantling be done before it is operated? Should chemical samples be combined or tested separately? What is the progression from nondestructive examination to destructive testing?

Test/Examination Procedures to be Followed

State the name of the test protocol, equipment, and citation, if it has been formalized, in the literature or elsewhere. Define and document the measurements to be produced. Specify chain-of-custody requirements, precautions and responsibilities, points of contact, and any security tasks. This section should state the specifications for the deliverables that will be produced and the quality-control criteria that will be used to verify the results.

Interpretation of Results

Hypothesize potential test outcomes and state how each potential outcome will be stated in event block format. If this task is done properly, the specific outcome may be uncertain, but there should be no surprises at the end of the test. The place to discover differences between you and the persons performing the work is in a backSTEP or logic tree procedure on paper, not after the test has been run, the money spent, and the results determined unsatisfactory.

Schedule of Testing

State what work will be accomplished, when it will start and where, the schedule for any drafts to be circulated if applicable, and when deliverables will be delivered.

Distribution of Deliverables

State who "owns" rights to the deliverables, who has authority to distribute them, and who can use or allocate them and for what purposes in the future. Specify any confidentiality or security precautions in this section.

Disposition of Tested Objects

State who will specify disposition of the tested object(s) and the time limit for disposition. Anticipated litigation may influence this section.

Funding of Test Work

Specify who pays what to whom. Who will pay for the test(s), and if more than one party is asking for work to be done, who will pay for what part of the test(s)? Who will spend and who will get what monies? Be aware that this requirement can be used very effectively in negotiations to dissuade proponents of unsound hypotheses to pay for tests or forego them. It separates the "needed" from the "nice to know" work.

OPTIONAL TEST PLAN ELEMENTS

Media Inquiries

Hazmat releases often generate media interest — especially large ones or ones that involved a lot of people, such as a traffic accident. Describe how to handle inquiries to the individuals and organizations actually performing the test(s) or others who might be contacted.

Safety Precautions

Where risk of injury or property damage is associated with the test procedures, state any required risk-control precautions and responsibilities.

Concurrence

When more than one party is involved, get every interested party — including the testers — to affix a signature to the test plan signifying concurrence in the plan.

GUIDING PRINCIPLES FOR TEST PLAN DEVELOPMENT

1. Whoever owns the ball calls the game.
2. **NO PLAN, NO TESTS!** This is a golden rule of investigation testing.
3. Keep test(s) relevant. (Get event blocks.)
4. Scale the plan to the value of the data it will produce.

TEST PLAN QUALITY ASSURANCE

The quality-control process begins with checking the quality of the event blocks created during the test. If they are flawed, further use will create problems.

Difficulty designing a test plan to produce the supporting data is usually an indicator that the event being sought may not be adequately defined or that the event may have to be broken down further to get supporting data. Sometimes you find you are looking at the wrong object to test for the data.

Flowchart the planned procedures on a time/actor work sheet, especially if any controversy occurs during the planning process or is expected during the test or after the results are received.

The concurrence process will disclose points of difference that may reflect quality problems as well as differences in opinions among investigators.

Make sure that the testers are familiar with the work sheet and your event block needs before they begin their planning, testing, or examination. Source: Benner, L, 10 Mes Investigation Guides, Events Analysis, Inc., Oakton, VA, 1994.

APPENDIX F
PHOTOGRAPHY SUPPORT FOR HAZMAT 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 accident 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 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.

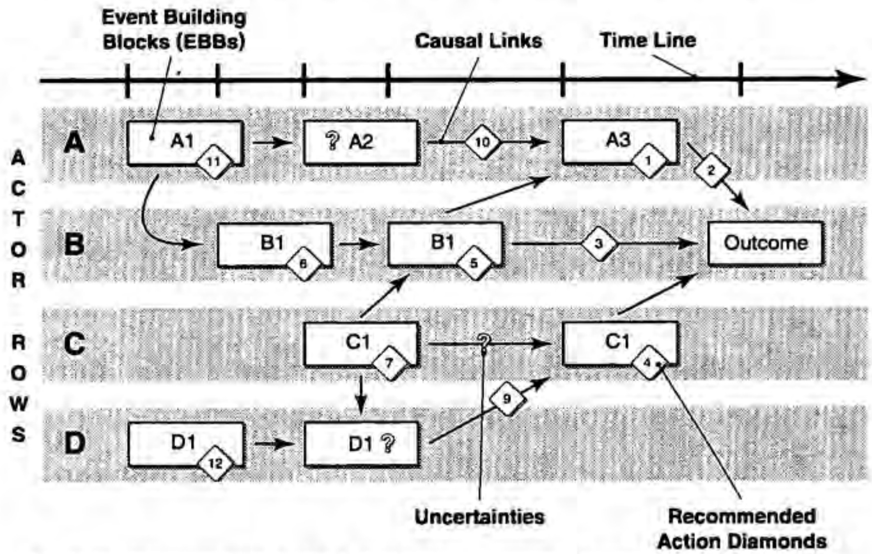
(Adapted from DOE MORT training.)

APPENDIX G
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.

Figure G.1 Time/Matrix Work Sheet Elements



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

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.

The same kind of display can be used to develop hazard analyses of new or existing systems. The process is similar to critical path project planning flowchart methods with the diamonds showing where potential problems might be predicted to exist.

APPENDIX H
GLOSSARY OF TERMS FOR HAZMAT INVESTIGATORS

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

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

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

Customer
Any user of an investigator's work products who depends on the investigator to produce valid descriptions and explanations of hazmat incidents.

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

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

Document
To capture observed data by recording them on paper with appropriate support such as statements, notes, photos, sketches, maps, samples, and reports.

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

Flowchart
A schematic representation of interactions among hazmat incident process components to show how an outcome was produced.

Hazmat Incident
An incidental process during which a hazardous material or substance reacted and escaped to produce a loss to exposed people, property, or systems. An incipient process during which hazardous materials were prevented from reacting, escaping, or producing a significant loss level by successful intervention actions by some person(s) or object(s).

Intervention
Action by people or objects to change the course of events constituting the hazmat incident 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.

State
A condition of existence of a person or thing; what is or was; may be static or dynamic.

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.

Work Product
Any tangible output produced by the investigator during an investigation.

Work Sheet
A matrix with time and actor coordinates on which are displayed the actors and actions that produced the hazmat incident process and outcome.

Appendix References

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NFPA 921, *Guide for Fire and Explosion Investigations,* Chapters 8 and 13, National Fire Protection Association, Quincy, MA, 1995.

Sax, N. Irving and Richard J. Lewis, *Hazardous Chemicals Desk Reference,* Van Nostrand Reinhold, New York, 1987.

U.S. Department of Energy, SSDC 37 *Time/Loss Analysis,* EG&G System Safety Development Center, Idaho Falls, ID, 1987.

Additional information:

Suppliers are required to furnish Material Safety Data Sheets (MSDS) for specific chemicals or hazardous materials to purchasers of their hazardous products. Contact the hazmat supplier for a copy of an MSDS when you know the name(s) of the hazmat(s).

U.S. Code of Federal Regulations, Title 49, Part 173-178, (49CFR173) and sections referenced in those regulations.

U.S. Department of Transportation, *Emergency Response Guide,*Washington, DC. Use current edition. Contact: Internet (hmix.dis.anl.gov) or (146.137.100.54).

U.S. Department of Transportation, Hazardous Materials Information Exchange, Washington, DC. Contact Internet (hmix.dis.anl.gov) or (146.137.100.54).

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