Technical manual

Note	This technical manual was consolidated for publication as one document as part of the transition to Fire and Emergency New Zealand.

Fire Investigation

FIM - 1

NATIONAL TRAINING

Status of this Document

This document is issued by the New Zealand Fire Service pursuant to the Fire Service Act 1975 S27(A) – Operational Instructions and Gazette Notice 84/2004 Operational Instructions.

What this means:
This document has the status of an Operational Instruction.
It is written to comply with:

- Other Operational Instructions
- Other National Training material
- NZFS policies
- Fire Service Act 1975
- Health and Safety and other relevant legislation
- NZ QA requirements

The document, its content and specified processes are not to be altered except through National Training processes.

Recommendations for Change:
National Training encourages and welcomes feedback on all its products and processes to ensure currency and continuous improvement.

Recommendations for changes to this material should be sent to National Training. Use the Feedback/Suggestions form available on FireNet. This may be found under Training Materials in the National Training section of FireNet.

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1	31st August 2007	Updating information in Fire Investigation Technical Manual	
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3	2 September 2008	Basic editing	

Technical Manual Sections

Acknowledgements

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Copyright acknowledgements

NZFA 921 (2008). *Guide for Fire and Explosion Investigations 2008 Edition.*

Legislative Framework

Section Contents

1. Purpose of Investigations and Role of the Investigator

Introduction

The best way to achieve fire prevention is to learn as much about how and why fires start in the first place. We need to work within, and have understanding of, a series of legislative requirements and the role of other key agencies. The better our understanding the more we can add significantly to our own community.

Fire Service Act

Section 20 (1)

The Commission is to take an active and co-ordinating role in the promotion of fire safety in New Zealand to reduce incidence of fire and attendant risk to life and property.
For further information go to:
http://www.brookers.co.nz/libraries/notes/{52C017D9}

Section 21

Fire Investigation should analyse whether a building performed as designed. Investigation of this kind will depend on access to key information such as the building's fire design. The ability to influence the ongoing use of a particular design, or to enforce changes to similar designs, is of obvious importance.

- Collection of critical information on performance of buildings and building designs in a fire
- Collection of critical information on human behaviour in fires
- Collection of information leading to the apprehension of arsonists
- Assistance to the police in the solving of serious crime related to the fire
- The continued shaping of fire safety policies and procedures
- Contributions to shaping or re-shaping of legislation related to fire safety and building design.

For further information go to:
http://www.brookers.co.nz/libraries/notes/{25C7274F}

Section 29 (1-4)

Section 29 enables NZFS fire investigators free access to all land and buildings (except household units) to conduct fire investigations to determine the cause of any fire or hazardous substance emergency.

Reasonable notice shall be given of any proposed entry, and identification shall be shown on entry and at any subsequent time if requested. This excludes Crown land or buildings that have been gazetted, and includes "premises of the mission" (as defined in Schedule 1 to the Diplomatic Privileges and Immunities Act 1968).
For further information go to:
http://www.brookers.co.nz/libraries/notes/{2B1CAF7D}

Legal proceedings

Legal Proceedings follow a standard format:

- Prepare and provide copies of field notes and the written report
- Provide witness statements to Police
- Attend briefing with Police Prosecutor
- Respond to questions in court from prosecutor
- Respond to cross-examination by defence council
- Provide information for a statement of credibility.

Establish the cause and origin

The purpose of fire investigation is to establish the cause and origin of fire.

Correctly establishing the cause and origin will have beneficial effects immediately relevant to the fire in question and more generally to the fields of fire engineering, building design, etc.

In the immediate context, efficient investigation can support any associated follow-up of criminal and insurance investigations.

In a wider context, it will highlight deficiencies in systems, manufacturing design and construction that may save lives and property later.

Without the feedback from fire investigation, manufacturers are not likely to amend their design principles nor are builders likely to change their construction practices. On-going knowledge of human behaviour can help programmes such as fire prevention campaigns and international research on human behaviour. Valuable lessons are learnt or re-enforced through investigation into fires.

Lessons learned or reinforced

Examples of lessons learned or reinforced include:

- The rapid growth of fire with lining materials such a softboard, hardboard, timber panelling, etc.
- The high flammability of clothing and bedding
- Rapid fire spread in furniture foams and the release of toxic chemicals and gasses
- Appliance faults – resulting in recalls and redesign
- Poor building design: submissions to Building Industry Authority leading to changes to the NZ Building Code.

However, the insight gained into the habits and customs of various cultural or socio-economic groups within a community is just as important. New Zealand has a wide range of ethnic groupings. People live their lives in different ways and this impacts on attitudes to safety and understanding of the dangers that modern living poses for all. Good investigation has revealed valuable information that can be used in the subsequent design of specific fire safety initiatives.

Opportunity to investigate

The New Zealand Fire Service is more often than not the first professional and responsible organisation on the scene of a fire and always the first to have access to potential evidence post-suppression. The way firefighters conduct themselves on the fireground will largely decide the value and eventual effect of any investigation.

It is also fair to say the New Zealand Fire Service is disinterested in its approach. It is not seeking to blame anybody or any particular process or product. It is simply interested in determining what happened so, if possible, actions may be taken to prevent it happening again. We have little, if any, commercial interest or social bias. As a consequence, we are among the most trusted of official interests on the incident ground. The New Zealand Fire Service also possesses the required expertise.

Of course, there are a wide range of other experts involved in the investigation process, e.g. Police officers, forensic scientists, electrical investigators, insurance investigators, metallurgists, building engineers, etc. Nevertheless, we should not lose sight of the fact the New Zealand Fire Service in first on the fireground and initially best placed to gather the various forms of evidence that can contribute to a successful investigation.

Responsibility to investigate

National Commander's Instructions

Section 17(n) of The New Zealand Fire Service Act 1975 empowers and requires the National Commander to issue instructions under Section 27(a) of the Act. These instructions enable and limit the actions of firefighters in their various responsibilities.

NCIs (National Commander's Instructions) are gazetted as they are officially announced and are collated in a manual at each station. They are also available on Firenet.

Among the NCIs is a stipulation for the Incident Controller to investigate and report on the origin and cause of a fire and any other pertinent facts.

Principal outcomes

It is important for firefighters to understand the variety of ways in which successful fire investigation contributes to safety and the rule of law. The most obvious outcomes of good investigative work are:

- Collection of critical information on performance of building and building designs in a fire
- Collection of critical information on human behaviour in fires
- Collection of information leading to the apprehension of arsonists
- Assistance to the police in the solving of serious crime related to the fire
- The continued shaping of fire safety policies and procedures
- Contributions to shaping or re-shaping of legislation related to fire safety and building design.

2. Official Information Act in Relation to Investigators

Introduction

This section describes the release of information under the Official Information Act (OIA) 1982.

Note that any release of information must be done in compliance with the Privacy Act which is covered in the next section.

The NZFS Media Policy is available on FireNet:
http://firenet.fire.org.nz/Firenet/htmlasp/policies/2_FSMCM/POLCM1-1.pdf

Compliance under the OIA

As a Crown Agency, the New Zealand Fire Service is subject to releasing documents under the OIA. This includes information about fire cause and other event information.

Common requests are from insurance assessors requiring:

- Fire Investigation Reports
- Statements and photos from incidents
- SMS reports.

Once a request has been received, the Fire Service has 20 working days to reply.

Professional response

The aim is to ensure that all requests for official information are dealt with quickly and professionally. To achieve this, the following New Zealand Fire Service procedures and use of standard letters are to be followed.

Central handling

Although CFOs have the authority to release information at the district level, it is recommended that all requests be handled centrally.

Compliance with legislation

Any CFO or DCFO who actions an OIA request must ensure that they are working within, and do not breech, the Official Information Act and Privacy Act.

Charges

The provision for charging under the OIA should not usually apply to the release of event-related information and reports.

Procedure

The procedure is:

- Send all requests for information to the District Office
- Information is sourced and edited (e.g. removing names of non-Fire Service personnel). If there will be a delay in responding, send a letter to the requester explaining the reason for the delay
- Return the information and standard cover letter to the requester
- The original request letter, copies of the reply and edited information are placed on file.

Process

The flow chart below shows the procedure for processing requests for information.

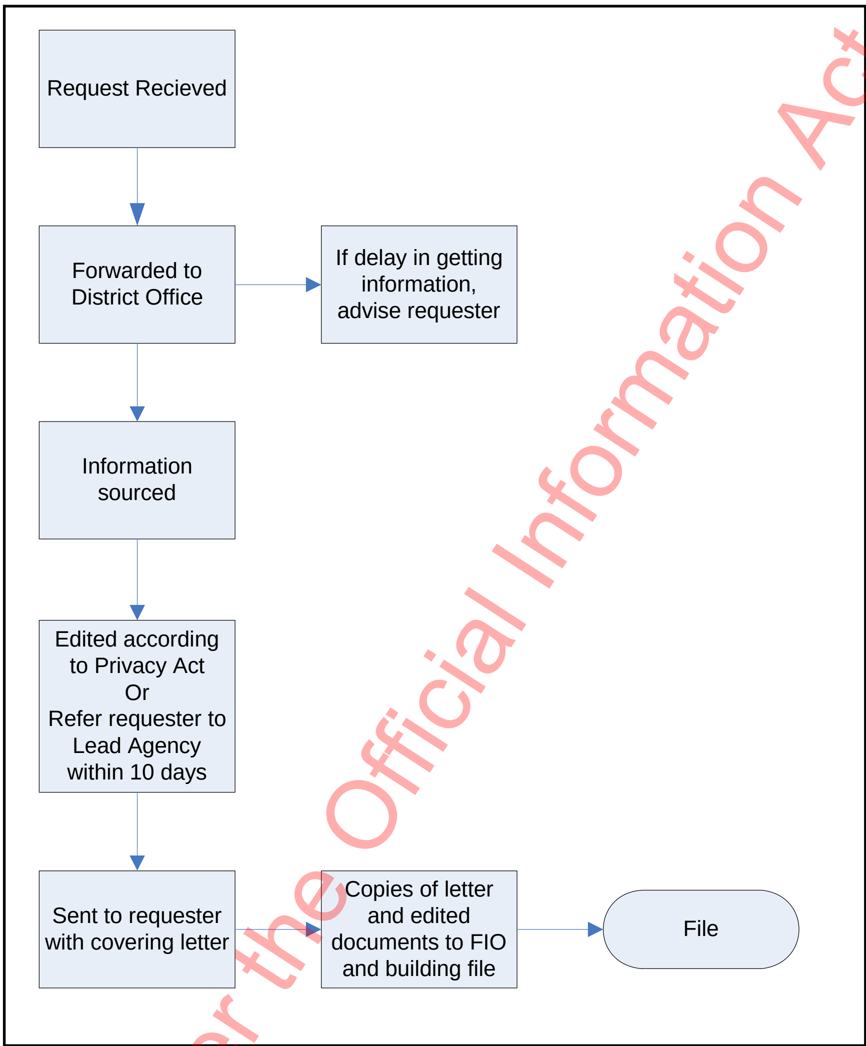


Figure 1 – OIA Request Process

3. Privacy Act 1993

Overview

This Section relates only to the release of information controlled under the Privacy Act 1993.

Compliance with the Privacy Act

As a Crown Agency, the New Zealand Fire Service is subject to releasing documents under the Official Information Act 1982 (OIA) and any such information released must comply with the Privacy Act 1993. This includes information about causes of fire and other event information. Common requests are from insurance assessors wanting:

- Fire investigation reports
- Statements and photos from incidents
- SMS reports.

Once a request has been received, the New Zealand Fire Service must ensure that released information complies with the Privacy Act 1993.

Note: For more information on the Official Information Act 1982 Privacy Act 1993, go to on FireNet:
POLLC1.7 -
http://firenet.fire.org.nz/firenet/htmlasp/policies/1_FSMLC/POLLC1-7.pdf

POLCM2.2 -
http://firenet.fire.org.nz/firenet/htmlasp/policies/2_FSMCM/POLCM2-2.pdf

Service strategy

The New Zealand Fire Service will ensure that all requests for official information are dealt with quickly and professionally. To achieve this aim, follow this procedure and use the standard letters.

All requests handled centrally

Any CFO or DCFO who actions an OIA request must ensure that they are working within and do not breech the Official Information Act and Privacy Act. Although CFO's have the authority to release information at district level, it is recommended that all requests be handled centrally.

Building file

Keep all correspondence about an OIA request, including a full copy of a reply, in the building file (where appropriate) or file securely.

Handling requests

Where information is to be released subject to the Privacy Act, the information shall be edited in such a way that individuals may not be identified.

Follow this procedure:

- Station or CFO receives request for information.
- Request letter forwarded to Fire Safety Officer or actioned at District.
- Information sourced.
- Documentation edited in accordance with Privacy Act requirements.
- This involves removing the names of non-Fire Service personnel.
- Where there will be a delay in supplying the information send an acknowledgment letter advising of the delay and the reason.
- Information returned to client with standard covering letter.
- Place the original request letter, copies of the reply and edited information on the building file.
- Complete SMS.

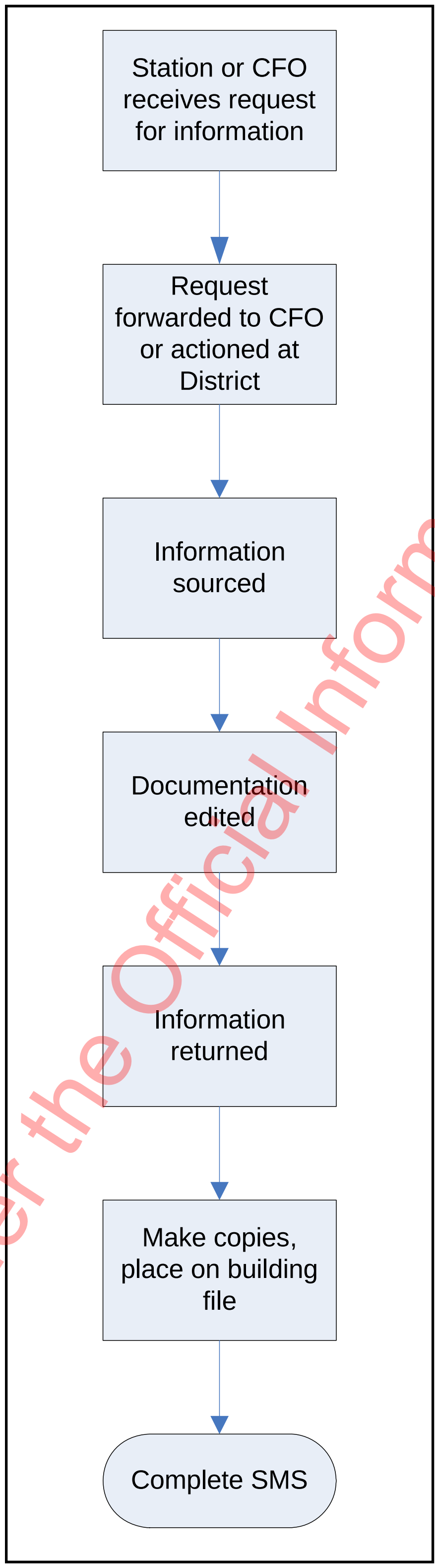


Figure 2 – Handling sensitive information in compliance with the Privacy Act

4. Crimes Act 1961

Introduction

The Crimes Act 1961 and the subsequent Amendments contain sections about fires.

The Police are the agency charged with acting to offences under the Crimes Act.

It is important that members of the New Zealand Fire Service are aware of the role of the Police and convey information to them where appropriate.

Sections of the Crimes Act

The sections of the Crimes Act that relate to fires are:

- Section 267 - Arson
- Section 268 – Attempted Arson
- Section 269 – Intentional Damage

Section 267 - Arson

Without providing an in depth legal definition of these sections, essentially arson (S. 267) is an intentional or reckless act involving fire or explosives causing any degree of heat or fire damage to property or is an intentional or reckless act committed by a person/s who knows or ought to know that danger to someone's life is likely (this includes members of the New Zealand Fire Service).

Section 268 – Attempted Arson

Attempted arson (S. 268) is the specific attempt to do the above.

Section 269 – Intentional Damage

Intentional damage (S. 269) is an intentional or reckless act causing destruction or damage of property which they may or may not own, or done to deprive someone else of that property, or in destroying or damaging the property they endanger life or safety of another person.

Other legislation

Other legislation provides for offences for:

- Wilful Damage (S. 11 Summary Offences Act 1981) – where property is damaged or trees or vegetation is set alight and they do not have a lawful excuse
- Lighting Fires (S. 36 Summary Offences Act 1981) – where without a reasonable excuse a fire is lit near any vegetation or structure, which they do not own or occupy so that it may be damaged.

Note:

In all cases where any fire or damage is caused as above, the Police are to be informed so that they can decide if there are sufficient grounds to take matters further.

5. Forest and Rural Fires Act 1977

Introduction

This Section is about the Forest and Rural Fires Act in relation to investigations. This is the primary act of law that is used in New Zealand by Rural Fire Authorities to exercise obligations and responsibilities in the safeguarding of life and property by the prevention, detection, control, restriction, suppression and extinction of fire in rural areas.

Definition of property

'Property' includes real and personal property, and any estate or interest in any real or personal property, and any debt, and any thing in action, and any other right or interest; and, without limiting the generality of the foregoing words, shall be deemed to include any public work (as defined by the Public Works Act 1981) situated within a district, and in particular any stopbank so situated (Forest and Rural Fires Act, Section 2).

This definition is wide enough to cover every kind of property within the usual meaning of the word. In particular, it includes vegetation and soil.

Cost recovery actions

The following is from the Forest and Rural Fires Act 1977, Part 3, Section 43 regarding cost recovery from the person/s responsible for fire:

Extract

1. Where any property has wholly or partially been destroyed or damaged by or safeguarded from an outbreak or threat of outbreak of fire, and responsibility for the outbreak is acknowledged by, or is established by action or otherwise as caused by, any person
   (a) The costs of control, restriction, suppression or extinction of the fire may be recovered from that person by the Fire Authority or the New Zealand Fire Service Commission or the eligible landholder or the eligible landholders of the forest area affected, as the case may be, incurring those costs pursuant to fire control measures under this Act; and
   (b) Any loss in, or diminution of, value of that property, and any consequential loss or damage not too remote in law, may be recovered from that person by the owner of the property
2. The amount of the costs so recoverable may be wholly or partially established by agreement or by a Rural Fire Mediator, or by proceedings under section 48(4) of this Act.
3. This section shall be deemed to be supplementary to and not in substitution for any other rights of recovery that may exist in law or by enactment or otherwise howsoever.
4. Before imposing any levy under section 46 (or section 46A) of this Act, a Fire Authority shall reasonably endeavour to recover its costs pursuant to this section.

Source – Forest and Fires Act 1977, Part 3, Section 43

Elements for a Section 43 recovery

Below is a list of elements that must be proved for a Section 43 Recovery:

	Element
1	The cause of the fire.
2	Responsibility for the cause which is likely to include an element of fault, whether by intention, negligence or otherwise, on the part of the responsible party.
3	The fire amounted to a “hazard” to life or to “property” (Sections 36(1)(a) and 43).
4	The property has been wholly or partially destroyed or damaged by or safeguarded from an outbreak or threat of outbreak of fire (Section 43).
5	The fire-control measures taken were reasonable and necessary or expedient (Section 36(1)(c).
6	The fire costs were properly incurred (Section 41).

Figure 3 – Elements for a Section 43 Recovery

6. Electricity and Gas Acts

Introduction

Under the Electricity Act 1992 and the Gas Act 1992, where an incident occurs involving electrical or gas appliances or faults, the occupier of the building is required to report the incident to Energy Safety(ES).

Where an electrical or gas fault is believed to have contributed to the cause of a fire, the person responsible for investigating the cause of the fire will notify Energy Safety.

Note: This includes fires caused or suspected to be the result of consumer product failure.

Electrical or gas accident

An electrical or gas accident is one involving gas or electricity that results in:

- serious injury or death
- significant damage to property.

Role of ES

The role of ES is to ensure safe use of electricity and gas in installations and appliances, to safeguard people and property.

By gathering information on certain types of fires, ES can improve installation work and maintain and ensure appliances conform and perform safely within the legislation and standards.

Notification to the ES

While the New Zealand Fire Service is not legally responsible for notifying the ES of such incidents, officers are expected to notify the Communication Centre who in turn will notify the ES. The ES is responsible for:

- organising an inspection, if required
- reporting the outcome of their investigations to the Incident Controller.

Section 16

Section 16 of the Electricity Act 1992 outlines the requirements for reporting electrical accidents and electrically caused fires:

Extract

16 Notification of accidents

- (1) This section applies to every accident that—
  - (a) is caused wholly or partly by, or involves or affects, electricity, or involves or affects the generation, conversion, transformation, conveyance, or use of electricity; and
  - (b) results in—
    - (i) serious harm to any person; or
    - (ii) damage to any place or part of a place that
    - renders that place or that part of that place unusable for any purpose for which it was used or designed to be used before that accident.

Source – Electricity Act 1992, Part 2, Section 16

Energy Safety has requested notification in the following specific instances:

- Major loss where the public have been present and may have been at risk and if electricity cannot be ruled out as a contributing factor
- Fatal fires in domestic premises that involve the installation of appliances as a causal factor
- Fatal fires in sensitive areas such schools, hospitals and nursing homes
- Fires involving appliances less than five years old, but NOT including misuse of an appliance operating correctly
- Installations less than five years old where wiring or switchboards are a potential causal factor
- Hospitals, schools and nursing homes where appliances are involved.
- In other instances which may change from time to time, such as fires involving compact fluorescent lights in 2008.

Note: In general, it is not necessary for ES to investigate fires in industrial or commercial premises unless serious injury or death has resulted.

Requesting an electrical or gas investigator

Refer to the flow chart below to determine if ES can be of assistance.

Contact Comcen by LMR and transmit an assistance message “K11-Electrical or Gas Inspector required (as appropriate)”, or contact Comcen by phone and request the same. The Comcen will contact ES and request their aid at the incident.

Energy Safety will arrange for an inspector to attend. The inspector will contact the Comcen or requesting officer if a telephone number has been given with an ETA or to discuss the incident and agree on a course of action.

If attendance is urgent, send the request by LMR or phone. Otherwise an Event Notification Form can be obtained from the Energy Safety website at: www.energysafety.govt.nz. Look for the shortcut to the form on the left hand side of the Energy Safety homepage.

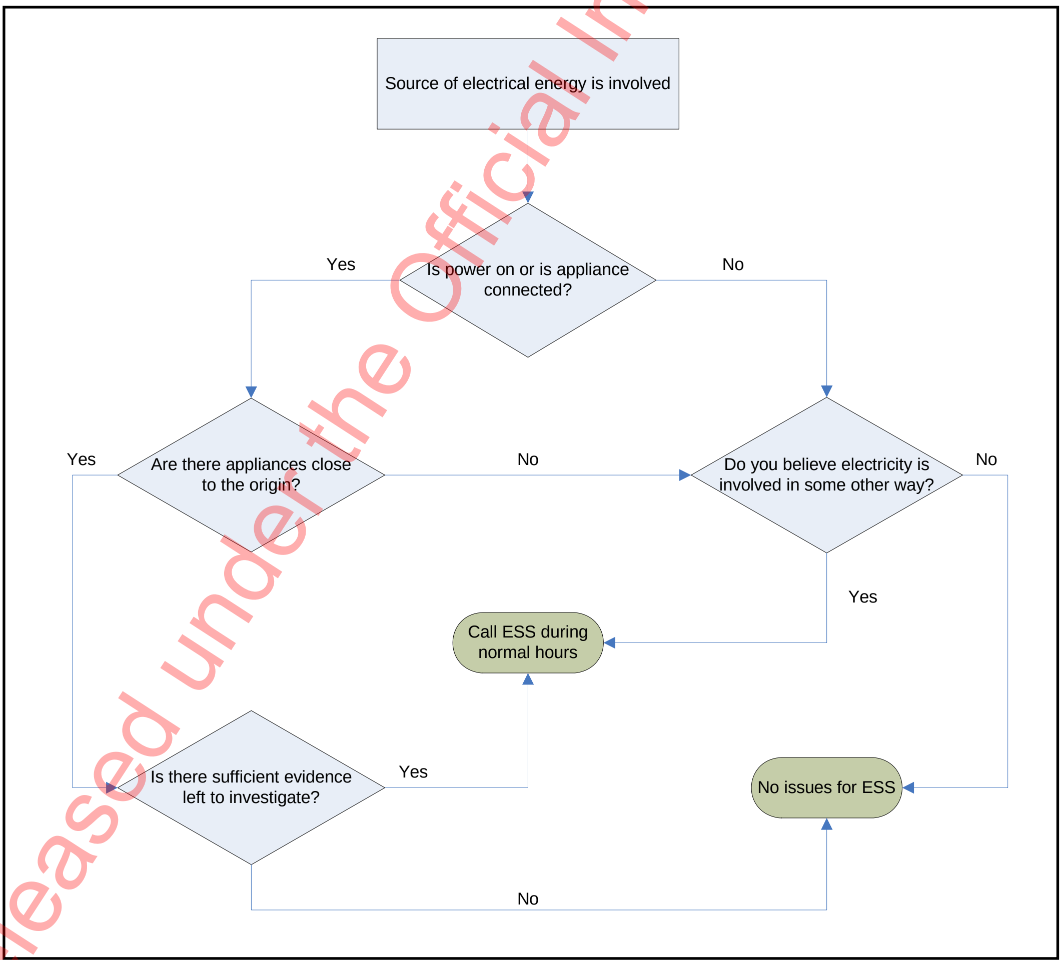


Figure 4 – When to notify the ESS

Preservation of evidence

Where any doubt exists over fire cause or if significant or unusual circumstances exist, all equipment involved should be safeguarded (not repaired or discarded) until ES confirm it is not required.

Right of access to property

Below is a summary of which situations various agencies and individuals have the right of access to a property.

Police	Only if a crime is committed, or by use of a search warrant.
NZ Fire Service	Access only if still burning. In all other situations reasonable notice in accordance with Section 29 of the Fire Service Act 1975.
Property Owner	Full access.
Gas Inspector	Only when gas is involved.
Insurance	Once a claim has been lodged the insurance company becomes the property owner.

7. Role of Other Key Agencies

Other key agencies

Agency	Role
IAAI Branch	International Association of Arson Investigators. Made up of various members of insurance and private fire investigators associations
Accident Compensation Corporation	Rehabilitation and injury prevention
ADT Fire Alarm Monitoring	Monitoring Fire Service connected, fire alarm systems
Ambulance Service	L.S.U.s, Humanitarian & Support Health Services
Area Health Department	DPSW homes, hospitals, rest homes
BRANZ	Building product research and testing
Building Industry Authority	Building Act Regulations and compliance with production of the Acceptable Solutions information, documents and training seminars
Building License	Licensed buildings, i.e., clubs, pubs, restaurants.
Burns trust	Official fire services charity
C.I.B.	Serious crime (enforcement)
C.Y.F.S.	Social welfare services for children
Chemical Industry Council	Chemical industry representation
Citizens Advice bureau	Information and advice on community groups and services
Ministry of Civil Defence and Emergency Management	National and local coordination of emergency services
Critical Incident Stress Group	Peer support
Department of Conservation	Fire protection (conservation areas)

Department of Labour	OSH inspector, fire works/explosives permits, workplace safety, dangerous goods
Earthquake Commission	Claims and prevention
Enforcement officers Territorial authority	Buildings regulations, over-crowding, dangerous, etc, after hours number general, WOF/COC, locks exit doors, etc.
ESR	Industrial and commercial scientific research & forensic testing
Fire Protection Association	Fire alarm companies association
Fire Protection Companies	Fire equipment/systems sales and services
Fire protection inspection services	Approval/inspection of fire systems
Forest Owner's Association	National Body
Forest Research	Forest fires
Gas line distribution	New Zealand National Gas Corp.
Health Inspectors	Smoke, problems, clean air act, resource management
Housing NZ Ltd	Housing
IFE	Examination, presentation, education
Industrial Fire Brigades	Fire protection (industrial sites)
Insurance Council	Insurance companies representative sometimes sets level of additional fire protection required in buildings before insuring
Maritime Safety Authority	Coastal safety navigation, industry training
Ministry of Agriculture and Forestry	Forestry management and bio-security
Ministry of Economic Development	Products safety, consumer magazine, Energy Safety
Ministry of Education	Schools, childcare
Ministry of Emergency Management	National coordination of emergency services
Ministry of Environment	Environmental risk management
Ministry of Health	Allocation of health resources Licensing rest homes, hospitals, community homes

Ministry of Transport	Roads, law enforcement, marine division, lifts rules enforcement
NZ Coastguard	Rescue coordination services
NZ Defence Force	Fire protection (defence areas)
NZ Police	General law enforcement Armed offenders Bomb threat procedures Search and rescue Coastguard assistance Youth aid / Victim support Youth education Traffic C.I.B.
NZQA / FRSITO	Training qualifications
Ports Company	Administration, shipping control
Power companies	Power distribution to roadside emergency crews
Rescue Fire Services	Civilian, military
Rescue Helicopter	Medical & emergency rescue, transportation
Rural Fire Authorities	Principal Rural Officers
Safe Kids	Children's welfare safety
SPCA	Animal rescue division
Standards New Zealand, Ltd.	Produces standards for all types of products, i.e. fire alarms, fire extinguishers, etc. Note: many joint standards with Australia apply.
Town Planning	Projects and future developments, impact reports, in fill developments
Traffic	Traffic law enforcement Police/helicopter T.A.G.
Transrail	Railways, passengers/shipping/freight
Water Services	Water supply reticulation

Policies

Section Contents

1. National Commanders Instruction

NCI 56

National Commanders Instruction 56 details the requirement for fire investigation and describes the consequent reporting requirements.

For further information, please refer to NCI 56 on Firenet.

NCI 7

National Commanders Instruction 7 details the requirement for fire investigation and describes deaths at incidents.

For further information, please refer to NCI 7 on Firenet.

2. Fatalities and Serious Injury

Introduction

Unfortunately, fatal fires will occur from time to time, regardless of the number and quality of fire safety education activities and messages.

Fatal fire incidents can invoke a high level of emotional response and it is important that the New Zealand Fire Service has a clearly defined and professional approach to the management of these types of incidents.

Coroner's Act 2006

The Coroner's Act 2006 lays down some occasions when a death must be reported to the coroner:

- When someone seems to have died in a violent or unnatural way, such as drowning, car crash or poisoning
- When the cause of death is unknown
- When someone dies in prison
- When someone dies "in care", e.g. in a psychiatric hospital or a children's home
- When someone appears to have taken his/her own life
- When someone dies while under anaesthetic or during or following a medical procedure, or as a result of anaesthetic or a medical procedure.

Reporting deaths to the police

Anyone finding a dead body, or knowing of a violent or unnatural death, must report this to the police who, in turn, inform the coroner.

See the Coroner's Act 2006, Section 14 – Reporting of Deaths to Police.

Fatal fire incidents

Fatal fire incidents are known as either:

- single incidents
- multiple incidents.

Fire fatality classifications

For the New Zealand Fire Service reporting, fire fatalities are generally classified as:

- residential
- other.

Cause of death classifications

For the New Zealand Fire Service reporting, cause of death are generally classified as:

- preventable
- non-preventable.

Confirming fatal fire incidents

The Incident Controller must confirm a fatal fire incident by transmitting a "K41 Message" suffixed by the number of deceased.

Example: To report a single fatality:

"From Senior Station Officer Searle at 20 Beatty Street, Otahuhu, Auckland City, K41 - 1".

Critical Incident Stress Management (CISM)

When a death has occurred at an incident, the Incident Controller should initiate the notification and request for Critical Incident Stress Management (CISM) debriefing and peer support.

Note: The Mitchell Model for CISM clearly recognises that death of a work colleague may result in an individual's experience to reactions and symptoms of stress.

Media liaison

The Police will often be the lead agency in terms of statements to the press at a fatal fire incident. The New Zealand Fire Service Incident Controller should aim to convey appropriate fire safety messages as part of any release of information to the media.

Additional resource considerations

The Incident Controller will also consider the need for additional pump appliances so that the first responding crews can temporarily stand down in order for them to complete statements and, when necessary be defused or debriefed.

Fire scene investigation and control

Fire scene investigation controller

The police will assume the role of lead agency in meeting the legal requirements associated with the discovery of a deceased person, including management of the scene and subsequent physical investigation.

Firefighting activities shall remain under the control of the New Zealand Fire Service in accordance with the Fire Service Act 1975 Section 28.

Actions and records

The Incident Controller will record the following details in writing at the time of the incident. These will be reported to the police on their arrival:

- Location of the deceased
- Position of the deceased prior to removal
- Any personal items that may have fallen from the deceased
- Retrieval of any body parts that may have been dismembered, including any prosthesis
- Name of persons involved in moving the deceased.

Note: The Command Unit can be used for crews to record written eyewitness statements.

Contamination of evidence

The Incident Controller will ensure any other supporting activities do not contaminate the scene. Examples include:

- Refuelling of lighting generators
- Location where refreshments and smoking by people might occur.

Note: Where contamination occurs, this may result in negating evidence completely or cause costly time and expense in DNA sampling to eliminate materials introduced by Fire Service personnel.

Scene security

Scene preservation	The Incident Controller must take all practical steps to ensure the security and preservation of the fire scene by ensuring: • Minimum fire suppression, salvage and ventilation activity • Non-disturbance of the body or bodies where possible.
Potential crime scene	The fire scene may be a crime scene. It is important the Incident Controller communicate this fact to officers and their crews.
Preservation of evidence	The Incident Controller must ensure preservation of all evidence and take all practical precautions to ensure there is limited contamination of the scene as a result of fire suppression and control activities.
Control of the scene	The fatal fire scene will come under the control of the police once Section 28 of the Fire Service Act 1975 is no longer being invoked by the Incident Controller of the New Zealand Fire Service.
Removal of fatalities	The Incident Controller may deem it necessary to remove the body of a fatal fire victim to prevent further damage to the body.

Health & Safety

Hazard Control	All Fire Service staff must be aware of the hazards associated with handling the deceased.
Significant Hazard	Contamination from handling deceased bodies and body fluids provides the most significant hazard to Fire Service staff.
Other hazards	Other potential hazards in handling deceased bodies include the risk of: • Strains • Critical Incident Stress.
Strains and sprains	Fire Service staff must use correct handling techniques whenever moving a body.
Sensitivity to people	Fire Service staff must act in a dignified and respectful manner around the deceased and towards any family members or significant others that are present.
Cultural issues	The Incident Controller must determine from the deceased's family and/or significant others present if there are any special cultural or religious needs the New Zealand Fire Service should be made aware.

Decontamination

Appropriate decontamination of personnel and gear shall be carried out when there has been exposure to deceased bodies and body fluids.

As a minimum, investigation staff must wear protective barrier gloves and disposable clothing. Wash hands as the minimum precaution before eating and/or smoking. Dispose of all disposable items in an appropriate manner.

Defusing and debriefing

The Incident Controller must ensure that all officers and their crews are defused before leaving the incident ground. The Incident Controller must also consider the need for a formal CIS debriefing. He needs to consider the welfare of the Fire Safety staff, ESR and police if they are exposed to the deceased for a long period of time during the investigation.

The Incident Controller, and/or a member of the Critical Incident Stress peer support team, should defuse the crews by reminding them of the following facts:

- Incidents involving death of infants, multiple deaths, deaths of co-workers, etc. have the potential for critical incident stress reactions.
- Individuals may experience heightened awareness of emotions, feelings, thoughts, or smells
- There may be heightened feelings, thoughts and awareness of significant people in their own lives – this is a normal and healthy reaction to the unusual event to which they were just exposed
- Peer support teams are available for a debriefing.

Professional Communication of Information

Section Contents

1. Professional Objectivity in Reporting

Objectivity

When conducting investigations members of the New Zealand Fire Service must display objectivity in their processes and reporting, by being impartial and considering all possibilities.

In terms of conducting a fire investigation and completing the associated reporting, investigators must base their conclusions and recommendations on facts. Investigations must follow the scientific method of collecting and analysing data, and then developing and testing hypotheses based on the facts. This method is outlined in NFPA921 chapter 17.2.

NFPA 921: NFPA 921 is a Guide for Fire and Explosion Investigation and was developed by a technical committee on Fire Investigations to assist in improving the fire investigation process and the quality of information on fires resulting from the investigative process. Within this technical manual there are extracts from NFPA 921.

Impartiality of reporting

Report writing must be factual and impartial. Do not use personal bias, prejudice and personal opinion. Keep to the facts and describe them as you see them.

Note taking

Take notes or fireground field notes at the incident or as soon as possible thereafter. The significance of this is to prove you were not relying on memory days later, which might exaggerate your finding.

Conflict of Interest Policy

The Conflict of Interest Policy can be found on FireNet.
(Type in ‘Conflict of Interest’ into the search field and the policy will come up).

2. Media Management at an Incident

Introduction

It is important for the New Zealand Fire Service to maintain a positive image through the media. The media can and does influence the way the public view the New Zealand Fire Service. The New Zealand Fire Service has guidelines and information available to help assist with managing the media at incidents:

- Firefighter’s Guide to the Media
- Media Policy (POLCM1.1)

Firefighter’s Guide to the Media

The Firefighter’s Guide to the Media is an online booklet that contains information on:

- responses to the media
- interview techniques
- legal matters
- helpful hints.

The guide is available on FireNet:
http://firenet.fire.org.nz/Firenet/BusinessUnits/MPC/Publications/

Media Policy

The NZFS Media Policy is available on FireNet:
http://firenet.fire.org.nz/firenet/htmlasp/policies/2_FSMCM/POLCM1-1.pdf

3. Legal Proceedings

Introduction

Fire Service personnel may be required to appear in a Court or Coroner's inquest to present information to assist the Court in deciding a matter. By giving testimony as a witness of fact is to convey to the Court what you saw or did.

Statement / Brief of evidence

Before attending Court you will be asked to help prepare a statement or brief of evidence. Often this will be done on your behalf. Before you sign the document make sure you read it carefully and be sure it reflects exactly what you wish to say. If it doesn't then ask for it to be corrected.
Once you are satisfied with the documents contents you will be asked to initial each page and sign the final page. A copy of the document will be made available to all parties involved.

As non-Fire Service personnel will read the document it is strongly recommended that Fire Service jargon be avoided, or if it must be used then explain in plain English what it means.

Appearing in Court

When appearing in Court you should be wearing your Fire Service uniform. Make sure you arrive early and that you have turned off all pagers and cell phones before entering the courtroom.

When in the courtroom:

- If you have to address the judge directly refer to them as "Your Honour"
- Listen carefully to the question or statement that is put to you by counsel
- Answer the question precisely and direct your answer to the jury if one is present, or the Judge
- Remain calm
- Qualify your answer with an explanation if necessary, if counsel interject before you finish, ask the Judge if you can finish your explanation
- Talk clearly and slowly so what you are saying can be recorded by the court staff
- Restrict your comments to areas you have direct knowledge in
- Listen to any question or direction of the Judge.

Expert witness

Staff with specialist training and experience may be called to give testimony not only to fact, but also based on their opinion. This will require them to be established as an "expert witness".
If you are appearing as an expert witness in any court you should make yourself familiar with the "High Court Rules - Code of Conduct for Expert Witness" document below.

Further assistance

Any staff member who requires any further assistance or advice about a court appearance should contact the Office Solicitor at National Headquarters preferably as early as possible.

Extract

Duty to the Court

1. An expert witness has an overriding duty to assist the Court impartially on relevant matters within the expert's area of expertise.

2. An expert witness is not an advocate for the party who engages the witness.

Evidence of expert witness

3. In any evidence given by an expert witness, the expert witness must -

   a. acknowledge that the expert witness has read this Code of Conduct and agrees to comply with it:

   b. state the expert witness' qualifications as an expert:

   c. state the issues the evidence of the expert witness addresses and that the evidence is within the expert's area of expertise:

   d. state the facts and assumptions on which the opinions of the expert witness are based:

   e. state the reasons for the opinions given by the expert witness:

   f. specify any literature or other material used or relied on in support of the opinions expressed by the expert witness:

   g. describe any examinations, tests, or other investigations on which the expert witness has relied and identify, and give details of the qualifications of any person who carried them out.

Source – High Court Rules, Schedule 4 R330A.

Extract

3. If an expert witness believes that his or her evidence or any part of it may be incomplete or inaccurate without some qualification, that qualification must be stated in his or her evidence.

4. If an expert witness believes that his or her opinion is not a concluded opinion because of insufficient research or data or for any other reason, this must be stated in his or her evidence.

Duty to confer

6. An expert witness must comply with any direction of the Court to -

   a. confer with another expert witness:

   b. try to reach agreement with the other expert witness on matters within the field of expertise of the expert witnesses:

   c. prepare and sign a joint witness statement stating the matters on which the expert witnesses agree and the matters on which they do not agree, including the reasons for their disagreement.

7. In conferring with another expert witness, the expert witness must exercise independent and professional judgment and must not act on the instructions or directions of any person to withhold or avoid agreement.

Source – High Court Rules, Schedule 4 R330A.

4. Specialist Investigator Brief

Introduction

The Incident Controller will brief the Specialist Investigator.

Important points

Briefing the Specialist Investigator should include reference to all relevant facts including:

- All Health & Safety issues:
  - protective clothing is worn
  - operational crews on standby attendance
  - site dangers
  - likelihood of collapse
- Completing, if required, the Preliminary Investigation form to gather information (sample attached)
- Updating the entry log by recording who enters the scene (sample attached). This is also useful in order to identify people who may be exposed to potential hazards and contaminants
- Identifying other agencies called to attend, e.g. police, power company, etc.
- Important information such as occupant injuries, fatalities, etc.
- Observations made during fire-fighting, e.g. location of most fire, fire spread, building security, fire-fighting tactics used
- Establish post-fire ventilation (e.g. opening of windows) and removal of any materials and their location
- Determine if there were any witnesses, and if, where and who interviewed them
- Establish probable area of origin
- Ascertain probable cause
- Communicate any other information that will assist the specialist investigator in determining a cause.

5. Forms used for Information Communication

Specialist Assistance Preliminary Fire Investigation Form

It is the responsibility of the Officer in Charge of an incident to investigate and report on the origin and cause of a fire and any other relevant facts. Every effort shall be made before specialist assistance is requested. Where it becomes obvious through your investigation that specialist assistance will be required, this form is to be completed by the officer investing the fire to the best of his/her ability, and is to be made available to the responding Fire Safety Officer on their arrival.

Incident No. ______________________ Date of Incident ____________________

Type of Occupancy ____

Address ____

____

Full Name of Officer Investigating Cause ____________________________

Watch: Green / Red / Brown / Blue / Volunteers

District ____

Contact phone number: Day ______________ Night ____________________

Available for interview by Police/Fire Safety same day: Yes / No

Or Date: __________________ At: _______________________________

Investigation Notes

Area most involved in fire on arrival: ___________________________________

____

Any structural collapse? Yes / No

If yes where? ____

____

Colour of flames: ____

Fire intensity: ____

Direction of fire travel: ____

Any unusual odours noticed: Yes / No

If Yes, give a brief description: ___________________________________

____

____

Electricity still connected at time of fire: Yes/No

Witnesses Interviewed

Owner/Occupiers (Names and contact numbers)

1. ______________________________ Phone Number: __________
2. ______________________________ Phone Number: __________
3. ______________________________ Phone Number: __________

Other Witnesses: (Names and contact numbers)

1. ______________________________ Phone Number: __________
2. ______________________________ Phone Number __________
3. ______________________________ Phone Number: __________

Special note is to be taken of those who are fully dressed at a fire scene during the early hours, particularly the occupants. If you have a camera, take a photograph of any bystanders.

Comments: ______________________________

____

____

Building secure on arrival: Yes/No

If secure, point of entry used by Fire Service to gain entry: __________

____

If unsecured, provide details: ______________________________

____

Details of Preliminary Fire Investigation

(Please give brief details)

Area of Origin: ______________________________

Firefighters Comments: ______________________________

Other Witness Comments: ______________________________

Please ensure that persons interviewed have been advised that the collection information recorded on this form is undertaken for New Zealand Fire Service purposes, and as such, the release of it is governed by the Official Information and Privacy Acts.

Sketch

Draw a sketch of the building showing the following:

1. Location of fire on arrival.
2. Wind direction
3. Where hose lines were established.
4. Direction of fire Travel.
5. Points of the compass.

Fire Ground Significant Hazard Identification

Identify all hazards on the fire ground. This page is to be affixed to the building entry or handed on to ANY other group who take control of the fire ground e.g. stand by crews, security guards, fire investigators.

Hazard	Location	Description of Hazard Controls in place	Originators signature, Date and Time

INCIDENT LOG

INCIDENT ADDRESS: DATE: / / EVENT NO:

INCIDENT CONTROLLER: LOG KEEPER: STATION

TIME IN	TIME OUT	NAME	ADDRESS	PHONE	AFFILIATION WITH SCENE	ESCORTED BY

Page Number: ____________

Reporting

Section Contents

1. Fire Investigating Reporting

Introduction

For the investigation to be beneficial, the reporting of the outcomes through the SMS system is necessary.

SMS

There are two levels of reporting through SMS. Incidents other than those directed in NCI 56 should be reported via the Incident Comments section.

Task	Description
Reassign an incident	A serious or unusual incident could be reassigned to a specialist investigator.
Complete an incomplete incident	To close an incident, the first and second item ignited must be identified.

Classification of cause

The four classes of fire cause as per NFPA 921 are:

- accidental
- natural
- incendiary
- undetermined.

These terms can further be subdivided as per the SMS incident cause classes.

Note: The use of the term "***suspicious***" is not an accurate description of a fire cause. Mere suspicion is not an acceptable level of proof for making a determination of cause within the scope of this guide and should be avoided. Such fires should be classified as **undetermined**.

A fire that has been deliberately lit is "***incendiary***". However it may be "***incendiary-lawful****" as in a deliberately lit incinerator fire. An attempt to burn a building down would be* "**incendiary-unlawful**".

Report writing skills

Fire Investigators strive to obtain and maintain credibility as an expert in their field. This is earned through training and experience and should therefore be nurtured and protected. Intelligent and accurate reporting and documenting of findings establish one's credibility.

"The comprehensive fire scene investigation, testing, reconstruction and documenting to find the origin and cause of the fire become worthless if…the fire investigator cannot write a report that accurately and precisely captures the events surrounding the fire".

(Dehann, 2002, P550)

Points to consider:

- Incorrect spelling, grammar & punctuation can have detrimental consequences on the overall context of the report
- Jargon should be kept to a minimum or be explained. If you must use jargon insert the definition from a recognised source
- You should be writing in past tense – because it happened in the past!
- Don't use contraction e.g.: **have not** rather than **haven't**
- Be gender inclusive e.g. he/she if you are unsure
- Compass points, e.g. south-west, do not have capitals
- Use 24 hour clock for consistency
- If the number is ten or below, write the word e.g. three bedrooms
- If the number is 11 or above, use numerals.

Peer review is a critical part of the report writing process. This may include the regional fire investigation co-ordinators, legal council, fire engineers and fire service media liaison staff to ensure the reports completeness.

Ultimately the report should only be released in accordance with the National Commanders policy (NZFS, POLCM.2, 2003) on releasing information to outside organisations and must be signed by the investigation manager.

These protocols are designed to protect the fire investigator and the organisation as a whole and essentially to maintain the credibility and avoid potentially damaging publicity to both parties.

2. Mobile Property Fire Investigation Report

Mobile Property Fire Investigation Report

The following report **must** be completed for all incidents attended involving incendiary fires involving mobile property incidents.

1. Incident Details			
Incident Address			
Event Number			
Time of call		**Time of Arrival**	
OIC		**Date**	

2. Who discovered the fire (Caller Identification)			
Name		**Phone Number/s**	
Address			

3. Vehicle Details			
Year/Make		**Model/Colour**	
Registration Number		**Engine Number**	
Chassis Number		**VIN Number**	
Owner's Details	Name Address Ph (H) Ph (W) Ph (M)		

4. Incident Details				
Tick the appropriate box:				
Vehicle reported stolen	Yes		No	
Number plates **present**	Yes		No	
Petrol filler cap **present**	Yes		No	
Accelerant container inside vehicle	Yes		No	
Accelerant container outside vehicle	Yes		No	
Ignition barrel **present**	Yes		No	
Vehicle locked	Yes		No	
Vehicle keys present, Location:………………………………..	Yes		No	
Hot wired	Yes		No	
Wheels **present**	Yes		No	
Wheel nuts **present**	Yes		No	
Stereo etc **present**	Yes		No	
Steering wheel **present**	Yes		No	
Battery **present**	Yes		No	
Panels **present**	Yes		No	
Engine **present**	Yes		No	

Mobile Property Fire Investigation Report, cont.

Area of fire origin	
Point of origin	

Describe heat and fire damage to vehicle **(Include description of area where fire damage is most severe or any pertinent details regarding the incident and how decisions reached)**

5. Estimate of damage to vehicle
%

6. How extinguished?				
	Number of deliveries used			
High pressure delivery hose line(s)				
Low pressure delivery hose line(s)				
Out on arrival				
CAF	Yes	☐	No	☐

7. Police In Attendance						
Were Police in attendance	*Yes*	☐	*No*	☐	**Name of Representative**	
Station					**Event Number (Police)**	

8. Photographic Evidence				
Photos taken	Yes	☐	No	☐
By whom				

9. Witnesses Interviewed			
Witness 1 Name			
Address		**Phone Number/s**	
Witness 2 Name			
Address		**Phone Number/s**	

10. Fire Cause							
Tick the appropriate box:							
Accidental	☐	Natural	☐	Undetermined	☐	Incendiary	☐

11. Scene released by Fire Service
Hours Date:

Reporting Officers Signature		**Date**	
Note:	*A copy of this report is to be forwarded to Fire Safety at Regional Office for filing.*		

Safety and Maintaining Operational Readiness

Section Contents

1. Safety During Investigations

Introduction

When conducting a fire investigation always ensure the scene is safe and secure before entering. Be aware of the signs that indicate damaged walls and collapsing roofing members.

Fully protect yourself with the appropriate headwear and protective clothing when conducting a fire investigation.

Remember that this is “last resort” protection and is not a substitute for removal or reduction of hazards.

At the beginning of a formal investigation, the fire is usually either extinguished or very close to being extinguished. However, the scene may not be safe enough to undertake a thorough investigation without risk of injury to personnel. The cooling and collapsing of the structural components and walls, which is often overlooked, may be the most dangerous time for fire scene investigators.

Sometimes, the hazards cannot be overcome and it is on such occasions the risk to personnel is unacceptable and the scene(s) should remain unexamined.

Please refer to FireNet:

- NCI 1.2
- NCI 1.3.

Appraisal of the scene

You should begin your fire investigation from the area of least damage and finish at the area of most damage, which is often pinpointed as the fire origin. It is your responsibility as fire scene investigator to be aware of any hazards as well as making various observations of the cause and origin of the fire.

Even if the fire has been confined within a structure and no apparent evidence of fire can be seen from the outside, the exterior of the scene should still be examined to identify or to discount hazards.

In a more severe fire, the most obvious areas of fire damage are usually the roof and walls. These often present the greatest risk because the structural components are over the most vulnerable part of the body – the head.

While carrying out an investigation, it is advisable to have a safety officer present to ensure the structure is safe and to warn personnel of impending structural collapse.

Roofing

The most common roofing materials in use are:

- corrugated sheet steel or aluminium
- fired clay
- concrete tiles.

Other types are sometimes encountered such as corrugated asbestos, concrete slab and various plastics.

Type	Description
Corrugated Metal	Corrugated metal is not as likely to cause the degree of impact damage as tiles because the weight is not as concentrated. Metal roofing such as iron, steel and aluminium have thin edges that could cut or cause amputation. If loose, all this type of roofing should be removed in a controlled manner before the internal examination of a structure. Take particular care in windy conditions as sheets of roofing may become dislodged without notice and move great distances. Therefore, not only the immediate area of the fire must be considered but also localities that are quite remote from the fire.
Tiles	Tiles are a common residential roof covering and are the most dangerous. When the roof members lose strength because of contact with fire, the tiles will collapse in numbers and may injury attending fire scene personnel. If tiles are loose and have begun to fall, remove the roof framing before commencing the internal examinations. When affected by heat, tiles become brittle and prone to fracture and therefore should not be walked on when viewing a scene from overhead. If it is important the scene is viewed from above with tiles still in place, a hydraulic platform or ladder should be used.
Asbestos roof sheeting	Not only is there a danger of inhalation of asbestos fibres but also asbestos roof sheeting is brittle and should not be walked on. Skylights constructed of a plastic material are often installed in these types of roofs and they break easily or melt away.

Walls

The most widely used materials in wall construction are timber, brick and concrete block, though many other types may be encountered. Often, the wall cladding is cosmetic and structural integrity is dependent on the state of the wall framing.

The same approach of evaluating the safety of roofs should apply when examining walls.

Type	Description
Timber	The majority of risks from deteriorated timber walls are impaling injuries to personnel caused by the sharp ends and edges from broken or burned timber. As burn patterns on timber such a charring and 'V' patterns are an integral part of the investigation, it is recommended the burnt timber be photographed then removed if posing a risk of injury.
Brick and concrete block	The effects of fire can weaken the mortar that maintains the strength of walls made of brick or concrete block. Both these materials have the potential of collapsing and causing considerable harm to attending personnel, whether inside or outside the premises. If there is any evidence that bricks or concrete blocks may fall, the correct action is to remove the hazard before working in the area.
Prefabricated concrete	Commonly referred to as tilt-slab concrete, prefabricated concrete is usually joined to the foundation of a building by bolts, clamps or steel pins. This type of building is reasonably fire resistant. Metal framework usually maintains the integrity of these walls but may have expanded and contracted because of the heat of a fire. Concrete slabs that show signs of cracking in any direction will have their integrity compromised. There is a possibility the entire wall may fall or fail with little or no warning. Therefore, consider not only personnel inside, but also those around the perimeter.
Cement Sheeting	Cement sheeting installed up to the 1980's may contain asbestos. The sheeting is not considered a problem when wet, however when the scene has dried about asbestos fibre maybe present in the air. Use suitable respiratory protection. Don't confuse asbestos with fibreglass, which is used in some modern products. For more information on asbestos, see NCI 1 – Operational Safety.

Framing

Whether the framing is constructed of timber, steel, concrete or other material, it is reasonable to expect that this will be the main load bearing component of a building and will therefore be substantially larger and heavier than either the roof or wall claddings. Although the framing is usually the last part of a structure to collapse, it will cause severe injury if the risk is not assessed and correctly managed.

Windows

The obvious risk involved with windows is glass. It often has the weight to cause impact injuries as well as the ability to cut, even through protective clothing.

Always consider glass as dangerous.

If there are glass panes over the area where the examination is occurring, check to see that it is solidly entrenched in its frame and not cracked. Ensure the area around the frame is intact and has not been weakened.

Remove the glass if there is any possibility or suspicion the glass is dangerous.

Flooring

The most common flooring is timber, usually in the form of tongue-and-groove floorboards. However, most modern structures now have particleboard flooring and, occasionally, plywood.

Particleboard flooring after absorbing water from firefighting becomes weakened and unable to carry weight, particularly a person's weight. This can lead to people falling through floors or possibly straddling floor joists uncomfortably.

Type	Description
Timber	Timber components used in flooring construction are a strong building material. However, if exposed to heat for any period of time, they will become weak. Weakened flooring is the most common cause of injury in the post-fire period, because holes in the flooring cannot be easily seen because of the debris on the floor hiding the danger. The only reasonable way to check the floor is stable is to check from underneath, although this is not always possible or practical, or to remove all debris (although this may jeopardise the investigation). Realistically, the only safe and practical way to examine a fire scene where the flooring may be suspect is to proceed with great caution. This may mean crawling across the floor or using planks across the floor joists. If no planks are available, ladders provide a useful alternative.
Plywood / particle board	Plywood has much the same characteristics as floorboards. However, be aware the strength of particleboard will decrease with the application of water. It is in this situation that particleboard may look as though it has not been affected at all, yet it will not have the ability to support even a few kilograms.

Ceilings

Type	Description
Plaster	Ceiling linings most commonly used are either: • plaster and lath (thin strip timber) • plaster sheet. These types of ceilings will weaken and fall when affected by heat or water. Rendered lath and plaster will deteriorate into small pieces and become hazardous when minute particles enter the eyes. However, plaster sheet, which will fail much earlier, can fall in large sheets creating the hazard of impact injuries. A tell-tale sign of impending collapse of plaster sheet is the bulge created when water has built-up.
Concrete	Concrete ceilings have the potential to cause serious injury. Although the degree of fire damage needs to be large to weaken such ceilings, care should be taken and all structural framing checked.

Staircases

The manner in which staircases are built and the fact they are usually against load bearing walls makes them a strong element of a building.

However, during a fire, a staircase will create a chimney or funnelling effect for the fire, drawing hot gases and flames from one level of a building to another. This will, in effect, negate it as one of the most robust sections of the structure and may now be one of the weakest.

If it is suspected that a stairway may collapse and it is necessary to work in that area, then the best way to overcome the risk is to extend a ladder over the area that spans the stairway.

Other hazards

Biological hazards

Besides structural damage, there are many other potential hazards at fire scenes. These include biological hazards such as:

- body fluids
- broken drainage and sewerage systems
- drug paraphernalia – syringes and needles.

Chemical hazards

Chemical hazards include:

- stored materials, e.g. acids, alkalis, solvents
- toxic and irritant combustion products
- clan labs.

Utility suppliers

Services such as gas and electricity supplies should be confirmed as “off” before examining the scene. Use special care if there are several separate supplies.

Note:

Remember that this assessment is a continuous dynamic process. What you do during the investigation may change the nature of the hazards or your exposure to them.

NFPA 921 Chapter 12 - Safety

Extract

H12.1H General.
Fire scenes, by their nature, are dangerous places. Fire investigators have a duty to themselves and to others such as other investigators, equipment operators, laborers, property owners who may be endangered at fire scenes during the investigation. This chapter will provide the investigator with some basic recommendations concerning a variety of safety issues, including personal protective equipment (PPE). It should be noted, however, that the investigator should be aware of and follow the requirements of safety-related laws (OSHA, federal, or state) or those policies and procedures established by their agency, company, or organization. Additionally, a first aid kit should be present at all fire scenes and the location of the nearest hospital/trauma center should be identified prior to beginning the scene examination.

12.1.1 Investigating the Scene Alone. Fire scene examinations should not be undertaken alone. A minimum of two individuals should be present to ensure that assistance is at hand if an investigator should become trapped or injured. If the fire scene is investigated by one investigator, a clear communications protocol needs to be established between the site investigator and an off-site contact person. An estimated completion time should be established, and periodic contacts between the scene investigator and off-site contact person should be made at regular intervals. If it is impossible for the investigator to be accompanied, he or she should at least notify a responsible person of where the investigator will be and of when he or she can reasonably be expected to return.

12.1.2 One of the first tasks that should be completed before a fire or explosion investigation is begun is a Hazard and Risk Assessment. Thereby the investigator will be able to determine the hazards present and control those hazards by engineering or administrative control or through the selection and use of appropriate personal protective equipment (PPE). Hazard and Risk Assessments are comprised of three different actions, as shown in 12.1.2.1 through 12.1.2.3.3.

12.1.2.1 Identify the Hazards. To simplify the process of hazard identification and to allow a more systematic and complete identification process, the investigator may use a classification system of the hazards. It should be remembered that classification of hazards is not the most important action. The most important aspect of this process is to identify the presence of the hazard.

12.1.2.1.1 Physical Hazards. Physical hazards, such as slip, trip, and fall hazards, or sharp surfaces, broken glass, and other such hazards, can cause a physical hazard to the investigator.

Source – NFPA 921 Chapter 12, 2008.

Extract

12.1.2.1.2 Structural Hazards. Many structural hazards are easily identified without the need to have specialized technical assistance, but in complex scenes or heavily damaged scenes the investigator may want to consider the assistance of a structural engineer.

12.1.2.1.3 Electrical Hazards. Electrical hazards at the investigation scene can come from the building's electrical utility service, emergency or standby power, or those tools and equipment the investigator brings on to the scene. The electrical service should be disconnected or the appropriate circuits isolated.

12.1.2.1.4 Chemical Hazards. Chemicals that are normally present at the scene or those that are a result of the incident should be considered. In commercial occupancies, the investigator may wish to obtain copies of Material Safety Data Sheets (MSDS) to determine the hazards of those products. The identification of chemical hazards that may be present as a result of the incident is more difficult. There are many reference documents the investigator may use to determine the hazards of suspected chemicals present at the investigation scene, including the National Institute of Safety and Health (NIOSH) *Pocket Guide to Chemical Hazards*.

12.1.2.1.5 Biological Hazards. Sources of biological hazards include bacteria, viruses, insects, plants, birds, animals, and humans. These sources can cause a variety of health effects ranging from skin irritation and allergies to infections (e.g., tuberculosis, communicable diseases), cancer, etc. Some of these hazards may not be recognized without specialized assistance.

12.1.2.1.6 Mechanical Hazards. Machinery and equipment present on the scene may have stored energy. Prior to working around machinery and equipment, the investigator will need to determine if they are at zero mechanical state or if they are still operational or functional. For specialized machinery or equipment, the investigator may need to seek the assistance of the property owner or other technical resource to assist in controlling the stored energy.

12.1.2.2 Determine the Risk of the Hazard. Depending on the specific hazard identified, the determination of the risks associated with the hazard could vary from simple qualitative assessments to complex quantitative assessments. Also, as a part of this analysis, the investigator will determine the likelihood that they will come in contact with that hazard. As an example, for a chemical (even if it is a chemical hazard) contained in a drum or other containment device, the risk is minimal. Given that example, a control mechanism may be to isolate the area where the container is in order to prevent damage and potential release.

12.1.2.3 Control the Hazard. Following the determination of the risk level, this level should be compared to a suitable benchmark or acceptance criteria. In some cases, the acceptance criteria has been established by regulators (OSHA). To control a hazard, the investigator can utilize several methodologies that include engineering controls, administrative controls, or the selection and use of appropriate PPE.

Source - NFPA 921 Chapter 12, 2008.

Extract

12.1.2.3.1 Engineering Controls. Engineering controls can be as simple as placing appropriate shoring to reinforce damaged structural elements or the demolition of those areas after they are properly documented. Or, they can be very complex solutions that will require a structural engineer to evaluate, design corrective measures, and manage the installation of the corrective measures.

12.1.2.3.2 Administrative Controls. Administrative controls can include the isolation of an area by the use of signs or barrier tape, by briefing of those that will be working in the area of the hazards and cautioning them that they are not to enter within the isolated area, by obtaining specialized resources that have expertise dealing with the hazard present, or by a combination of methodologies.

12.1.2.3.3 Proper Selection and Use of Personal Protective Equipment (PPE). The use of PPE is generally considered the least effective of the control measures. However, due to the conditions that the investigator may encounter at the scene and the duration of the work, PPE can be a suitable control mechanism. Care will need to be taken to determine the hazard present to ensure that the PPE selected is acceptable for the hazard present and that the user of the PPE is trained and capable to use it.

12.1.3 Safety Clothing and Equipment. Proper personal protective equipment, including safety shoes or boots with a protective mid-sole, gloves, safety helmet, eye protection, and protective clothing, should be worn at all times while investigating the scene. The type of protective clothing will depend on the type and level of hazard present. When there is a potential for injuries from falling objects or potential cuts or scrapes from sharp objects, fire-fighting turnout gear or similar clothing that provides this type of protection may be the best choice. When an investigator is dealing with a potential exposure of toxic substances and debris, disposable coveralls as required by some safety-related regulations may be necessary. In high hazard atmospheres, *hazardous environmental suits* may be required. Whenever PPE is worn to provide protection from a hazardous environment, it should be properly decontaminated or disposed of in order to avoid subsequent exposure to residues. Even when choosing to wear standard cloth coveralls or fire-fighting turnout gear, consideration should be given to the safe handling of the clothing so as not to create additional exposure.

Source - NFPA 921 Chapter 12, 2008.

Extract

12.1.3.1 Appropriate respiratory protection is necessary at most fire scenes. Immediately following fire extinguishment there may be combustible gases and smoke, low oxygen concentrations, toxic or carcinogenic airborne particles, and high heat conditions present. In these atmospheres, the investigator should utilize SCBA and other PPE that are appropriate and should recognize that air-purifying respirators should not be utilized in atmospheres where the oxygen level is below 19.5 percent or Immediately Dangerous to Life and Health (IDLH) atmospheres are present. The act of disturbing the fire debris can create dust and release organic vapors, which should be considered hazardous, and the investigator should be wearing a filter mask and an air purifying respirator with appropriate cartridges. The decision to wear a full-face respirator versus a half-face respirator will be up to the employer and depends on the hazards present. In the respirator selection process, consideration should be given to eye protection, as many toxic substances can be absorbed through the sclera. If a half-face respirator is selected, then wearing a pair of vented goggles will provide protection from this type of hazard. If respiratory protection is worn, the investigator or other individual will need to be properly trained, medically and physically fit, and have been properly fit tested when required for the particular respiratory protection being worn. Additional guidance concerning respirators and the responsibilities of the employer and employee are contained in Occupational Safety and Health Administration (OSHA) Regulation 29 CFR, Section 1910.134 (Respiratory Protection).

12.1.3.2 The proper selection of gloves that provide puncture protection or protection from biological or chemical contamination should also be considered. When conducting scene excavation or debris removal, puncture-resistant fire-fighting gloves or lighter leather gloves should be selected. Additional protection from the leaching of toxic substances should be provided by wearing latex (or similar) gloves underneath the leather gloves, or the investigator may need to select gloves that would be more appropriate for the hazard present.

12.1.3.3 Certain other equipment might also be necessary to maintain safety. This equipment includes flashlights or portable lighting, fall protection equipment, environmental monitoring and sampling equipment, and other specialized tools and equipment. Some of this equipment requires special training in its use.

12.1.4 Fire Scene Hazards. The investigator should remain aware of the general and particular dangers of the scene under investigation. The investigator should keep in mind the potential for serious injury at any time and should not become complacent or take unnecessary risks. The need for this awareness is especially important when the structural stability of the scene is unknown or when the investigation requires that the investigator be working above or below ground level.

12.1.5 Personal Health and Safety. The investigator should be cognizant of factors associated with chemical, biological, radiological, or other potential hazards that may threaten personal health and safety while conducting fire scene examinations. Where these conditions exist, special precautions should be taken, as mentioned in 12.1.3.

Source - NFPA 921 Chapter 12, 2008.

Extract

12.1.5.1 Industries are becoming more cognizant of these hazards. Proper identification or labeling may have been destroyed as a result of the fire. The fire investigator should seek out knowledgeable persons from the facility to identify any possible substances that may endanger those working in and around the fire scene. The facility should have material safety data sheets (MSDSs), safety plans, and standard operating procedures (SOPs) that reference their hazardous commodities and that will also be beneficial to the investigator.

12.1.5.2 Of further concern is the use of hazardous substances as a form of terrorism. Whenever there is suspicion that the scene may be a crime scene as a result of a terrorist act, all precautions should be implemented.

12.1.6 Investigator Fatigue.

12.1.6.1 It is common for investigators to put in long periods of strenuous personal labor during an incident scene investigation. This labor may result in fatigue, which can adversely influence an investigator's physical coordination, strength, or judgment to recognize or respond to hazardous conditions or situations. Keep in mind that the use of heavy safety clothing and respiratory protection will further increase fatigue.

12.1.6.2 Periodic rest, fluid replacement, and nourishment should be provided in a safe atmosphere, remote from but convenient to the fire scene. Sanitation facilities that include a restroom and washing station are necessary on large or major incidents. The hazard to the fire investigator is not just through aspiration and absorption but also through ingestion, so it is essential that eating and drinking occur out of the scene after removal of contaminated gear and the washing of face and hands.

12.2 Factors Influencing Scene Safety.
Many varying factors can influence the danger potential of a fire or explosion scene. The investigator should be constantly on the alert for these conditions and should ensure that appropriate safety precautions are taken by all persons working at the scene.

12.2.1 Status of Suppression.

12.2.1.1 If the investigator is going to enter parts of the structure before the fire is completely extinguished, he or she should receive permission from the fire ground commander. The investigator should coordinate his or her activities with the fire suppression personnel and keep the fire ground commander advised of the areas into which he or she will be entering and working. The investigator should not move into other areas of the structure without informing the fire ground commander. The investigator should not enter a burning structure unless accompanied by fire suppression personnel, and unless appropriately trained to do so.

Source - NFPA 921 Chapter 12, 2008.

Extract

12.2.1.2 When conducting an investigation in a structure soon after the fire is believed to be extinguished, the investigator should be mindful of the possibility of a rekindle. The investigator should be alert for continued burning or a rekindle and should remain aware at all times of the fastest or safest means of egress.

12.2.2 Structural Stability. By their nature, most structures that have been involved in fires or explosions are structurally weakened. Roofs, ceilings, partitions, load-bearing walls, and floors may have been compromised by the fire or explosion.

12.2.2.1 The investigator's task requires that he or she enter these structures and often requires that he or she perform tasks of debris removal that may dislodge or further weaken these already unsound structures. Before entering such structures or beginning debris removal, the investigator should make a careful assessment of the stability and safety of the structure. If necessary, the investigator should seek the help of qualified structural experts to assess the need for the removal of dangerously weakened construction or should make provisions for shoring up load-bearing walls, floors, ceilings, or roofs.

12.2.2.2 The investigator should also be especially mindful of hidden holes in floors or of other dangers that may be hidden by standing water or loosely stacked debris. The investigator should keep in mind that the presence of pooled extinguishment water or of weather-related factors — such as the weight of rain water, high winds, snow, and ice — can affect the ability of structures to remain sound. For example, a badly damaged structure may only continue to stand until the ice melts.

12.2.3 Utilities. The investigator should determine the status of all utilities (i.e., electric, gas, and water) within the structure under investigation. Determine before entering if electric lines are energized (primary, secondary, or temporary electrical service), if fuel gas lines are charged, or if water mains and lines are operative. Determining the status of all utilities is necessary to prevent the possibility of electrical shock or inadvertent release of fuel gases or water during the course of the investigation.

12.2.4 Electrical Hazards. Although the fire investigators may arrive on the scene hours or even days later, they should recognize potential hazards in order to avoid injury or even death. Serious injury or death can result from electric shocks or burns. Investigators as well as fire officers should learn to protect themselves from the dangers of electricity while conducting fire scene examinations. The risk is particularly high during an examination of the scene immediately following the fire. When conditions warrant, the investigator should ensure that the power to the building or to the area affected has been disconnected prior to entering the hazardous area. The investigator should also recognize that buildings may have several utility feeds and should ensure that all feeds are disconnected prior to entering the hazardous area. The fire investigator should not disconnect the building's electric power but should ensure that the authorized utility does so.

Source - NFPA 921 Chapter 12, 2008.

Extract

12.2.4.1 When electrical service has been interrupted and the power supply has been disconnected, a tag or lock should be attached to the meter, indicating that power has been shut off. In considering potential electrical hazards, always assume that danger is present. The investigator should personally verify that the power has been disconnected. This verification can be accomplished with the use of a voltmeter. Some meters allow the accurate measuring of volts, ohms, and resistance. Other devices are designed simply to indicate the presence of alternating current. These pencil-sized products give an audible or visual alarm when the device tip is placed on the wire (bare or jacketed). When utilizing voltage-testing equipment, it is imperative that the testing device be rated for the voltage supplied to the structure under investigation. Utilization of equipment that is not rated properly exposes the investigator to electrocutions and puts other investigators in the area of the testing at great risk. If any doubt exists as to whether the equipment is energized, the local electric utility should be called for verification.

12.2.4.2 The investigator may be working at fire scenes that have been equipped with temporary wiring. The investigator should be aware that temporary wiring for lighting or power arrangements is often not properly installed, grounded, or insulated and, therefore, may be unsafe.

12.2.4.3 The investigator should consider the following electrical hazards shown in 12.2.4.3(A) through 12.2.4.3(L) when examining the fire scene.

(A) All wires should be considered energized or "hot," even when the meter has been removed or disconnected.

(B) When approaching a fire scene, the investigator should be alert to fallen electrical wires on the street; on the ground; or in contact with a metal fence, guard rail, or other conductive material, including water.

(C) The investigator should look out for antennas that have fallen on existing power lines, for metal siding that has become energized, and for underground wiring.

(D) The investigator should use caution when using or operating ladders or when elevating equipment in the vicinity of overhead electric lines.

(E) It should be noted that building services are capable of delivering high amperage and that short circuiting can result in an intense electrical flash, with the possibility of serious physical injury and burns.

(F) Rubber footwear should not be depended on as an insulator.

(G) A flooded basement should not be entered if the electrical system is energized. Energized electrical equipment should not be turned off manually while standing in water.

(H) Operation of any electrical switch or non-explosionproof equipment in the area that might cause an explosion if flammable gas or vapors are suspected of being present should be avoided. *(See 12.2.7.)* When electric power must be shut off, it should be done at a point remote from the explosive atmosphere.

(I) Lines of communication and close cooperation with the utility company should be established. Power company personnel possess the expertise and equipment necessary to deal with electrical emergencies.

Source - NFPA 921 Chapter 12, 2008.

Extract

(J) The investigator should locate and avoid underground electric supply cables before digging or excavating on the fire scene.

(K) The investigator should be aware of multiple electrical services that may not be disconnected, extension cords from neighboring buildings, and similar installations.

(L) A meter always should be used to determine whether the electricity is off.

12.2.5 Standing Water.

12.2.5.1 Standing water can pose a variety of dangers to the investigator. Puddles of water in the presence of energized electrical systems can be lethal if the investigator should touch an energized wire while standing in a puddle.

12.2.5.2 Pools of water that may appear to be only inches deep may in fact be well over the investigator's head. Pools of water may also conceal hidden danger such as holes or dangerous objects that may trip or otherwise injure the investigator.

12.2.6 Safety of Bystanders.

12.2.6.1 Fire and explosion scenes always generate the interest of bystanders. Their safety, as well as the security of the scene and its evidence, should be addressed by the investigator.

12.2.6.2 The investigation scene should be secured from entry by curious bystanders. This security may be accomplished by merely roping off the area and posting "Keep Out" signs and barricade tape, or it may require the assistance of police officers, fire service personnel, or other persons serving as guards. Any unauthorized individuals found within the fire investigation scene area should be identified and their identity noted; then they should be required to leave.

12.2.7 Safety of the Fire Scene Atmosphere.

12.2.7.1 Fires and explosions often generate toxic or noxious gases. The presence of hazardous materials in the structure is certain. Homes contain chemicals in the kitchen, bath, and garage that can create great risk to the investigator if he or she is exposed to them. Commercial and business structures are generally more organized in the storage of hazardous materials, but the investigator cannot assume that the risk is less in such structures. Many buildings built prior to 1975 will contain asbestos. The investigator should be aware of the possibility that he or she could become exposed to dangerous atmospheres during the course of an investigation.

Source - NFPA 921 Chapter 12, 2008.

Extract

12.2.7.2 In addition, it is not uncommon for atmospheres with insufficient oxygen to be present within a structure that has been exposed to fire or explosion. Fire scene atmospheres may contain ignitible gas, vapors, and liquids. The atmosphere should be tested using appropriate equipment to determine whether such hazards or conditions exist before working in or introducing ignition sources into the area. Such ignition sources may include electrical arcs from flashlights, radios, cameras and their flashes, and smoking materials.

12.3 Criminal Acts or Acts of Terrorism.

Fire is an event that can result from a criminal act. The initial incendiary device that created the fire or explosion may not be the only device left at the scene by the perpetrator. A secondary incendiary or explosive device may be left at the scene with the intent to harm fire, rescue, or investigative personnel. Of further concern are the chemicals used in the device that may leave a residue, creating an additional exposure.

12.3.1 Secondary Devices. The potential endangerment from a secondary incendiary or explosive device is remote compared to other hazards created at the scene from the initial device. However, the investigator should always be wary of any unusual packages or containers at the crime scene. If there is reason to believe that such a device may exist, it is necessary to contact the appropriate authorities to have specialists “sweep” the area. Close cooperation between investigative personnel and the explosive ordnance disposal (EOD) specialists can preclude the unnecessary destruction of the crime scene.

12.3.2 Residue Chemicals. If the incendiary or explosive device is rendered safe by the appropriate personnel, care should be taken when handling the rendered device or any residue from the device. Exposure to the chemical residue could endanger the investigator. Appropriate protective clothing and breathing apparatus should be worn while in the process of collecting such evidence.

12.3.3 Biological and Radiological Terrorism. There is a potential for a terrorist to release biological or radiological particulates as a part of his or her terrorist act. Usually the emergency response personnel will be aware of such an act while mitigating the emergency incident. If there is any suspicion that either type of hazardous substance has been released, the scene must be rendered safe prior to the entry of investigative personnel. If this rendering is not possible and the investigation is to go forward, only those investigative personnel trained to work in such atmospheres should be allowed to enter the scene.

12.3.4 Exposure to Tools and Equipment. Many of the tools and equipment used in the process of conducting an investigation may be rendered unsafe after being used in hazardous atmospheres. The necessary procedures, equipment, tools, and supplies to render your equipment safe should be in place prior to undertaking the investigation. Precautions should also be in place to dispose of the tools safely should they be incapable of being rendered safe.

Source - NFPA 921 Chapter 12, 2008.

Extract

12.4 Safety in Off-Scene Investigation Activities.

12.4.1 Safety considerations also extend to ancillary fire investigation activities not directly related to the fire or explosion scene examination. Such ancillary investigation activities include physical evidence handling and storage, laboratory examinations and testing, and live fire or explosion recreations and demonstrations. The basic safety precautions dealing with use of safety clothing and equipment, and the proper storage and prominent labeling of hazardous materials evidence, thermal, inhalation, and electrical dangers of fire and explosion recreations or demonstrations should be followed.

12.4.2 Valuable safety information may be found in NFPA 30, *Flammable and Combustible Liquids Code*, NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, NFPA 1403, *Standard on Live Fire Training Evolutions*, and NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*. Additional information may also be obtained by the appropriate government agency regulations such as Occupational Safety and Health Administration (OSHA) documents, Environmental Protection Agency (EPA) documents, state and local regulations, and documents written by other standards-making organizations such as the Compressed Gas Association (CGA), American Petroleum Institute (API), American Society of Testing and Materials (ASTM), American National Standards Institute (ANSI), and others that may impact the investigation activities.

Source - NFPA 921 Chapter 12, 2008.

2. Personal Safety

Health & Safety during fire scene examination

Working in a fire scene is working in an unstable and potentially unsafe environment. All staff and the New Zealand Fire Service have a shared responsibility to:

- Protect themselves in their duties
- Ensure that we work in a safe as possible environment.

To provide adequate protection we must first analyse where the dangers lie and the types of injuries that can be sustained. We must also look for the presence of any chemicals and determine any associated dangers.

Safety procedures at the scene

Liaise with the OIC immediately on attending a fire scene. Questions to ask the OIC to learn scene safety requirements include:

- Has the power been turned off?
- Is there a possibility of structural collapse? (Including roof, walls, floor)
- What type of structure is it?
- Is the first attending crew still present?
- Are there any chemicals involved?
- Did the attending crews experience any problems with, or in, the structure of the fire scene? (this may help identify a dangerous area)
- Have any injuries occurred?

Potential hazards

Most injuries are received from the following hazards:

1. **Inhalation** – of toxic substances
2. **Ingestion** – of particles
3. **Injection** – from sharp objects
4. **Vision impairment** – from airborne particles such as dust, gasses, vapours etc.
5. **Absorption** – hazardous substances entering the body
6. **Tripping** – on fire debris
7. **Falling** – items from above, chain reactions from other items being dislodged and through holes or collapse of weakened structures
8. **Electrical** – hanging wires.

To identify the best method of protection we must assess all the above and ensure we have a strategy to prevent occurrence, or mitigate the effects of its impact.

1. Inhalation

Use respiratory protection if there is still smouldering debris, aerosols present, or while turning over fire debris, as excavation will usually cause a rise in particulates that could be inhaled.

It is important to remember products of combustion can often be more harmful following extinguishment than during the initial fire.

Each fire scene is different and has specific protection requirements and so suitable respirators must be used. These differ depending on the scene and range from:

- **Nose and mouth filters** – will filter heavy particles but will not protect from chemicals in the atmosphere.
- **Full-face respirators** – will protect against *some* chemicals and dangerous particles being inhaled. To ensure complete protection if chemicals are present check the Hazchem book, or other references.
- **Breathing apparatus** – protects against all chemicals and dangerous particles being inhaled. Hazchem recommends use because of specific dangers.

Obtain correct information before entering a fire scene. The investigator needs to be aware of what chemicals are present, how they are stored and how they may have reacted with other chemicals during or after the fire. Study labels where possible if they have not been burnt or washed away, to recover information about flammable liquids.

2. Ingestion

Taking of food or liquid into the body or accidental swallowing can occur at the fire scene of:

- Particulates
- Aerosols
- Biological diseases.

Suitable facemasks and careful washing of hands can prevent ingestion.

The investigator should always wear suitable gloves and when you have finished at a scene the gloves should be removed, appropriately disposed of, and your hands washed with plenty of soap and water.

Biological substances can absorb through your skin and the investigator needs to be aware of sharp objects, body fluids and dangers of ingestion. Biohazards should be treated as would any other hazardous substance. The procedures are outlined in the Manual of Operations (FSM8), Operational Procedures (Part 2), and Operational Instruction No 21.

3. Injection

An investigator must wear substantial footwear and strong gloves to be protected from:

- Glass
- Nails
- Pieces of metal
- Splinted timber
- Used syringes with needles.

4. Airborne Particles

To prevent eye injury from airborne particles use a good pair of goggles.

5. Absorption

There are many harmful substances present, or potentially present, at fire scenes which could be absorbed through the skin. These can be either a result of the use of the premises or as a result of the combustion process, or both. Some of these substances are carcinogenic. Fortunately, however, fortunately these are usually in minute amounts, if present at all.

Investigators should utilise barriers to prevent absorption of these potentially hazardous substances in to the body.

6. & 7. Tripping or Falling

Fire scenes can be a mass of twisted debris. The investigator must be aware of this and have an understanding of how structures react during and following a fire.
The four main building materials are:

- **Timber** – take note of the thickness of structural members, the load it is carrying and any sound emanating as creaking and groaning indicate movement and therefore an unstable structure.
- **Steel** – unprotected steel will expand, lose strength and potentially collapse. The investigator should pay attention to location and condition of steel beams and trusses etc.
- **Concrete** – this construction is most unpredictable and can be affected by extremely low fire temperatures and when affected topple like a deck of cards in all directions. Concrete when subjected to fire, tends to break away at the surface (spalling). Colour changes that occur from pink to yellow at high temperatures indicate a loss of strength.
- **Masonry and brick structures** can weaken when subjected to fire. Look for cracking, leaning, bowing or collapse of supporting floors or roof frames.

When working with building materials that have a risk of falling, keep in mind the following:

- If it is possible to remove the materials without risk of injury or compromising the scene, do so before entering
- Always wear protective gear including a hard hat
- If it is not necessary for you to be there *don't be*!

8. Electrical hazards

Electricity in structures should also be considered and the main fuse should be switched off to ensure all power is off or isolated before entering the premises to commence investigation. Make sure you:

- Turn off all power
- Check of any exposed, hanging or cut wires
- Check switches and/or circuit breakers
- Remove all electrical appliances from sockets
- Don't stand in puddles of water
- Use a voltage tester if available.

3. Tools and Equipment

NFPA 921, Chapter 14.4

The ideal tool complement for fire investigation can be found below. However, most fire appliances carry only basic equipment, which may necessitate some improvisation.

Extract

14.4.1 Equipment and Facilities. Each person on the fire scene should be equipped with appropriate safety equipment, as required. A complement of basic tools should also be available. The tools and equipment listed in 14.4.2 and 14.4.3 may not be needed on every scene, but in planning the investigation, the investigator should know where to obtain these tools and equipment if the investigator does not carry them.

14.4.2 Personal Safety Equipment. Recommended personal safety equipment includes the following:

(1) Eye protection
(2) Flashlight
(3) Gloves
(4) Helmet or hard hat
(5) Respiratory protection (type depending on exposure)
(6) Safety boots or shoes
(7) Turnout gear or coveralls

14.4.3 Tools and Equipment. Recommended tools and equipment include the following:

(1) Absorption material
(2) Axe
(3) Broom
(4) Camera and film *(See 15.2.3.2 and 15.2.3.3 for recommendations.)*
(5) Claw hammer
(6) Directional compass
(7) Evidence-collecting container *(See Section 16.5 for recommendations.)*
(8) Evidence labels (sticky)
(9) Hand towels
(10) Hatchet
(11) Hydrocarbon detector
(12) Ladder
(13) Lighting
(14) Magnet

Source - NFPA 921 Chapter 14.4, 2008.

Extract

(15) Marking pens
(16) Paint brushes
(17) Paper towels/wiping cloths
(18) Pen knife
(19) Pliers/wire cutters
(20) Pry bar
(21) Rake
(22) Rope
(23) Rulers
(24) Saw
(25) Screwdrivers (multiple types)
(26) Shovel
(27) Sieve
(28) Soap and hand cleaner
(29) Styrofoam cups
(30) Tape measure
(31) Tape recorder
(32) Tongs
(33) Tweezers
(34) Twine
(35) Voltmeter/ohmmeter
(36) Water
(37) Writing/drawing equipment

Source - NFPA 921 Chapter 14.4, 2008.

Clean any equipment used thoroughly between attendances at subsequent fire scenes to avoid contamination of the scene.

Tools should not have a film of oil or anything similar applied to preserve them. Attendance at MVA's or other fuel spillages within the preceding seven days should be advised to the investigator as to cross contamination potential.

There are many other sources of contamination. Some of the most common are:

- Tools
- Boots and gloves
- Hose lines
- Salvage sheets.

Soot, fuels or materials from a previous incident may be contained in common items. Keep them clean, that is, wash with detergent between incidents.

The Investigation Process

Section Contents

1. Planning the Investigation

Introduction

The intent of this section is to identify areas of concern to the investigator before investigating the incident scene.

Regardless of the number of people involved, the need to plan investigations remains constant.

The person responsible for the investigation of the incident should identify the resources at his or her disposal and those available from outside sources before starting the investigation. It is his or her responsibility to get extra resources as needed.

Gain help by early identification of external agencies that may be of assistance such as:

- local building officials
- many other public and private agencies.

It is important to liaise and discuss their involvement and the parameters of their contribution. Within the CIMS framework, it is important to identify the lead agency, the authority to investigate, and the appropriate forms of reporting.

Basic incident information

Before beginning the incident scene investigation identify any events, facts and circumstances. Accuracy is important, since a mistake at this point could jeopardise the subsequent investigation results.

The investigator should obtain as much background information to the incident.

Date and time of incident

The investigator should accurately determine the day, date and time of the incident.

Weather conditions

Weather at the time of the investigation may force the need for special clothing and equipment. Weather may also determine the time the team members can work an incident scene.

It is important to note the weather conditions such as wind direction and velocity, temperature, and rain during a fire because all can have an effect on the ignition and fire spread.

Size and complexity of incident

The size the complexity of the incident scene may suggest the need for assistance for the investigator.

Type and use of structure

The investigator should identify the type and use of the structure involved. The use or occupancy of the structure (e.g. industrial plant, chemical processing plant, storage warehouse, nuclear facility or radiological waste storage) may necessitate special containment of debris and contamination, including water run-off at the scene.

Also, appropriate hazardous materials or contamination clothing, breathing apparatus, and other protective devices and equipment may be necessary to ensure safety at the incident scene. Conditions at certain scenes may be so dangerous the investigators should work within monitored stay times.

Knowledge of construction and construction materials will provide the investigator with valuable background information and allow anticipation of circumstances and problems to be encountered by the investigation.

Nature and extent of damage

Information on the condition of the scene may alert the investigator to special requirements for the investigation, such as utility testing equipment, specialised expertise, extra staffing and special safety equipment.

Security of scene

The investigator should promptly determine the identity of the individual, authority, or entity that has possession or control of the scene. Physical security of the scene immediately prior to the fire needs to be established if possible and recorded. If forced entry has been made, the identification of the person who did it needs to be established – Fire Service person (by name) or other persons.

Purpose of investigation

While planning the investigation, the investigator should remain aware of their role, scope and areas of responsibility. Investigators may be involved from both the private and public sectors. Mutual respect and cooperation in the investigation is required.

Organising the investigation functions

There are basic functions that are common in each investigation. These are:

- photography
- note taking
- mapping
- diagramming
- interviewing witnesses
- searching the scene
- evidence collection
- preservation
- safety assessment.

The safety assessment is a continuous dynamic process – note the similarity with the Safe Person Concept used by the New Zealand Fire Service. At all times, the scene must be comprehensively and continuously reassessed for risk hazard. What you do during the investigation may change the nature of the hazards or your exposure to them.

In addition, specialised expertise in various fields is often needed. The investigator should, if possible, fulfil these functions with the personnel available. In assigning functions, those special talents or training that individual members have should be utilised.

NFPA 921, Chapter 14 – Planning the Investigation

Extract

Introduction.
The intent of this chapter is to identify basic considerations of concern to the investigator prior to beginning the incident scene investigation.

14.1.1 Regardless of the number of people involved, the need to preplan investigations remains constant. Considerations for determining the number of investigators assigned include budgetary constraints, available staffing, complexity, loss of life, and size of the scene to be investigated.

14.1.2 The person responsible for the investigation of the incident should identify the resources at his or her disposal and those available from outside sources before those resources are needed. It is his or her responsibility to acquire additional resources as needed. Assistance can be gained from local or state building officials, universities and state colleges, and numerous other public and private agencies.

14.1.3 The "team concept" of investigating an incident is recommended. It is understood that at many incident scenes, the investigator may have to photograph or sketch the scene, collect evidence, interview, and be responsible for the entire scene investigation without other assistance. These functions and others described in this document should be performed regardless of the number of people involved with the investigation.

14.2 Basic Incident Information.
Prior to beginning the incident scene investigation, numerous events, facts, and circumstances should be identified. Accuracy is important, because a mistake at this point could jeopardize the subsequent investigation results.

14.2.1 Location. The investigator, once notified of an incident, should obtain as much background information as possible relative to the incident from the requester. If the travel distance is great, arrangements may be required to transport the investigation team to the incident scene. The location of the incident may also dictate the need for specialized equipment and facilities. *(See 14.4.1.)*

14.2.2 Date and Time of Incident. The investigator should accurately determine the day, date, and time of the incident. The age of the scene may have an effect on the planning of the investigation. The greater the delay between the incident and the investigation, the more important it becomes to review pre-existing documentation and information such as incident reports, photographs, building plans, and diagrams.

14.2.3 Weather Conditions. Weather at the time of the investigation may necessitate special clothing and equipment. Weather may also determine the amount of time the team members can work an incident scene. Extreme weather may require that greater safety precautions be taken on behalf of the team members, for example, when the weight of snow on a structure weakens it. Weather conditions such as wind direction and velocity, temperature, and rain during a fire should be noted because all can have an effect on the ignition and fire spread.

Source – NFPA 921, Chapter 14, 2008.

Extract

14.2.4 Size and Complexity of Incident.

14.2.4.1 The size and complexity of the incident scene may suggest the need for assistance for the investigator. A large incident scene area may create communication problems for investigators, and arrangements for efficient communications should be made.

14.2.4.2 The size and complexity of the scene will also affect the length of the investigation, and preparations may be needed for housing and feeding the team members. Generally, the larger the incident scene, the greater the length of time required to conduct the investigation.

14.2.5 Type and Use of Structure.

14.2.5.1 The investigator should identify the type and use of the incident structure. The use or occupancy of the structure (e.g., industrial plant, chemical processing plant, storage warehouse, nuclear facility, or radiological waste storage) may necessitate special containment of debris, contamination, or radiation, including water runoff at the scene. Additionally, appropriate hazardous materials or contamination clothing, breathing apparatus, and other protective devices and equipment may be necessary to ensure safety at the incident scene. Conditions at certain scenes may be so hazardous that the investigators should work within monitored stay times.

14.2.5.2 Knowledge of the type of construction and construction materials will provide the investigator with valuable background information and allow anticipation of circumstances and problems to be encountered by the investigation team.

14.2.6 Nature and Extent of Damage.

14.2.6.1 Information on the condition of the scene may alert the investigator to special requirements for the investigation, such as utility testing equipment, specialized expertise, additional staffing, and special safety equipment. The investigator may be operating under time constraints and should plan accordingly.

14.2.6.2 The investigator should ensure that initiation of the investigation will not be contrary to post-incident orders issued by local, state, or federal regulatory agencies. Issues that often lead to such orders may involve structural stability and the presence of hazardous materials.

14.2.7 Security of Scene. The investigator should promptly determine the identity of the individual, authority, or entity that has possession or control of the scene. Right of access and means of access should be established. Scene security is a consideration. If possible, arrangements should be made to preserve the scene until the arrival of the investigator(s). If this is not possible, arrangements should be made to photograph and document existing conditions prior to disturbance or demolition.

Source - NFPA 921, Chapter 14, 2008.

Extract

14.2.8 Purpose of Investigation.

14.2.8.1 While planning the investigation, the investigator should remain aware of his or her role, the scope of the investigation, and areas of responsibility. Numerous investigators may be involved, from both the private and public sectors. Mutual respect and cooperation in the investigation is required.

14.2.8.2 The investigator, particularly the private sector investigator, may need to make a reasonable effort to notify all parties, identifiable at that time, who may have a legal interest in the investigation. *(See Section 11.3.)*

14.3 Organizing the Investigation Functions.

14.3.1 There are basic functions that are commonly performed in each investigation. These are the leadership/coordinating function; photography, note taking, mapping, and diagramming *(see Chapter 15)*; interviewing witnesses *(see Chapter 13)*; searching the scene *(see Chapter 17)*; evidence collection and preservation *(see Chapter 16)*; and safety assessment *(see Chapter 12)*.

14.3.2 In addition, specialized expertise in such fields as electrical, heating and air conditioning, or other engineering fields is often needed. The investigator should, if possible, fulfill these functions with the personnel available. In assigning functions, those special talents or training that individual members possess should be utilized.

14.4 Pre-Investigation Team Meeting.
If the investigator has established a team, a meeting should take place prior to the on-scene investigation. The team leader or investigator should address questions of jurisdictional boundaries and assign specific responsibilities to the team members. Personnel should be advised of the condition of the scene and the safety precautions required.

Source - NFPA 921, Chapter 14, 2008.

2. Preserving the Scene

Introduction

One of the major difficulties of fire investigation is the fire scene has all the elements that a fire investigator would wish were not there.

The ideal scene has no personnel present other than the investigator and any co-workers. It is relatively clean and orderly with items of evidence readily visible.

Fire scenes are just the opposite. The person who detects the fire is often a member of the public and may unwittingly compromise the scene. The scenes are almost always populated by large numbers of firefighters and their supervisors, onlookers and the press. The fire and its suppression can cause a great deal of damage and disorder.

Most significantly, unlike other scenes where a body, broken window, or some other anomaly indicates that a crime has been committed, suspicions of criminal fire activity are not raised until long after the efforts of suppression.

Deliberate fires are unique in that the fire destroys rather than creates evidence as it progresses.

Responsibility of firefighters

The 'first person on the scene' is the most valuable witness as to the nature of the undisturbed scene and the circumstances surrounding it. These 'first people on the scene' can be a valuable asset to you.

In the event of any incendiary nature of a fire, firefighters are instructed to use extra caution with the following when at a fire scene:

- suppression
- overhaul
- salvage.

All three of these activities are part of the duties of the firefighter, but each of them can complicate the scene, if not making it worthless. With the proper precautions, unnecessary damage of disruption might be avoided.

Avoid the use of excessive quantities of water at high pressures. Large quantities of water can flush important evidence away from the scene or complicate the scene investigation by making extensive clean-up efforts necessary.

Scenario

An example of this is demonstrated in the following scenario:
Fire damage was limited to four rooms of a single-story frame house. There had been no penetration into the roof space, however, the firefighters on the scene thought it necessary to pump a large quantity of water into the roof area of the dwelling. The plasterboard ceiling, unable to withstand the weight of the water collapsed onto the fire scene.

Investigators found it necessary to spend nearly an entire day removing sodden plasterboard and waterlogged fibreglass insulation from the scene before they could begin origin and cause determination.

Where the investigation could have been completed in less than six hours, the clean-up activities forced an on-scene time of nearly two days.

Firefighting techniques

Firefighting involves fast, effective entry procedures and the rapid suppression of fire. However, before the suppression process begins take some actions on the arrival at the fire scene to be of assistance:

- Avoid unnecessary structural damage, such as removal or destruction of windows, walls, and doors
- The use of water jet streams is strongly discouraged. Water jet streams have been seen to disrupt badly burned bodies and destroy the fragile remains of incendiary devices
- Water fog or spray suppression methods are more effective in most interior attacks and create less destruction than jet streams
- Fire crews are also known to push the walls of buildings into a burning pile to reduce post-fire clean up. This practice does not benefit the investigative team and does nothing to help with preserving the fire scene
- To gain rapid entry to a fire scene may require a forcible entry. Subsequent requirements to vent the scene may result in breaking many windows. Firefighters should try to note which doors or windows were broken or open as well as those that were locked on their arrival
- Recognition of the signs of forced entry, such as broken doorframes or torn window screens, are also valuable to the investigation and should be communicated to the investigator
- During the early stages of suppression, firefighters are in the best position to detect multiple points of fire origin. The realisation that several fires have simultaneously established themselves in separate areas of a building is an important step in the detection of multiple fire seats, which is a common technique for fire setters
- Investigators will be interested in not only the location and extent of the fire but the direction of suppression efforts, the points at which the fire was attacked, and the manner in which the structure was vented, since all of these can affect fire patterns
- The firefighters should note any unusual flames, smoke colours, odours, and weather conditions (wind direction and intensity, temperature, etc.).

Minimising post-fire damage

During the salvage portion of the fire scene clean up, owners, tenants and employees are sometimes allowed to enter the fire scene to remove items of value. The Incident Controller responsible for the scene should not allow the removal of materials from the scene until the fire scene investigator has had a chance to evaluate those items.

There have been cases reported where the 'victim' has returned to the fire scene to pick up some valuables then proceeded to destroy the evidence of one or more fire seats for which they have been responsible. 'Victims' have also been known to remove different items that are relevant to the investigation process.

The fire crews, therefore, have the best opportunity to detect suspicious circumstances because they can be aware of unusual conditions, contents, or fire behaviour. It is the responsibility of the New Zealand Fire Service to maintain custody and control of the scene until the investigation is complete, even if that entails using operational support staff, fire police, or police for assistance.

Prior to the beginning of the overhaul, identify the area of origin and, if necessary, using barrier tape to preserve this area and ensure public safety. This is to reduce the possible damage to the area and facilitate an optimum investigation. Overhaul should not start until the area of origin and cause has been determined.

To avoid confusion, firefighters should remove all tools from the fire scene area once suppression has been completed. If a shovel, for example, is found near the origin of fire, enquire whether that tool belongs to the New Zealand Fire Service or is part of the fire scene.

According to Occupational Health and Safety policies, personnel are entitled to refreshments on the fireground. However, objects such as water bottles and cigarette butts left in the fire area can impact on the investigation. This could prolong the detection of origin and cause and could also lead you away from the true conclusion in determining the fire cause.

For example, the picture below shows a fire scene that contributed to $100,000 worth of damage to the adjacent building. A firefighter had collected the water bottles used by operational staff and thrown them away in a rubbish bin, which in turn contaminated the scene since the fire was actually started deliberately in the same bin!

Figure 1 – Contamination of a Fire Scene
(Source – New Zealand Police Forensic Photography 2007)

Officer role and responsibility

Operational Officers

Operational officers are responsible for preserving the scene. This means:

What to do . . .	Why
Use **minimal tactics**	to cause minimal damage to the fire scene. The strategy is to stabilise and control the situation, yet inflict the least amount of damage to the fire scene.
Maintain **professional discipline** among firefighters	to ensure maximum preservation of evidence and minimum contamination.
Restrict **access**	to ensure that authorised people only enter an area.
Protect **key areas**	to ensure security of the area, as it may contain a potential source of evidence.

"Big picture" attitude

Applying a "big picture" attitude includes a determination to preserve as much of the fire scene as possible. This is the responsibility of all firefighters. John de Haan, perhaps the world's most pre-eminent fire investigator, described the failure to preserve a scene as "juvenile destructiveness".

Remember	Why is this important?
If it's not necessary then don't do it!	It will protect evidence from being compromised. • So often when asked by an investigator, "Why are you here?" firefighters will say, "Oh, just looking around" • This applies to the public and other interested agencies • This also applies to selecting tactics. Given the priorities of the situation, use less water more efficiently.
Guard against contamination	Firefighters must regard everything they take on to the fireground as a potential source of contamination. Initially, this is a difficult concept to take in, but it is important.

Contaminantion

Contamination may be described as a process of transferring particles by direct contact from one area to another. As the technology for detecting small traces of evidence develops, there is an increasing opportunity for the investigator to unintentionally cross contaminate between fire scenes.

Common contaminants

There are many cases on record where an investigation has been unsuccessful because of the introduced materials and objects brought on to the fireground have so contaminated the scene that it has made any meaningful decision impossible. More importantly perhaps, there have been cases where contaminating the scene has led to miscarriages of justice (people have been wrongly convicted) or conversely people who are clearly guilty have been allowed to go free because the defence lawyers have been able to prove the evidence is unreliable.

Sources of contamination

Petrol engines, generators, PPV, and the like are a ready source of contamination. If possible, they should not be introduced on to the scene. Furthermore, they should not be refuelled anywhere near the scene if this can be avoided. In particular, carefully note any spillage of fuel. It is not difficult to understand the potential distorting effect of the presence of petrol or similar fuels on a scene where arson may be suspected.

There are many other sources of contamination. Some of the most common are:

- tools
- boots and gloves
- hose lines
- salvage sheets.

Soot, fuels or materials from a previous incident may be contained in common items. Keep them clean, that is, wash with detergent between incidents.

Clean any tools used for collecting samples and protective clothing used by the investigator between incidents. Record the cleaning date and time so no claims of cross contamination between scenes can be made. This is important where the fire scene may also be a crime scene.

Absorbent materials are most likely to allow liquid transfer and contamination from one part of the scene to another. As a practice guide investigators should ensure they clean all non disposable items thoroughly from one scene to the next and occasionally divide the scene into smaller areas and ensure that equipment is cleaned between sampling.

Throughout the investigation process the fire investigator must take care to ensure the fire scene does not suffer from contamination.

Avoid cross-contamination

Tools should not have a film of oil or anything similar applied to preserve them. Attendance at MVAs or other fuel spillages within the preceding seven days should be advised to the investigator as to cross contamination potential.

Legal consequences

Remember, in a court of law, defence lawyers can use carelessness on the part of firefighters against the New Zealand Fire Service. If they are able to prove any contamination of the scene by the New Zealand Fire Service, then potentially significant evidence could be ruled inadmissible.

Recognition

Firefighters must learn to recognise the physical evidence that can help to pinpoint the area of origin. This is a complex area that needs constant application and a determination to improve existing knowledge and skills.

Recognition is a foundation block of proof. If court action results, proof is the only benchmark.

Firefighters must also learn to rely on more than just the obvious. A good investigator can use the five senses they have to gather more information about an incident:

- Sight – Look for evidence
- Smell – strong smells can indicate accelerants
- Hearing – noises of potential collapse in a building
- Touch – feel of possible accelerants and hot spots
- Taste – acrid tastes in the air can indicate accelerants (although it might not be a good idea to lick anything while looking for this!).

Importance of preservation

Preservation of the scene is the principal concern after the safety of everybody on the scene and fire suppression. Every firefighter must be aware of the need to leave the scene intact, as far as possible.

Evidence is required to determine the cause of the fire. Therefore, preservation of evidence is vital. Here are a few key points:

- Firefighters must be disciplined to make every attempt to protect and preserve the entire fire scene, if possible, leaving all contents, fixtures and fittings in their original locations. This applies equally to the outside of buildings especially where there is a suspicion of foul play. Take care where practical not to wash any tyre marks or trample over footprints, etc. Carelessness at the scene can irrevocably damage valuable evidence
- Jets of water easily move items of significance. Consider the use of fog or foam
- Large volumes of water will dilute flammable liquids that might be linked to early fire growth
- When dealing with hot spots or smouldering remains, their location should be noted. Longer burning causes deep char and can distract the investigation from the true point of origin. Can the hot spot be managed by using a bucket – do you need to drag a hose through the scene?
- Knobs, switches, and so on are best left untouched or at least with their original position documented. Services can often be remotely disconnected leaving switches untouched and any fingerprints intact
- Fingerprinting can be successful at fire scenes if careless handling of objects is avoided.

Investigation at night

The early stages of many fire investigations begin at night. On many of these occasions, the investigator cannot do the job adequately and will want to preserve the scene until daylight. In the dark, it is easy to overlook important clues and this can be just as true in artificial light conditions.

The need to preserve the scene for several hours has to be weighed against the possibility of re-ignition. Understandably, the instinct of the operational personnel will be to damp down to prevent this occurring. It is important to maintain a balance between damping down and drowning the scene – which may, of course, wash away valuable information. The IC may also wish to remove potential fuel sources, such as mattresses, to prevent reignition. This effectively changes the scene and any such action should be noted carefully with supporting diagrams.

The investigating officer can make strong recommendations to the IC for complete preservation overnight, but this will always be the IC's call. Much will depend on resources available for securing the site and maintaining a watch on potential reignition. This is not always possible. Many regions have established relationships with other agencies to assist with this aspect of the investigation. If the services cannot provide attendance, then security guards can be very cost-effective.

NFPA 921, Chapter 16 – Physical Evidence

Extract

General.
During the course of any fire investigation, the fire investigator is likely to be responsible for locating, collecting, identifying, storing, examining, and arranging for testing of physical evidence. The fire investigator should be thoroughly familiar with the recommended and accepted methods of processing such physical evidence.

16.2 Physical Evidence.

16.2.1 Physical evidence, defined generally, is any physical or tangible item that tends to prove or disprove a particular fact or issue. Physical evidence at the fire scene may be relevant to the issues of the origin, cause, spread, or the responsibility for the fire.

16.2.2 The decision on what physical evidence to collect at the incident scene for submission to a laboratory or other testing facility for examination and testing, or for support of a fact or opinion, rests with the fire investigator. This decision may be based on a variety of considerations, such as the scope of the investigation, legal requirements, or prohibition. *(See Section 13.2.)* Additional evidence may also be collected by others, including other investigators, insurance company representatives, manufacturer's representatives, owners, and occupants. The investigator should also be aware of standards and procedures relating to evidentiary issues and those issues related to spoliation of evidence.

16.3 Preservation of the Fire Scene and Physical Evidence.

16.3.1 General. Every attempt should be made to protect and preserve the fire scene as intact and undisturbed as possible, with the structure, contents, fixtures, and furnishings remaining in their pre-fire locations. Evidence such as the small paper match shown in Figure 16.3.1 could easily be destroyed or lost in an improperly preserved fire scene.

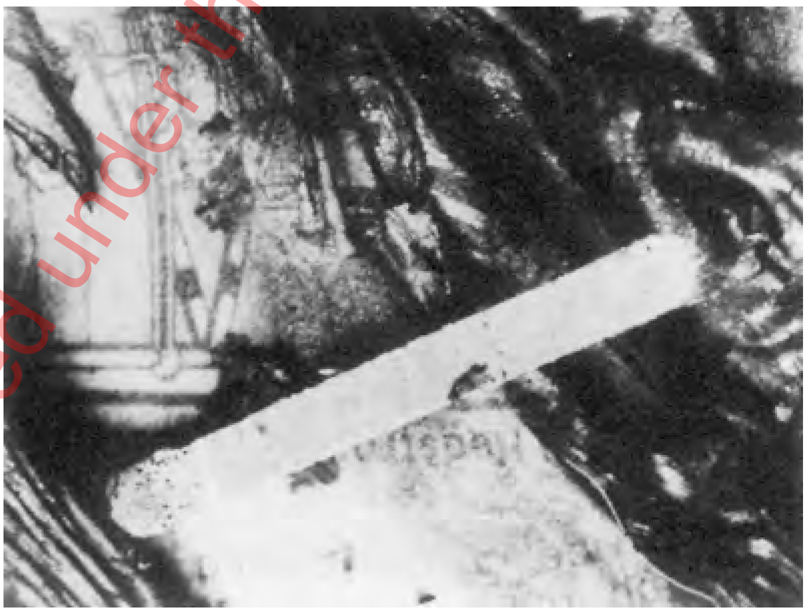


FIGURE 16.3.1 Physical Evidence at a Fire Scene.

Source – NFPA 921, Chapter 16, 2008.

Extract

16.3.1.1 Generally, the cause of a fire or explosion is not known until near the end of the investigation. Therefore, the evidentiary or interpretative value of various pieces of physical evidence observed at the scene may not be known until, at, or near the end of the fire scene examination, or until the end of the complete investigation. As a result, the entire fire scene should be considered physical evidence and should be protected and preserved. Consideration should be given to temporarily placing removed ash and debris into bags, tarps, or other suitable containers labeled as to the location from which it was removed. This way, if components from an appliance or an incendiary device are found to be missing they can be more easily found in a labeled container.

16.3.1.2 The responsibility for the preservation of the fire scene and physical evidence does not lie solely with the fire investigator, but should begin with arriving fire-fighting units or police authorities. Lack of preservation may result in the destruction, contamination, loss, or unnecessary movement of physical evidence. Initially, the incident commander and, later, the fire investigator should secure or ensure the security of the fire scene from unnecessary and unauthorized intrusions and should limit fire suppression activities to those that are necessary.

16.3.1.3 Evidence at the fire scene should be considered not only in a criminal context, such as in traditional forensic evidence (e.g., weapons, bodily fluids, footprints), nor should it be limited to arson-related evidence, items, or artifacts, such as incendiary devices or containers. Potential evidence at the fire scene and surrounding areas can include the physical structure, the contents, the artifacts, and any materials ignited or any material on which fire patterns appear.

16.3.2 Fire Patterns as Physical Evidence. The evidentiary and interpretative use of fire patterns may be valuable in the identification of a potential ignition source, such as an incendiary device in an arson fire or an appliance in an accidental fire. Fire patterns are the visible or measurable physical effects that remain after a fire. These include thermal effects on materials, such as charring, oxidation, consumption of combustibles, smoke and soot deposits, distortion, melting, color changes, changes in the character of materials, structural collapse, and other effects. *(See Section 6.3.)*

16.3.3 Artifact Evidence. Artifacts can be the remains of the material first ignited, the ignition source, or other items or components in some way related to the fire ignition, development, or spread. An artifact may also be an item on which fire patterns are present, in which case the preservation of the artifact is not for the item itself but for the fire pattern that is contained thereon.

16.3.4 Protecting Evidence.

16.3.4.1 There are a number of methods that can be utilized to protect evidence from destruction. Some methods include posting a fire fighter or police officer as a sentry to prevent or limit access to a building, a room, or an area; use of traffic cones or numerical markers to identify evidence or areas that warrant further examination; covering the area or evidence with tarpaulins prior to overhaul; or isolating the room or area with rope, caution tape, or police line tape. The investigator may benefit from supervising overhaul and salvage operations.

16.3.4.2 Items found at the fire scene, such as empty boxes or buckets, may be placed over an artifact. However, these items may not clearly identify the artifact as evidence that should be preserved by fire

Source - NFPA 921, Chapter 16, 2008.

Extract

16.3.5 Role and Responsibilities of Fire Suppression Personnel in Preserving the Fire Scene.

16.3.5.1 Generally, fire officers and fire fighters have been instructed during basic fire training that they have a responsibility at the fire scene regarding fire investigation.

16.3.5.1.2 Prompt control and extinguishment of the fire protects evidence. The ability to preserve the fire scene is often an important element in the investigation. Even when fire officers and fire fighters are not responsible for actually determining the origin or cause of the fire, they play an integral part in the investigation by preserving the fire scene and physical evidence.

16.3.5.2 Preservation. Once an artifact or other evidence has been discovered, preliminary steps should be taken to preserve and protect the item from loss, destruction, or movement. The person making the discovery should notify the incident commander as soon as practical. The incident commander should notify the fire investigator or other appropriate individual or agency with the authority and responsibility for the documentation and collection of the evidence.

16.3.5.3 Caution in Fire Suppression Operations. Fire crews should avoid causing unnecessary damage to evidence when using straight-stream hoselines, pulling ceilings, breaking windows, collapsing walls, and performing overhaul and salvage.

16.3.5.3.1 Use of Water Lines and Hose Streams. When possible, fire fighters should use caution with straight-stream applications, particularly at the base of the fire, because the base of the fire may be the area of origin. Evidence of the ignition source can sometimes be found at the area of origin. The use of hoselines, particularly straight-stream applications, can move, damage, or destroy physical evidence that may be present.

(A) The use of water hoselines for overhaul operations such as washing down, or for opening up walls or ceilings, should also be restricted to areas away from possible areas of origin.

(B) The use of water should be controlled in areas where the investigator may wish to look at the floor for possible fire patterns. When draining the floor of standing water, the drain hole should be located so as to have the least impact on the fire scene and fire patterns.

16.3.5.3.2 Overhaul.
(A) It is during overhaul that any remaining evidence not damaged by the fire is susceptible to being destroyed or displaced. Excessive overhaul of the fire scene prior to the documentation and analysis of fire patterns can affect the investigation, including failure to determine the area of origin.

(B) While the fire fighters have a responsibility to control and extinguish the fire and then check for fire extension, they are also responsible for the preservation of evidence. These two responsibilities may appear to be in conflict and, as a result, it is usually the evidence that is affected during the search for hidden fire. However, if overhaul operations are performed in a systematic manner, both responsibilities can be met successfully.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.3.5.3.3 Salvage. The movement or removal of artifacts from a fire scene can make the reconstruction difficult for the investigator. If the investigator cannot determine the pre-fire location of the evidence, the analytical or interpretative value of the evidence may be lost. Moving, and particularly removing, contents and furnishings or other evidences at the fire scene should be avoided until the documentation, reconstruction, and analysis is completed.

16.3.5.3.4 Movement of Knobs and Switches. Fire fighters should refrain from turning knobs and operating switches on any equipment, appliances, or utility services at the fire scene. The position of components, such as the knobs and switches, may be a necessary element in the investigation, particularly in developing fire ignition scenarios or hypotheses. These components, which are often constructed of plastics, can become very brittle when subjected to heating. Their movement may alter the original post-fire state and may cause the switch to break or to become impossible to relocate in its original post-fire position. (See 24.5.3.)

16.3.5.3.5 Use of Power Tools. The use of gasoline- or diesel-powered tools and equipment should be controlled carefully in certain locations. The refueling of any fuel-powered equipment or tools should be done outside the perimeter of the fire scene. Whenever fuel-powered equipment is used on the fire scene, its use and location should be documented and the investigator advised.

16.3.5.3.6 Limiting Access of Fire Fighters and Other Emergency Personnel. Access to the fire scene should be limited to those persons who need to be there. This precaution includes limiting fire fighters and other emergency or rescue personnel to those necessary for the task at hand. When possible, the activity or operation should be postponed until the evidence has been documented, protected, evaluated, and collected.

16.3.6 Role and Responsibilities of the Fire Investigator. If the fire fighters have not taken the preliminary steps to preserve or protect the fire scene, then the fire investigator should assume the responsibility for doing so. Then, depending on the individual's authority and responsibility, the investigator should document, analyze, and collect the evidence.

16.3.7 Practical Considerations. The precautions in this section should not be interpreted as requiring the unsafe or infinite preservation of the fire scene. It may be necessary to repair or demolish the scene for safety or for other practical reasons. Once the scene has been documented by interested parties and the relevant evidence removed, there is no reason to continue to preserve the scene. The decision as to when sufficient steps have been taken to allow the resumption of normal activities should be made by all interested parties known at that time."

Source - NFPA 921, Chapter 16, 2008.

3. Origin Determination

NFPA 921, Chapter 17 – Origin Determination

Extract

17.1 Introduction.
This chapter recommends a methodology to follow in determining the origin of a fire. The *area of origin* is defined as: the room or area where the fire began. The *point of origin* is defined as: the exact physical location where a heat source and a fuel come in contact with each other and a fire begins. The origin of a fire is one of the most important hypotheses that an investigator develops and tests during the investigation. Generally, if the origin cannot be determined, the cause cannot be determined, and generally, if the correct origin is not identified, the subsequent cause determination will also be incorrect. The purpose of determining the origin of the fire is to identify in three dimensions the location at which the fire began.

17.1.1 This chapter deals primarily with the determination of origin involving structures; however, the methodology generally applies to all origin determinations. Separate chapters address the particular requirements for determining origin in non-structure fire incidents (motor vehicles, boats, wildfire, etc.).

17.1.2 Determination of the origin of the fire involves the coordination of information derived from one or more of the following:

(1) *Witness Information.* The analysis of observations reported by persons who witnessed the fire or were aware of conditions present at the time of the fire

(2) *Fire Patterns.* The analysis of effects and patterns left by the fire *(See Chapter 6.)*

(3) *Arc Mapping.* The analysis of the locations where electrical arcing has caused damage and the documentation of the involved electrical circuits *(See Section 8.10.)*

(4) *Fire Dynamics.* The analysis of the fire dynamics, that is, the physics and chemistry of fire initiation and growth *(see Chapter 5)*, and the interaction between the fire and the building's systems *(See Chapter 7.)*

Source – NFPA 921, Chapter 17, 2008.

Extract

17.2 Overall Methodology.

The overall methodology for determining the origin of the fire is the scientific method as described in Chapter 4. This methodology includes recognizing and defining the problem to be solved, collecting data, analyzing the data, developing a hypothesis or hypotheses, and most importantly, testing the hypothesis or hypotheses. In order to use the scientific method, the investigator must develop at least one hypothesis based on the data available at the time. These hypotheses should be considered "working hypotheses," which upon testing may be discarded, revised, or expanded in detail as new data is collected during the investigation and new analyses are applied. This process is repeated as new information becomes available. *(See Figure 17.2.)*

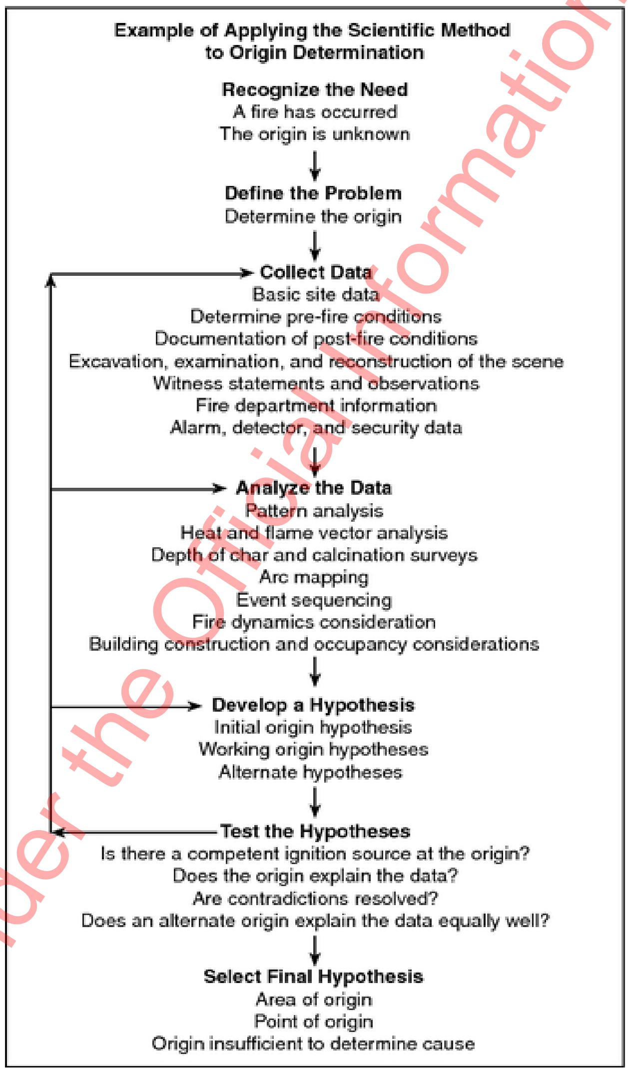


FIGURE 17.2 An Example of Applying the Scientific Method to Origin Determination.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.2.1 Testing any origin hypothesis requires an understanding of the associated fire events as well as the growth of the fire and how the fire spread through the structure. A narrow focus on only identifying the first item ignited and a competent ignition source fails to take into account important data that can be used to test any origin hypothesis. In such a narrow focus, the growth and spread of the fire and the resulting fire damage are not well considered.

17.2.1.1 The purpose of the fire spread analysis is to determine whether the resulting physical damage and available data are consistent with the area of origin hypothesis. For example, a fire starting in a wastebasket is a plausible working hypothesis, but the resulting fire damage would be highly dependent on the position of the initial fuel and any subsequently ignited fuels. If the wastebasket had been located in an area with no adjacent fuel, then the results may be significantly different than if the wastebasket had been located next to a polyurethane sofa. Both hypotheses posit the same first item ignited, but the outcome is very different. Thus, if the origin hypothesis is not consistent with the resulting growth and spread of the fire, it is not a valid hypothesis. Fire spread scenarios within a compartment or building should be analyzed using the principles of fire dynamics presented in Chapter H5H and fire pattern development in Chapter 6.

17.2.1.2 In some instances, a single item, such as an irrefutable article of physical evidence or a credible eyewitness to the ignition, or a video recording, may be the basis for a determination of origin. In most cases, however, no single item is sufficient in itself. The investigator should use all available resources to develop origin and spread hypotheses and to determine which hypotheses fit all of the evidence available. When an apparently plausible hypothesis fails to fit some item of evidence, the investigator should try to reconcile the two and determine whether the hypothesis or the evidence is erroneous.

17.2.1.3 In some cases, it will be impossible to fix the point of origin of a fire. Where a single point cannot be identified, it can still be valuable for many purposes to identify the area(s) of origin. In such instances, the investigator should be able to provide plausible explanations for the area of origin with the supporting evidence for each option. Not identifying a point of origin will not necessarily preclude determining an origin and cause. In some situations, the extent of the damage may reduce the ability to specifically identify the point of origin, without removing the ability to put forward credible origin and cause hypotheses.

17.2.2 Sequence of Activities. The various activities required to determine the origin using the scientific method (data collection, analysis, hypothesis development, and hypothesis testing) occur continuously. Likewise, recording the scene, note taking, photography, evidence identification, witness interviews, cause investigation, failure analysis, and other data collection activities may be performed simultaneously with these efforts. Generally, the various activities of origin determination will follow a routine sequence, while the specific actions within each activity may be taking place at the same time.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.2.3 Sequential Pattern Analysis. The area of origin may be determined by examining the fire effects and fire patterns. The surfaces of the fire scene record all of the fire patterns generated during the lifetime of the event, from ignition through suppression, although these patterns may be altered, overwritten, or obliterated after they are produced. The key to determining the origin of a fire is to determine the sequence in which these patterns were produced. Investigators should strive to identify and collect sequential data and, once collected, organize the information into a sequential format. Sequential data not only indicate what happened, but the order in which it happened. Identifiable fire spread patterns should be traced back to an area or point of origin. Once the area of origin has been established, the investigator should be able to understand and explain the fire spread.

17.2.4 Systematic Procedure. Investigators should establish a systematic procedure to follow for each type of incident. By following a familiar procedure, the investigator can concentrate on the incident at hand and need not dwell on the details of what the next step in the procedure will be. By doing so, the investigator may avoid overlooking significant evidence and will avoid forming premature conclusions about the origin.

17.2.5 Recommended Methodology. This chapter discusses a recommended methodology for the examination of the fire scene. This methodology consists of an initial scene assessment, development of a preliminary fire spread hypothesis, an in-depth examination of the fire scene and reconstruction of the fire scene, development of a final fire spread hypothesis, and identification of the fire's origin. Origin identification may occur earlier in the process, depending on the types and time of arrival of various data. This recommended methodology serves to inform the investigator but is not meant to limit the origin determination to only this procedure. Investigators, within the scope of their investigations, should consider all aspects of the fire event during the investigation. Witness statements, the investigator's expertise, and fire-fighting procedures play important roles in the determination of the fire origin.

17.3 Data Collection for Origin Determination.
This section describes the data collection process for origin determination, including initial scene assessment, excavation and reconstruction, and collection of additional data from witnesses and other sources.

17.3.1 Initial Scene Assessment. An initial assessment should be made of the fire scene. As the investigator starts the initial scene assessment, data collection for the determination of the origin begins. Care should be taken during each of the steps within the initial scene assessment to protect the investigator from scene hazards and preserve the scene. The purpose of this initial examination is to determine the scope of the investigation, such as equipment and manpower needed, to determine the safety of the fire scene, and to determine the areas that warrant further study.

17.3.1.1 Safety Assessment. The investigator should first make an initial safety assessment. The investigator should determine if it is safe to enter the scene. If it is not safe to enter, the investigator must determine what steps are required to provide for personal safety or to render the scene safe to enter. Each of the hazards described in Chapter H12H should be assessed. There is no reason the investigator should compromise safety.

17.3.1.2 Scope of the Examination. After safety issues have been addressed, the investigator may begin the initial scene assessment. The purpose of this initial assessment is to determine the complexity and extent of the investigation, identify required equipment and staffing, and determine the areas that warrant further analysis.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.3.1.3 Order of the Examination. This assessment may take place concurrently with the initial documentation of the scene. The assessment should include an overall look at the entire scene or structure, both exterior and interior, and all pertinent areas. The order in which the assessment takes place may vary, depending on scene conditions. Some investigators prefer to start with the least damaged area and move toward the most damaged area. Some investigators prefer to start at the highest point in a scene and work downward. Whatever order is selected for a particular scene, the point is to assess all areas that are pertinent to the origin and spread of the fire.

17.3.1.4 Surrounding Areas. Investigators should include in their examination the site or areas around the scene. These areas may exhibit significant evidence or fire patterns, away from the main body of the scene, that may enable the investigator to better define the site and the investigation. Anything of interest should be documented as to its location in reference to the scene. This phase of the examination can be used to canvass the neighborhood for witnesses to the fire and for persons who could provide information about the incident.

17.3.1.5 Structure Exterior. An inspection of the entire perimeter of the structure may reveal the extent and location of damage and may help determine the size and complexity of the scene. The general construction method and occupancy classification should be noted. The construction refers to how the building was built, types of materials used, exterior surfaces, previous remodeling, and any unusual features that may have affected how the fire began and spread. A significant consideration is the degree of destruction that can occur in a structure consisting of mixed types and methods of construction.

17.3.1.5.1 The occupancy classification refers to the current use of the building. Use is defined as the activities conducted and the manner in which such activities are undertaken. The number and circumstances of those individuals occupying the space may also be relevant. If the occupancy classification or use of the structure has changed, this should be considered and noted. Changes in use and occupancy classification sometimes require modifications to the structural, architectural, or fire protection features in accordance with applicable codes. Such modifications may or may not have been undertaken.

17.3.1.5.2 The fire damage and evidence of significant smoke, heat, and flame venting on the exterior should be documented and considered to assist in determining those areas that warrant further study. An in-depth examination of fire effects and patterns is not necessary at this point in the investigation.

17.3.1.6 Structure Interior. On the initial assessment, investigators should examine all rooms and other areas that may be relevant to the investigation, including those areas that are fire damaged or adjacent to the fire and smoke damaged areas. The primary purpose of this assessment is to identify the areas that require more detailed examination. The investigator should be observant of conditions of occupancy, including methods of storage, nature of contents, housekeeping, and maintenance. The type of construction, interior finish(es), and furnishings should be noted. Areas of damage, and extent of damage in each area (severe, minor, or none) should be noted. This damage should be compared with the damage seen on the exterior. During this examination, the investigator should reassess the soundness of the structure.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.3.1.7 Post-Fire Alterations. During this assessment, the investigator should document any indication of post-fire alterations. Such alterations may affect the investigator's interpretation of the physical evidence. Alterations may include debris removal or movement, contents removal or movement, electrical service panel alterations, changes in valve positions on automatic sprinkler systems, and changes to fuel gas systems. If alterations are indicated, attempts should be made to contact the person(s) who altered the scene. They should be interviewed as to the extent of the alterations and the documentation they may have of the unaltered site.

17.3.1.8 At the conclusion of the preliminary scene assessment, the investigator should have determined the safety of the fire scene, the probable staffing and equipment requirements, and the areas around and in the structure that will require a detailed examination. The preliminary scene assessment is an important aspect of the investigation. The investigator should take as much time in this assessment as is needed to make these determinations. Time spent in this endeavor may save significant time and effort in later stages of the investigation.

17.3.2 Excavation and Reconstruction. Fire scene excavation and reconstruction allows the investigator to observe patterns on the exposed surfaces and to locate other evidence that can assist the investigator to make an accurate origin analysis. The purpose of fire scene reconstruction is to recreate as nearly as practicable the pre-fire positions of contents and structural components. Interviews, diagrams, photographs, and other means can be helpful in establishing pre-fire conditions.

17.3.2.1 Scope of Excavation and Reconstruction. Because the preliminary scene assessment has identified the areas warranting further examination, the task of fire scene reconstruction may not require the removal of debris and the replacement of the contents throughout the entire structure. As mentioned previously, the preliminary scene assessment should not be done hastily. Careful analysis of the fire scene may help to reduce to a practical level the strenuous task of debris removal. If the area to be reconstructed cannot be reduced, then the investigator should accept the necessity of removing the debris from the entire area of interest.

17.3.2.2 Safety. Safe work practices throughout this effort are required. Debris excavation and removal can weaken a structure and cause it to collapse. Debris removal can also expose hazardous substances, uncover holes in the floor, and can expose energized electrical wiring. All significant risks that may be encountered during an investigation should be minimized before the investigation continues. See Chapter H12H for a detailed discussion on safety.

17.3.2.3 Excavation. Adequate debris removal is essential for a thorough fire investigation. Inadequate removal of debris and the resultant exposure of limited portions of the fire patterns and other evidence may lead to an incorrect analysis. A fire scene investigation normally involves dirty and strenuous work. Acceptance of this fact is essential in conducting a proper fire investigation.

17.3.2.3.1 The removal of debris during the overhaul stage of fire suppression operations is an area of concern for the fire investigator. Firefighters may disturb the scene, thus making origin determination more difficult. Only those overhaul and suppression operations necessary to ensure complete extinguishment should be conducted. When these operations call for substantial scene alterations, an attempt should be made to document the fire scene with photography and notes prior to the alterations, if practical.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.3.2.3.2 Investigators should consider where debris will be placed during removal. In some instances, it may be desirable to move the debris to a secure location. Debris should only be moved to an area that has already been examined or has no future need for examination or documentation. Moving debris twice is counterproductive. Debris removal should be performed in a planned and systematic fashion. This means that debris should be removed in layers, with adequate documentation as the process continues. If more than one investigator is doing the removal, they should discuss the purpose for the debris removal prior to starting. A discussion may prevent one investigator from discarding something the other investigator considers important. Each layer should be examined for significant artifacts as the debris is being removed.

17.3.2.3.3 During the excavation of a scene there exists a danger of evidence destruction. Although it is desirable to work efficiently, the use of heavy equipment to remove debris should only be undertaken if it is not practical to use hand tools to accomplish the task. Inappropriate use of mechanized excavating equipment can potentially destroy more evidence than it reveals.

17.3.2.4 Heavy Equipment. An investigation may require the use of heavy equipment such as cranes, backhoes, or front-end loaders. The condition of the fire scene may necessitate removal of building components or contents, because they constitute a safety hazard, are blocking access, or need to be removed during the systematic examination of the scene. Before using heavy equipment, the scene should be documented in the same manner as in all investigations. Documentation should also be conducted at frequent intervals when heavy equipment is being used.

17.3.2.4.1 Working with heavy equipment can be dangerous and noisy. One investigator should be appointed to communicate with the heavy equipment operator. A briefing session including the goals for this section should be held with the crew/operator as the investigation advances into new physical areas. The speed at which fire investigations occur is substantially slower than the ordinary speed at which heavy equipment operates. A commonly understood set of hand signals should be confirmed before beginning to use heavy equipment so that the crew/operator is clear from where direction comes and about the meaning of hand signals indicating specific actions. To reduce the risk of personal injury, the operation of heavy equipment should cease whenever a person enters the area of hazard where the machine is operating.

17.3.2.4.2 Prior to the use of heavy equipment, areas where the presence of ignitible liquid residue is suspected should be identified, if practicable. When possible, the samples should be collected prior to the use of equipment in those areas. Prior to use, heavy equipment should be inspected and any leaks of petroleum products should be noted. Fueling of the equipment should occur in a designated area, removed from the areas of interest, that will not contaminate the scene or items entering the scene. If contamination is of concern, samples of the equipment fluids should be collected for comparison purposes.

17.3.2.4.3 It is preferable to utilize the heavy equipment in a manner that has the least impact on the scene. The least destruction is usually accomplished by positioning the equipment outside the building and using the equipment to lift or move items from the inside to the outside of the building. When lifting a potential piece of evidence, rigging can be used to minimize damage to the removed item. If large components such as walls need to be demolished, it is preferable to do so in a manner that does not change or add debris to the underlying area to be examined. Safety concerns and site constraints can preclude this practice. Shoring should be considered as an alternative to demolition when possible and appropriate.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.3.2.4.4 Items that are removed from the building can be examined and documented, and can remain at the fire scene if needed for further investigation. The removal of debris offsite can limit further investigation, but is sometimes necessary. Removal off site should be well documented.

17.3.2.4.5 Some investigations will require the use of heavy equipment inside the scene. In such cases, equipment should be used in a manner that is the least disruptive of the scene. One method involves using the equipment to systematically progress into a building. The equipment is initially positioned outside the building and used to aid the examination of a portion of the interior of the building. Once that area is examined, documented, and the debris removed, the heavy equipment is brought onto that cleared location. From that new position, the equipment is used to aid in the examination of adjacent areas. This progression is repeated as many times as needed. At all times, the equipment is only located in areas that have been previously examined and documented. At all times, the equipment operator should be under the direction of a fire investigator. The collection and unloading of each load should be observed for relevant evidence. Preplanning the progression of the examination can help to limit unnecessary alteration of the scene.

17.3.2.5 Avoiding Spoliation. During the excavation, care should be taken to avoid damaging ignition sources, fuels, or other potentially important evidence within the scene. If the investigator's area of interest contains important evidence, consideration should be given to suspending the investigation and putting potentially interested parties on notice, to give them an opportunity to see the evidence in place. For more guidance on the subject of avoiding spoliation, refer to Chapter 11.

17.3.2.6 Avoiding Contamination. To avoid scene contamination, extreme care should be taken with respect to the use of portable liquid-fueled equipment, such as gasoline-powered saws. Re-fueling of such equipment should be done away from the structure.

17.3.2.7 Washing Floors. After adequate debris removal has occurred, necessary samples have been taken for examination or testing, and proper scene documentation is completed, it may be useful to flush the floor or surface with water. This flushing may help to better reveal fire patterns. The use of high pressure and straight streams should be used with caution because such activities may harm significant evidence.

17.3.2.8 Contents. Any contents, or their remains, uncovered during debris removal should be documented as to their location, condition, and orientation. Once the debris has been removed, the contents can be placed in their pre-fire positions for analysis.

17.3.2.8.1 When the contents have been displaced during fire suppression or overhaul, post-fire reconstruction becomes much more difficult. The position where the item was located may exhibit a protected area or other indicator from the item, such as table legs leaving small clear spots on the floor. The problem is knowing which leg goes to which spot. If a definite determination is not possible by scene analysis or witness identification, then all potential orientations should be considered. Otherwise, the orientation should not be included in the fire scene reconstruction. A guess as to how contents were oriented may be wrong, thereby contributing false data to the analysis process. An alternative is to document the contents in all probable positions in the hope that later information will pinpoint the accurate location.

17.3.2.8.2 In addition to the replacement of contents, reconstruction may also include the replacement of structural elements (e.g., doors, joists, studs, sections of walls and floors) that may have recorded fire patterns.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.3.3 Additional Data Collection Activities for Origin Determination. The following paragraphs describe activities in addition to the scene examination and reconstruction, which will lead to the development of data useful in the determination of the origin.

17.3.3.1 Pre-Fire Conditions. The pre-fire conditions of the structure should be determined to the extent practicable. Details such as the state of repair, condition of foundations and chimneys, insect damage, the presence and condition of fire protection systems, and so forth may prove to be significant data. Obtaining pre-fire photographs or video may be beneficial, but be aware that changes may have occurred between the time the photograph was taken and the time of the fire. Owners, employees, or occupants may be able to provide information and diagrams of pre-fire conditions. Checking with neighbors may also provide photographs showing the structure. Some jurisdictions now offer pre-fire photographs of the structure on tax record websites. There are companies specializing in aerial photography, primarily of commercial structures, which may offer pre-fire views. Satellite images are also available for many areas and may offer pre-fire documentation of both the site and the surrounding area. Additional information may be available from the fire department, which could include photographs, structure diagrams, special hazards, and fire protection systems. Other government agencies may also have pre-fire information and records.

17.3.3.2 Description of Fuels. The investigator should identify the fuels present in the building or area of interest and the characteristics of those fuels. When considering the area of origin, the type, quantity, and specific location of structural and content fuels should be identified to assist in the analysis of the fire patterns, fire growth, and spread characteristics. In this process, it is not only important to identify the potential first fuel ignited, but also to identify subsequent fuels involved.

17.3.3.3 Structure Dimensions. The physical dimensions of a structure are important data. In many instances, the post-fire structure provides the only means of obtaining dimensions. Dimensions should be recorded for all areas of the structure that may be used to understand fire growth, and smoke and fire spread. Dimensions should include the width, length, and height of a room or structure. The location, size, and condition (opened/closed) of all openings should be recorded, as well as any structures or obstructions that would affect the flow of fire gases. The effort associated with obtaining the dimensions can be time consuming and the amount of information collected may be limited depending on the extent of destruction. Specific dimensional information is necessary to reconstruct the fire event via a fire model or hand calculations *(see Chapter H20H)*. When the scene is no longer available, information may be obtained from the investigative photographs, notes and diagrams of previous investigators, or from architects, engineers, contractors, insurance companies, or government offices such as building departments. The investigator should assess the accuracy of the plans and whether the plans actually represent the "as-built" structure. *(See the discussion of building design in Section 7.2.2.6.)*

17.3.3.4 Building Systems and Ventilation. Building systems may cause fires or influence the fire spread. The investigator should consider collecting information regarding the pre-fire conditions of the electrical, HVAC, fuel gas, and fire protection systems in a structure. This collection should be performed in all cases when a system is believed to be involved in the cause, detection, spread, or extinguishment of a fire.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.3.3.5 Weather Conditions. The investigator should document weather factors that may have influenced the fire. The surrounding area may provide evidence of the weather conditions. Wind direction may be indicated by smoke movement or by fire damage sustained by structures or vegetation. Additionally, post-fire weather may cause changes to the physical condition of the scene.

17.3.3.6 Electrical Systems. The electrical system should be documented. The means used to distribute electricity should be determined, and damage to the systems should be documented. The documentation process should begin with the incoming electrical service. The main panel amperage and voltage input should be noted. The type, rating, position (on/tripped/off), and condition of the circuit protection devices may be relevant to the investigation and should be documented.

17.3.3.7 Electrical Loads. Note the location of electrical receptacles and switches within the room or area of origin. Electrical items plugged into the receptacles should be identified and documented. The investigative process may involve the tracing of circuits throughout a structure. The purpose for tracing these circuits is to identify the switches, receptacles, and fixtures on a particular circuit, as well as which over-current device protects that circuit, and its position and condition. Electrical appliances and loads should be noted. A more detailed documentation of electrical systems and devices may be necessary where they are believed to be the fire cause or a contributing factor, or when arc mapping is used. Use caution when interpreting damage to electrical wiring and equipment because it may be difficult to distinguish cause from effect. For a more detailed explanation of electrical systems, see Chapter H8H.

17.3.3.8 HVAC Systems. The air movement through HVAC systems can affect the growth and spread of a fire and can transport combustion products throughout a structure. The investigator should record the location, size, and function (supply/return/exhaust) of vents in the area of interest, and whether the vent was open, closed, or covered at the time of the fire. Checking filters may provide evidence of heat or smoke damage and soot deposition to determine whether the HVAC system was operating at the time of the fire. Some HVAC systems are equipped with detectors designed to change the operation of the system in case of fire. Some systems are equipped with manual or automatic dampers designed to control fire spread, smoke movement, or airflow. Where these devices are present, their specific location and condition should be noted and any activation records should be obtained. The location and setting of any thermostats, switches, or controls for the HVAC system should be identified and documented.

17.3.3.9 Fuel Gas Systems. The fuel gas supply should be identified and documented. The purpose of this examination is to assist in determining whether the fuel gas contributed to the fire. If the examination reveals that fuel gases may have been a contributing factor, then the system should be examined and documented in detail. This examination should include testing for leaks, if possible, and determining the supply pressure, if possible. As with electrical systems, it may be difficult to distinguish between evidence of cause and effect. Fires can, and frequently do, compromise the integrity of gas distribution systems. The investigator should document the condition and position (open/closed) of system valves. Valves are frequently turned off during fires, so an attempt should be made to ascertain if anyone operated any valves during the event.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.3.3.10 Liquid Fuel Systems. A variety of liquid fuel systems and appliances exists. These may be permanent systems, such as oil-fired space heaters and water heaters, or portable systems, such as kerosene or white gas heaters. In either case, the location and quantity of fuel present should be documented. Supply lines and valves to connected fuel supplies in remote tanks should also be documented. If the device contains an attached or integral tank, the amount of fuel remaining in the device should be estimated or measured. If the heating device is a suspected cause, or its fuel is believed to have contributed to the spread of the fire, a sample of the fuel should be preserved.

17.3.3.11 Fire Protection Systems. The examination of all involved fire protection systems (fire detection, fire alarm, and fire suppression systems) is important in determining if each system functioned properly, and can assist in tracking the growth and spread of a fire. If the system was monitored, records should be obtained from the monitoring service. In some instances, information can be downloaded from the central panel to indicate alarm and trouble signal locations and times. This is volatile data and care must be taken in extracting it from the alarm panel. Extracting this data generally requires specific knowledge and equipment. A qualified technician should be employed for downloading the data as substantial permanent loss of data can occur if this is done incorrectly. In many cases, building electrical power may be discontinued after a fire so that a limited amount of time is available for recovering the data while the system is operating on its backup battery. This limited time window should be taken into account when ordering scene activities.

17.3.3.12 Fire Protection System Data. Device locations and conditions should be documented, including the height of wall-mounted devices or the distance of ceiling-mounted devices from walls. Which sprinklers activated should be considered when examining fire spread patterns. Both detector activation and sprinkler activation may provide sequential data. In some cases, the specific location or zone of the first activating detector or sprinkler can be used to narrow down an area of origin, allowing an investigator to assess specific ignition sources in that area. Some systems provide only alarm or water flow data, and do not specify a particular zone. This information can be helpful in comparing the time of system activation to the time and observations of first arriving fire fighters or other witness, in assessment of the growth and spread of the fire.

17.3.3.13 Security Cameras. Security cameras that monitor buildings or ATMs may be very useful, particularly for providing "hard" times *(see the discussion of timelines in Chapter 20)*. Events before or during the fire including, in some cases, the actual ignition and development of the fire may have been recorded. The video recorder may be found in a secure area or a remote location. It should be recovered and reviewed even if damaged.

17.3.3.14 Intrusion Alarm Systems. An intrusion system may activate during a fire due to heat, smoke movement, the destruction of wiring, or loss of power. A monitored intrusion system may send a trouble signal to the monitoring station if a transmission line is compromised or power is lost. As with fire alarm systems, attempts should be made to recover the alarm panel history before the alarm system is reset. This frequently requires special expertise. Some alarm systems may record the identity of persons entering and leaving the building.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.3.3.15 Witness Observations. Observations by witnesses are data that can be used in the context of determining the origin. Such witnesses can provide knowledge of conditions prior to, during, and after the fire event. Witnesses may be able to provide photographs or videotapes of the scene before or during the fire. Observations are not necessarily limited to visual observations. Sounds, smells, and perceptions of heat may shed light on the origin. Witness statements regarding the location of the origin create a need for the fire investigator to conduct as thorough an investigation as possible to collect data that can support or refute the witness statements. When witness statements are not supported by the investigator's interpretation of the physical evidence, the investigator should evaluate each separately.

17.4 Analyze the Data.
The scientific method requires that all data collected be analyzed. This is an essential step that must take place before the formation of any hypotheses. The identification, gathering, and cataloging of data does not equate to data analysis. Analysis of the data is based on the knowledge, training, experience, and expertise of the individual doing the analysis. If the investigator lacks the knowledge to properly attribute meaning to a piece of data, then assistance should be sought from someone with the necessary knowledge. Understanding the meaning of the data will enable the investigator to form hypotheses based on the evidence, rather than on speculation or subjective belief.

17.4.1 Fire Pattern Analysis. An investigator should read and understand the concepts of fire effects, fire dynamics, and fire pattern development described in Chapters H5H and H6H. This knowledge is essential in the analysis of a scene to determine the origin of the fire.

17.4.1.1 Consideration of All Patterns. All observed patterns should be considered in the analysis. Accurate determination of the origin of a fire by a single dominant fire pattern is rare, as in the case of very limited fire damage where there may be only one fire pattern.

17.4.1.2 Sequence of Patterns. While fire patterns may be the most readily available data for origin determination, the investigator should keep in mind that the damage and burn patterns observed after a fire represent the total history of the fire. A major challenge in the analysis of fire pattern data is to determine the sequence of pattern formation. Patterns observed in fires that are extinguished early in their development can present different data than those remaining after full room involvement or significant building destruction. Patterns generated as a result of a rekindle may impact the perception of the fire's history or sequence of pattern production.

17.4.1.3 Pattern Generation. The investigator should not assume that the fire at the origin burned the longest and therefore fire patterns showing the greatest damage must be at the area of origin. Greater damage in one place than in another may be the result of differences in thermal exposure due to differences in fuel loading, the location of the fuel package in the compartment, increased ventilation, or fire-fighting tactics. For similar reasons, a fire investigator should consider these factors when there is a possibility of multiple origins.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.1.3.1 The size, location, and heat release rate of a fuel package may have as much effect on the extent of damage as the length of time the fuel package was burning. An area of extensive damage may simply mean that there was a significant fuel package at that location. The investigator should consider whether the fire at such a location might have spread there from another location where the fuel load was smaller.

17.4.1.3.2 Fuel packages of identical composition and equal size may burn very differently, depending on their location in a compartment. The possible effect of the location of walls relative to the fire should be considered in interpreting the extent of damage as it relates to fire origin. In making the determination, the possibility that the fuel in the suspected area of origin was not the first material ignited and that the great degree of damage was the result of wall or corner effects should be considered.

17.4.1.4 Ventilation. Ventilation, or lack thereof, during a fire has a significant impact on the heat release rate and consequently on the extent of observable burn damage. The analysis of fire pattern data should, therefore, include consideration that ventilation influenced the production of the pattern. Ventilation-controlled fires tend to burn more intensely near open windows or other vents, thereby producing greater damage. Knowledge of the location and type of fuel is important in fire pattern analysis. During full room involvement conditions, the development of fire patterns is significantly influenced by ventilation. Full room involvement conditions can cause fire patterns that developed during the earlier fuel-controlled phase of the fire to evolve and change. In addition, fires can produce unburned hydrocarbons that can be driven outside the compartment through ventilation openings. This unburned fuel can mix with air and burn on the exterior of the compartment, producing additional fire patterns that indicate the fire spread out of the original compartment. Thus, knowledge of changes in ventilation (e.g., forced ventilation from building systems, window breakage, opening or closing of doors, burn-through of compartment boundaries) is important to understand in the context of fire pattern analysis. Determination of what patterns were produced at the point of origin by the first item ignited usually becomes more difficult as the size and duration of the fire increases. This is especially true if the compartment has achieved full room involvement.

17.4.1.5 Movement and Intensity Patterns. As discussed in Chapter H6H, fire patterns are generated by one of two mechanisms: the spread of the fire or the intensity of burning. As discussed above, fuel composition, rate of heat release, location, and ventilation differences may lead to differences in the intensity patterns that do not necessarily point to the area where the first fuel was ignited. Patterns that arise from the growth and movement (spread) of the fire are invariably better indicators of the area of origin. It may be difficult, however, to distinguish movement patterns from intensity patterns. Further, some patterns display a combination of intensity and movement (spread) indicators.

Source – NFPA 921, Chapter 17, 2008.

Extract

Heat and Flame Vector Analysis. Heat and flame vector analysis, along with accompanying diagram(s), is a tool for fire pattern analysis. Heat and flame vectoring is applied by constructing a diagram of the scene. The diagram should include walls, doorways and doors, windows, and any pertinent furnishings or contents. Then, through the use of arrows, the investigator notes the interpretations of the direction of heat or flame spread based upon the identifiable fire patterns present. The size of the arrows should reflect the scaled magnitude (actual size) of the individual patterns depicted. The arrows can point in the direction of fire travel from the heat source, or point back toward the heat source, as long as the direction of the vectors is consistent throughout the diagram. The investigator should identify each vector as to the respective fire pattern it represents. In a legend accompanying the diagram the investigator may give details of the corresponding fire pattern, such as height above the floor, height of the vertex of the pattern, the nature of the surface upon which the pattern appears, the pattern geometry, the particular fire effect which constitutes the pattern, and the direction(s) of fire spread which the pattern(s) represent. For example, as shown in Figure 17.4.2, Vector #7 represents burn damage on the carpet with decreasing fire damage as one moves northeast, Vector #8 represents comparison of the burn damage differences between the two sides of the chair with the south side displaying more severe damage, and Vector #10 represents a truncated cone pattern with decreasing fire damage and increasing height to the line of demarcation as one moves north.

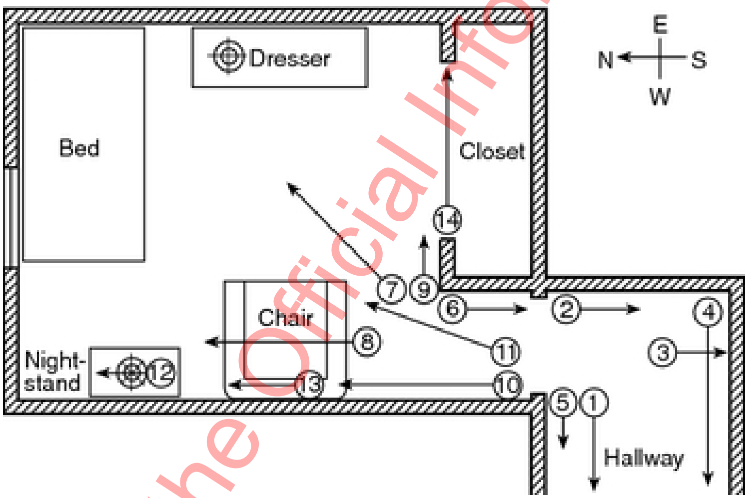


FIGURE 17.4.2 Heat and Vector Analysis Diagram Showing Vectors of the Physical Size and Direction of Heat Travel of the Fire Patterns and Demonstrating a Fire Origin in the Area of Vectors 6, 10, and 11. (Source: Kennedy and Shanley, "USFA Fire Burn Pattern Tests — Program for the Study of Fire Patterns.")

17.4.2.1 Complementary Vectors. Complementary vectors can be considered together to show actual heat and flame spread directions. In that case, the investigator should clearly identify which vectors represent actual fire patterns and which vectors represent heat flow derived from the investigator's analysis of these patterns. An important point to be made regarding this discussion is the terminology heat source and source of heat. These terms are not synonymous with the origin of the fire. Instead, these terms relate to any heat source that creates an identifiable fire pattern. The heat source may or may not be generated by the initial fuel. It is imperative that the use of heat and flame vector analysis be tempered by an accurate understanding of the progress of the fire and basic fire dynamics. A vector diagram can give the investigator an overall viewpoint to analyze. The diagram can also be used to identify any conflicting patterns that need to be explained. The ultimate purpose of the vector analysis is to discuss and graphically document the investigator's interpretation of the fire patterns.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.2.2 Heat Source. A heat source can be any fuel package that creates an identifiable fire pattern. The pattern may or may not be produced by the initial fuel. Consider a fire that spreads into a garage and ignites flammable liquids stored there. The burning liquid represents a new heat source that leaves fire patterns on the garage's surfaces. Therefore, it is imperative that fire pattern analysis be tempered by an accurate understanding of the progress of the fire and basic fire dynamics.

17.4.2.3 Additional Tools for Pattern Visualization. When fire patterns are not visually obvious, a depth of char or depth of calcination survey may help the investigator to locate areas of greater or lesser heat damage and recognized lines of demarcation defining patterns. Survey results should be plotted on a diagram. On such diagrams, the depth of char or calcination measurements are recorded to a convenient scale. Once the depth of char or calcination measurements have been recorded on the diagram, lines can be drawn connecting points of equal, or nearly equal, char or calcination depths. The resulting lines may reveal identifiable patterns. *[See Figure 15.4.2(f).]*

17.4.3 Depth of Char Analysis. Analysis of the depth of charring is most reliable for evaluating fire spread, rather than for the establishment of specific burn times or intensity of heat from adjacent burning materials. By measuring the relative depth and extent of charring, the investigator may be able to determine what portions of a material or construction were exposed the longest to a heat source. The relative depth of char from point to point is the key to appropriate use of charring — locating the places where the damage was most severe due to exposure, ventilation, or fuel placement. The investigator may then deduce the direction of fire spread, with decreasing char depths being farther away from a heat source. Certain key variables affect the validity of depth of char pattern analysis. These factors include the following:

(1) Single versus multiple heat or fuel sources creating the char patterns being measured. Depth of char measurements may be useful in determining more than one fire or heat source.

(2) Comparison of char measurements, which should be done only for identical materials. It would not be valid to compare the depth of char from a wall stud to the depth of char of an adjacent wooden wall panel.

(3) Ventilation factors influencing the rate of burning. Wood can exhibit deeper charring when adjacent to a ventilation source or an opening where hot fire gases can escape.

(4) Consistency of measuring technique and method. Each comparable depth of char measurement should be made with the same tool and same technique. *[See Figure 15.4.2(f).]*

17.4.3.1 Depth of Char Diagram. Lines of demarcation that may not be visually obvious can often be identified for analysis by a process of measuring and charting depths of char on a grid diagram. By drawing lines connecting points of equal char depth (isochars) on the grid diagram, lines of demarcation may be identified.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.3.2 Measuring Depth of Char. Consistency in the method of measuring the depth of char is the key to generating reliable data. Sharp pointed instruments, such as pocket knives, are not suitable for accurate measurements because the sharp end of the knife will have a tendency to cut into the noncharred wood beneath. Thin, blunt-ended probes, such as certain types of calipers, tire tread depth gauges, or specifically modified metal rulers are best. Dial calipers with depth probes of round cross-section, shown in Figure 17.4.3.2(a), are excellent depth of char measurement tools. Figure 17.4.3.2(b) illustrates their use. The same measuring tool should be used for any set of comparable measurements. Consistent pressure for each measurement while inserting the measuring device is also necessary for accurate results.

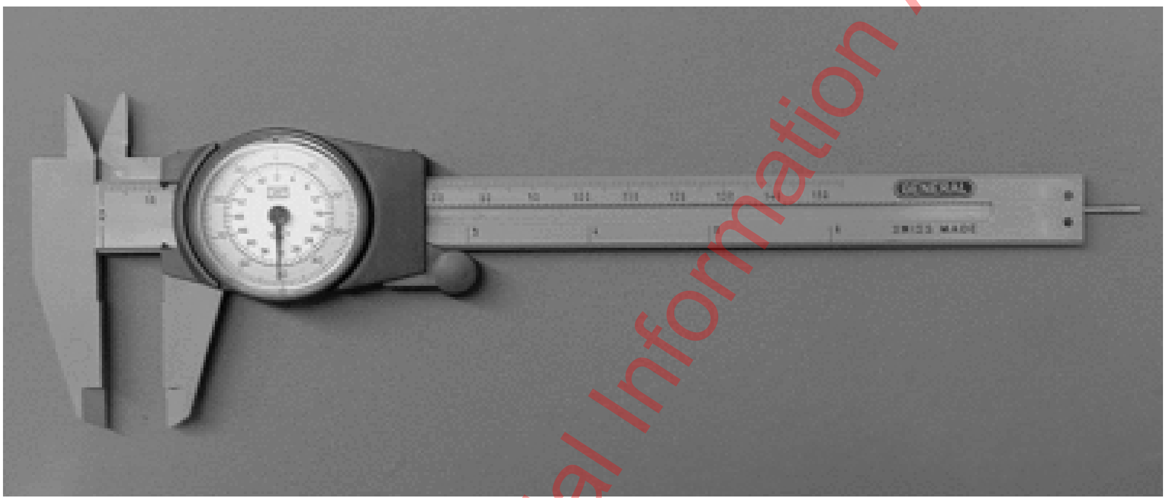


FIGURE 17.4.3.2(a) Dial Calipers with Depth Probes.

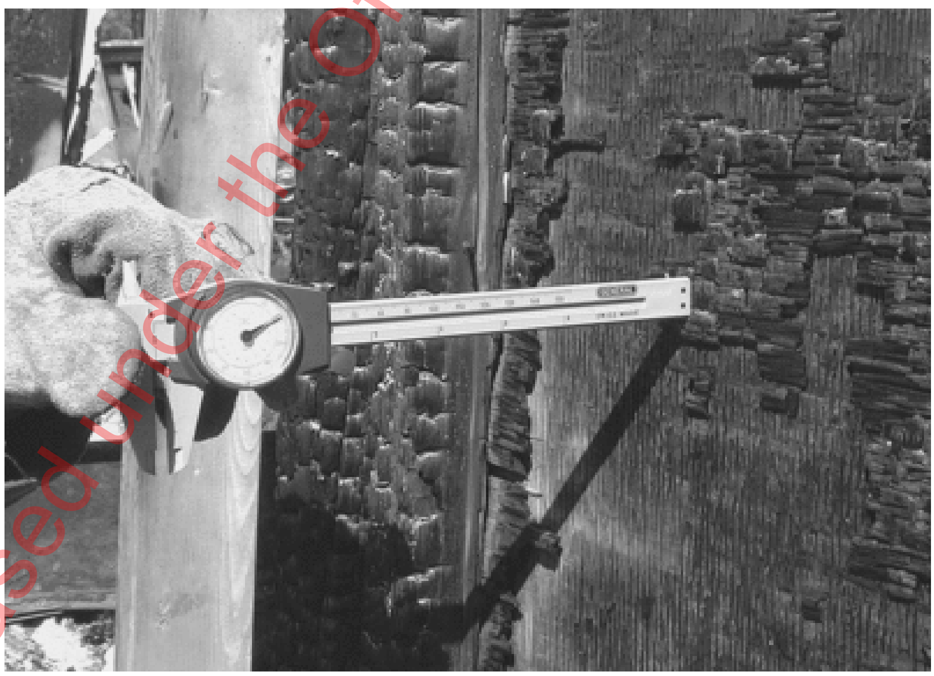


FIGURE 17.4.3.2(b) Using Dial Calipers to Measure Depth of Char.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.3.3 Char depth measurements, illustrated in Figure 17.4.3.3, should be made at the center of char blisters, rather than in or near the crevasses between blisters.

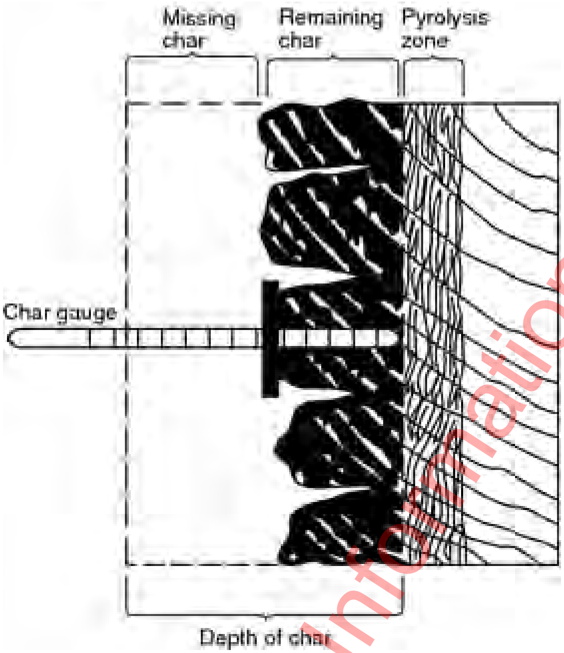


FIGURE 17.4.3.3 Measuring Depth of Char.

17.4.3.4 Missing Wood. When determining the depth of charring, the investigator should take into consideration any burned wood that may have been completely destroyed by the fire and add that missing depth of wood to the overall depth measurement.

17.4.3.5 Depth of Char Surveys with Fuel Gases. When fugitive fuel gases are the initial fuel sources for fires, they produce relatively even depths of char over the often wide areas that they cover. Progressive changes in depth of char that are used by investigators to trace fire spread might exist only in those areas to which the fire spreads from the initial locations of the pocketed fuel gases. Deeper charring might exist in close proximity to the point of gas leakage, as burning might continue there after the original quantity of gas is consumed. This charring may be highly localized because of the pressurized gas jets that can exist at the immediate point of leakage and may assist the investigator in locating the leak.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.4 Depth of Calcination Survey. Relative depth of calcination can indicate differences in total heating of the fire-exposed gypsum wallboard. Deeper calcination readings indicate longer or more intense heating (heat flux), and the higher temperatures that those areas of the wallboard achieved during the fire. Certain key variables affect the validity of depth of calcination analysis. These factors include the following:

(1) Single versus multiple heat or fuel sources, creating the calcination patterns being measured, should be considered. Depth of calcination patterns may be useful in determining multiple heat or fire sources.

(2) Comparisons of depth of calcination measurements should be made only from the same material. It should be recognized that gypsum wallboard comes in different thicknesses, is made of different materials of construction, and changes with time. The investigator should carefully consider sections of walls or ceilings that may have had new sections inserted as a repair.

(3) The finish of the gypsum wallboard (e.g., paint, wallpaper, stucco) should be considered when evaluating depth of calcination. The investigator should recognize that some of these finishes are combustible and may affect the patterns if they are ignited.

(4) Measurements should be made in a consistent fashion to reduce errors in this data collection.

(5) Gypsum wallboard can be damaged during suppression, during overhaul, and post-fire by hose streams and standing water. Wetting of the calcined wallboard can soften the gypsum to the point where no reliable measurements can be made.

17.4.4.1 Depth of Calcination Diagram. A depth of calcination diagram can be produced in the same manner as that for depth of char.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.4.2 Measuring Depth of Calcination. The technique for measuring and analyzing depth of calcination can use a visual observation of cross-sections or a probe survey. The visual method requires careful removal of small, full-thickness sections [minimum approximately 50 mm (2 in.) diameter] of walls or ceilings to observe and measure the thickness of the calcined layer. The probe method requires that a survey of the depth of calcination be undertaken by inserting a small cross-section probe device, such as illustrated in Figure 17.4.4.2(a) and Figure 17.4.4.2(b), and recording the depth at which a relative difference in resistance of the calcined gypsum is felt. When using the probe method the investigator should conduct the survey at regular lateral and vertical grid intervals along the surface of the involved wallboard, usually in increments of 0.3 m (1 ft) or less. Care should be taken to use approximately the same insertion pressure for each measurement. Such surveys can be made on either wall or ceiling installations of wallboard.

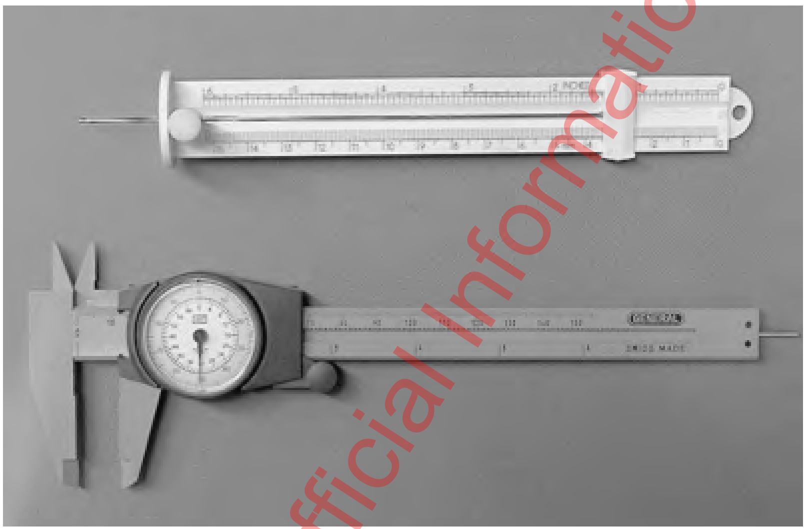


FIGURE 17.4.4.2(a) Two Instruments That Can be Used to Measure the Depth of Calcination.

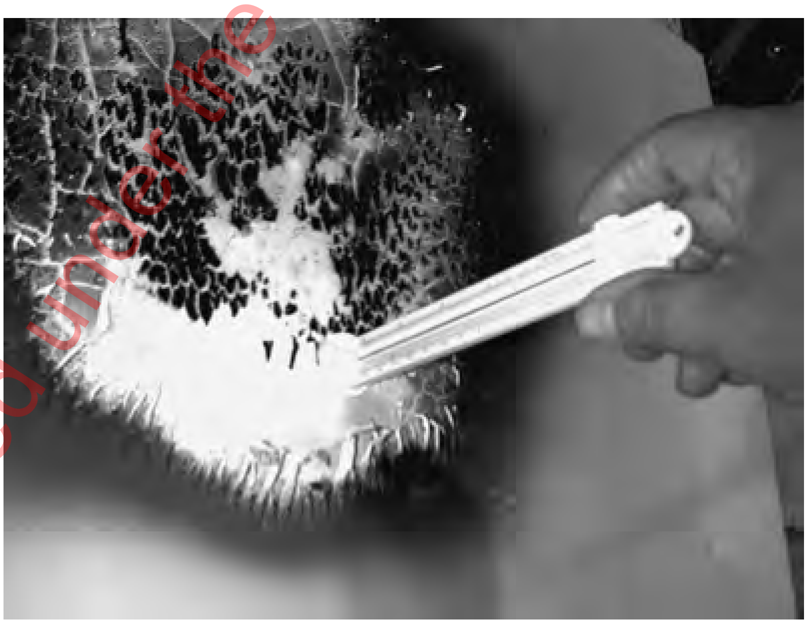


FIGURE 17.4.4.2(b) Measuring Depth of Calcination on a Piece of Gypsum Wallboard.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.5 Arc Surveys or Arc Mapping. Arc surveys (also known as arc mapping) is a technique in which the investigator uses the identification of arc locations or "sites" to aid in determining the area of fire origin. This technique is based on the predictable behavior of energized electrical circuits exposed to a spreading fire. The spatial relationship of the arc sites to the structure and to each other can be a pattern, which can be used in an analysis of the sequence in which the affected parts of the electrical system were compromised. This sequential data can be used in combination with other data to more clearly define the area of origin. There are circumstances, such as complete destruction of the branch circuits, melting of conductors from fire exposure, post-fire re-energizing of the electrical system, or the inability to recognize arc damage on conductors, that make it more difficult or impossible to use this technique. The identification of arc sites in the area of fire origin may help to identify a potential ignition source(s) for consideration. The investigator is cautioned to consider that conductors only pass through certain areas, and therefore, the amount of information available will be limited by the spatial distribution of the conductors available for arcing. Mapping of arcs on conductors that are exposed to the developing fire, such as appliance cords or branch circuit conductors that are in the compartment of the fire, may provide the most useful information. Branch circuits that are located behind some type of thermal barrier, such as gypsum board or plywood, may not provide useful arc mapping information, as the circuit protection may open prior to the fire damaging the conductors located behind ceilings and walls.

17.4.5.1 Suggested Procedure. One procedure to perform an arc survey is as follows:

(1) Identify the area that will be surveyed.
(2) Sketch and diagram the area as completely and accurately as possible.
(3) Identify zones within the survey area, such as ceiling, floor, north wall, south wall, etc.
(4) Identify all conductors of the electrical circuits passing through the zone, noting, when possible, loads on each circuit, direction of power flow (upstream versus downstream), locations of junction boxes, outlets, switches (or any such control), size of each conductor, and the over-current protection size, type, and status.
(5) Select a zone for examination and begin the process of systematically examining each of the conductors in that zone.
(6) Examine and feel each conductor, for the purpose of identifying surface anomalies or damage, such as beads and notches. When it is necessary to remove conductors from conduits, take care to prevent damage to the conductors.
(7) Determine if the surface anomaly occurred from arcing, environmental heat, or eutectic melting (alloying of metals).
(8) Locate the arc site on the sketch and document its physical characteristics (faulted to another conductor in same cable, faulted to conductor from another cable, completely severed conductor, partially severed conductor, faulted to grounded metallic conduit, or a conductive building element).
(9) Flag the location of the arc site(s) with a suitable marking and document such location(s).
(10) Preserve the items as evidence, when warranted.

17.4.5.2 Arc Survey Diagram. The drawing used to plot the arc sites should be as detailed as possible. Precision in sketching the drawing will aid in reducing errors in the subsequent analysis. When setting the boundaries of each zone, keep in mind that some or all of the conductors may be routed through other zones as well. Having a compass or reference direction on the drawing is particularly useful. When analyzing the status of the overcurrent protection device for each circuit, note the type of device such as fuse, circuit breaker, ground fault circuit interrupter (GFCI), or arc fault circuit interrupter (AFCI).

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.5.3 Locating Arc Sites. Typically, examining each conductor can be accomplished by passing the conductor through one's fingertips, feeling the conductor's surface for imperfections or anomalies, either convex or concave. Dragging a cotton ball along the conductor is another way to detect surface imperfections. Once the imperfection is detected, the location is examined visually to assess if the imperfection is the result of conductor metal loss or deposit (indications of possible arc sites), or from some other reason, such as dirt accumulation, oxidation, or charred insulation scale. Search the entire length of the damaged conductor in case there are multiple sites where arcing occurred on the same conductor. Locate each arc site on the plan and elevation drawings as precisely as possible.

17.4.5.3.1 The identification of arc damage is not a simple task. Fire melting of conductors, also called environmental melting, can be difficult to distinguish from melting caused by arcing. The primary distinction between the two is the relative area where the melting is found. Arcing creates highly localized damage where the temperatures exceed the melting point of the conductor metal. Arcing creates complementary damage to adjacent conductors or grounded surfaces. The edges of the melted areas are generally quite distinct. Melting from environmental heating can be relatively widespread and may involve numerous conductors in an area. Chapter H8H provides several photographic examples of the two types of damage. Some locations of melting on the conductors may not indicate what caused the melting. Such locations can be noted on the documentation as possibilities or as unknowns.

17.4.5.3.2 The visibility of arc damage is related to the duration of the arc, as well as the timing of the arc. In alternating current circuits, the potential difference between two conductors depends on the point in the AC cycle when the arc occurs. Circuit breakers or fuses may operate to cut off power in as little as one-half cycle (0.8 ms in 60 cycle circuits, 1.0 ms in 50 cycle circuits). During each typical 120 VAC cycle, the potential between the "hot" conductor and the neutral conductor or ground ranges between +120V and -120V. As the potential approaches 0V, arc damage will tend to become less severe, and therefore less visible.

17.4.5.4 Documenting Arc Sites. To document arc sites, attach visible markers such as colored ribbon, colored cable ties, or tape to the conductors and document using photographs or videotape. Should the need exist to take as evidence the proof of the arc survey, then one can collect the electrical circuits in the structure. Collecting each circuit, both those that arced and those that did not, will be of value, only if the spatial relationship of the circuits is maintained. The relationship in space of the arc sites to those conductors that did not arc, and the individual arc sites, not the fire-damaged conductors taken out of context, are the significant evidence.

17.4.5.5 Arc Survey Evidence Collection. Take care to properly identify, tag, and collect electrical conductors. The conductors are sometimes brittle and can be quite fragile. Handling may result in fractures, which make labeling and tagging much more tedious. Attachments to the conductors, such as junction box remains, may become loose and fall away, which can potentially prevent any future circuit tracing.

17.4.5.6 Arc Survey Utilization. The utility of arc mapping is primarily the analysis of the data to determine the sequence of events, but it should be noted that arc mapping can be useful in both formulating and testing hypotheses. Clearly, if a conductor is arc-severed, it can be correctly concluded that any arcing events electrically downstream of the arc-severed point happened before the severance. Exceptions to this rule exist when the conductors are back-fed through a pre-fire wiring error, uninterruptible power supply (UPS) systems, or generators. Further, if an area is hypothesized as the origin of a fire, then, in the absence of contrary evidence, one would expect that the origin area would be one of the first areas where the electrical system was compromised.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.4.6 Analysis of Sequential Events. The analysis of the timing or sequence of events during a fire can be useful in determining the origin. Much of the data for this analysis will come from witnesses. In some instances, a witness may be found who saw the fire in its incipient stage and can provide the investigator with an area of fire origin. Such circumstances create a burden on the fire investigator to conduct as thorough an investigation as possible to find facts that can support or refute the witness's statements. Means to verify such statements could include patterns analysis, arc mapping, or matching smoke detector, heat detector, and security detector activation times with the witness's observations. This analysis can identify gaps or inconsistencies in information, assist in developing questions for additional witness interviews, and provide support in the analysis and reconstruction of the progression of the fire. A more detailed discussion of time lines is included in Section 20.2.

17.4.7 Fire Dynamics. Fundamentals of fire dynamics can be used to analyze the data to aid in the development of origin hypotheses and to complement other origin determination techniques. Such analyses can help in the identification of potential fuels that may have been the first item to ignite, the sequence of subsequent fuel involvement, the recognition of other data that may need to be collected, the analysis of fire patterns, and the identification of potential competent ignition sources.

17.5 Developing an Origin Hypothesis.

Based on the data analysis, the investigator should now produce a hypothesis or group of hypotheses to explain the origin and development of the fire. This hypothesis should be based solely on the empirical data that the investigator has collected. It is understood that when using the scientific method, an investigator may continuously be engaged in data collection, data analysis, hypothesis development, and hypothesis testing. An investigator may develop an origin hypothesis early in the investigative process, but when the process is completed, regardless of the order of steps followed, the investigator should be able to describe how those steps conform to the scientific method. Figure 17.2 shows how the procedures set forth in this chapter follow the scientific method.

17.5.1 Initial Hypothesis. The initial origin hypothesis is developed by considering witness observations, by conducting an initial scene assessment, and by attempting to explain the fire's movement through the structure. This process is accomplished using the methods described in earlier sections of this chapter. The initial hypothesis allows the investigator to organize and plan the remainder of the origin investigation. The development of the initial hypothesis is a critical point in the investigation. It is important at this stage that the investigator attempt to identify other feasible origins, and to keep all reasonable origin hypotheses under consideration until sufficient evidence is developed to justify discarding them.

17.5.2 Modifying the Initial Hypothesis. The investigation should not be planned solely to prove the initial hypothesis. It is important to maintain an open mind. The investigative effort may cause the initial hypothesis to change many times before the investigation is complete. The investigator should continue to reevaluate potential areas of origin by considering the additional data accumulated as the investigation progresses.

17.6 Testing of Origin Hypotheses.

In order to conform to the scientific method, once a hypothesis is developed, the investigator must test it using deductive reasoning. A test using deductive reasoning is based on the premise that *if* the hypothesis is true, *then* the fire scene should exhibit certain characteristics, assuming that the fire did not subsequently obliterate those characteristics. For example, if a witness stated that a specific door was closed during the fire, then there should be a protected area on the door jamb, which would tend to prove the hypothesis that the door was closed. *(See Chapter 4 and Appendix A.4.3.6.)*

Source – NFPA 921, Chapter 17, 2008.

Extract

17.6.1 Means of Hypothesis Testing. During the investigation, the investigator may develop and test many hypotheses about the progress of the fire. For example, the investigator often has to determine whether a door or window was open or closed. Ultimately, the origin determination is arrived at through the testing of origin hypotheses. A technically valid origin determination is one that is consistent with the available data. In testing the hypothesis, the questions addressed in 17.6.1.1 through 17.6.1.3 should be answered.

17.6.1.1 Is there a competent ignition source at the hypothetical origin? The lack of a competent ignition source at the hypothesized origin should make the hypothesis subject to increased scrutiny. Investigators should be wary of the trap of circular logic. While the cause of the fire was at one time necessarily located at the point of origin, the investigator who eliminates a potential ignition source because it is "not in the area of the hypothesized origin," needs to be especially diligent in testing the origin hypothesis and in considering alternate hypotheses. *(See Section 18.2.)* This is particularly true in cases of full room involvement. Unless there is reliable evidence to narrow the origin to a particular portion of the room, every potential ignition source in the compartment of origin should be given consideration as a possible cause.

17.6.1.2 Can a fire starting at the hypothetical origin result in the observed damage? The investigator should be cautious about deciding on an origin just because a readily ignitible fuel and potential ignition source are present. The sequence of events that bring the ignition source and the fuel together and cause the observed damage indicates the origin, and ultimately the cause. The hypothetical origin should not only account for physical damage to the structure and contents, but also for the exposure of occupants to the fire environment.

17.6.1.3 Is the growth and development of a fire starting at the hypothetical origin consistent with available data at a specific point(s) in time? Few data are more damaging to an origin hypothesis than a contradictory observation by a credible eyewitness. Any data can be contradictory to the ultimate hypothesis. The data must be taken as a whole in considering the hypothesis, with each piece of data being analyzed for its reliability and value. Ultimately, the investigator should be able to explain how the growth and development of a fire, starting at the hypothesized origin, is consistent with the data.

17.6.2 Analytical Techniques and Tools. Analysis techniques and tools are available to test origin hypotheses. Using such tools and techniques to analyze the dynamics of the fire can provide an understanding of the fire that can enhance the technical basis for origin determinations. Such analyses can also identify gaps or inconsistencies in the data. The utility of fire dynamics tools is not limited to hypothesis testing. They may also be used for data analysis and hypothesis development. Techniques and tools include time line analysis, fire dynamics analysis, and experimentation.

17.6.2.1 Time Line Analysis. Time lines are an investigative tool that can show relationships between events and conditions associated with the fire. These events and conditions are generally time-dependent, and thus, the sequence of events can be used for testing origin hypotheses. Relevant events and conditions include ignition of additional fuel packages, changes in ventilation, activation of heat and smoke detectors, flashover, window breakage, and fire spread to adjacent compartments. Much of this information will come from witnesses. Fire dynamics analytical tools *(see 20.4.8)* can be used to estimate time-dependent events and fire conditions. A more detailed discussion of time lines is included in Section 20.2.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.6.2.2 Fire Modeling. Fundamentals of fire dynamics can be used to test hypotheses regarding fire origin. Such fundamentals are described in the available scientific literature and are incorporated into fire models ranging from simple algebraic equations to more complex computer fire models *(see Section 20.4.8)*. The models use incident-specific data to predict the fire environment given a proposed hypothesis. The results can be compared to physical and eyewitness evidence to test the origin hypothesis. Models can address issues related to fire development, spread, and occupant exposure.

17.6.2.3 Experimental Testing. Experiments can be conducted to test the hypothesized origin. If the experimental results match the damage at the scene, the experiment can be said to support the hypothesis. If the experiment produces different results, a new origin hypothesis or additional data may need to be considered, taking into account potential differences between testing and actual fire conditions. The following is an example of such an experiment. The hypothesized origin is a wicker basket located in the corner of a wood-paneled room. The data from the actual fire shows the partial remains of the basket, undamaged carpet in the corner, and wood paneling still intact in the corner. A fire test replicating the hypothesized origin totally consumes the carpet, the wicker basket, and the wood paneling. Thus (assuming the test replicated the pre-fire conditions), testing revealed that this hypothesized origin is inconsistent with the damage that would be expected from such a fire.

17.7 Selecting the Final Hypothesis.

Once the hypotheses regarding the origin of the fire have been tested, the investigator should review the entire process, to ensure that all credible data are accounted for and all credible alternate origin hypotheses have been considered and eliminated. When using the scientific method, the failure to consider alternate hypotheses is a serious error. A critical question to be answered by fire investigators is, “Are there any other origin hypotheses that are consistent with the data?” The investigator should document the facts that support the origin determination to the exclusion of all other potential origins.

17.7.1 Defining the Area of Origin. Although *area of origin* is common terminology used to describe the origin, the investigator should describe it in terms of the three-dimensional space where the fire began, including the boundaries of that space.

17.7.2 Inconsistent Data. It is unusual for a hypothesis to be totally consistent with all of the data. Each piece of data should be analyzed for its reliability and value — not all data in an analysis has the same value. Frequently, some fire pattern or witness statement will provide data that appears to be inconsistent. Contradictory data should be recognized and resolved. Incomplete data may make this difficult or impossible. If resolution is not possible, then the origin hypothesis should be re-evaluated.

17.7.3 Case File Review. Other investigators can assist in the evaluation of the origin hypothesis. An investigator should be able to provide the data and analyses to another investigator, who should be able to reach the same conclusion as to the origin. Review by other investigators is almost certain to happen in any significant fire case. Differences in opinions may arise from the weight given to certain data by different investigators or the application of differing theoretical explanations (fire dynamics) to the underlying facts in a particular case.

Source – NFPA 921, Chapter 17, 2008.

Extract

17.8 Origin Insufficiently Defined.
There are occasions when it is not possible to form a testable hypothesis defining an area that is useful for identifying potential causes. The goal of origin investigation is to identify the precise location where the fire began. In practice, the investigator has an origin hypothesis when first arriving at a fire scene. The origin is the scene. Sometimes, it is not possible to find an area or volume that is any smaller than the entire scene. Thus, a conclusion of the origin investigation can be the identification of a volume of space too large to identify causal factors, or where no practical boundaries can be established around the volume of the origin. An example of such an origin can be a building that has been totally burned, with no eyewitnesses. Such fires are sometimes called total burns. The area of origin is the building, but in reality no further testable origin hypothesis can be developed because there is insufficient reliable data.

17.8.1 Large Area Adequate for Determination. There are cases in which a lack of an origin determination does not necessarily hinder the investigation. An example is a case in which a fire resulted from the ignition of fuel gas vapors inside a structure. The resulting damage may preclude the defining of the location where the fuel combined with the ignition source. However, probable ignition sources may still be hypothesized.

17.8.2 Justification of a Large Area of Origin. The origin analysis should identify the data that justify the conclusion that the area of fire origin cannot be reduced to a practical size. Examples of such data could include establishing the fact that there were no significant patterns to trace, that most or all combustible materials were consumed, or that other methods of origin determination were attempted but no reasonable conclusion could be established.

17.8.3 Eyewitness Evidence of Origin Area. If the origin is too large to be useful, then the determination of the fire’s cause may become very difficult, or impossible. In some instances, where no further testable origin hypothesis can be developed by examination of the scene alone, a witness may be found who saw the fire in its incipient stage and can provide the investigator with an area of fire origin.

Source – NFPA 921, Chapter 17, 2008.

NFPA 921, Chapter 6 – Fire Patterns

Extract

6.1 Introduction.

6.1.1 The major objective of any fire scene examination is to collect data as required by the scientific method (*see 4.3.3*). Such data include the patterns produced by the fire. A fire pattern is the visible or measurable physical changes or identifiable shapes formed by a fire effect or group of fire effects. Fire effects are the observable or measurable changes in or on a material as a result of exposure to the fire. The collection of fire scene data requires the recognition and identification of fire effects and fire patterns. The data can also be used for fire pattern analysis (i.e., the process of interpreting fire patterns to determine how the patterns were created). This data and analysis can be used to test hypotheses as to the origin of the fire as discussed in Chapter H17H. The purpose of the discussion in this chapter is to aid the investigator in the recognition and identification of fire effects and fire patterns as well as the interpretation of patterns through fire pattern analysis.

6.2 Fire Effects.

6.2.1 To identify fire patterns, the investigator must recognize the changes that have occurred in materials due to fire. These changes are referred to as fire effects, which are the observable or measurable changes in or on a material as the result of a fire.

6.2.2 Temperature Estimation Using Fire Effects. If the investigator knows the approximate temperature required to produce an effect, such as melting, color change, or deformation a material, an estimate can be made of the temperature to which the material was raised. This knowledge may assist in evaluating the intensity and duration of the heating, the extent of heat flow, or the relative rates of heat release from fuels.

6.2.2.1 When using materials such as glass, plastics, and white pot metals for estimating temperature, the investigator is cautioned that there is a wide variety of material properties for these generic materials. The best method for utilizing such materials as temperature indicators is to take a sample of the material and have its properties ascertained by a competent laboratory, materials scientist, or metallurgist.

6.2.2.2 Wood and gasoline burn at essentially the same flame temperature. The turbulent diffusion flame temperatures of all hydrocarbon fuels (plastics and ignitible liquids) and cellulosic fuels are approximately the same, although the fuels release heat at different rates. Burning metals and highly exothermic chemical reactions can produce temperatures significantly higher than those created by hydrocarbon- or cellulosic-fueled fires.

6.2.2.3 Heat transfer is responsible for much of the physical evidence used by fire investigators. The temperature achieved by a material at a specific location within a structure depends on the amount of heat energy transferred to the material. As discussed in Section 5.5, heat energy is transferred by three modes: conduction, convection, and radiation. All three modes can contribute to a change in the temperature of a specific material in a fire. The temperature achieved will depend on the individual contribution from each mode of heat transfer. The individual contribution associated with each mode is dependant on the variables discussed in Section 5.5.

Source – NFPA 921, Chapter 6, 2008.

Extract

6.2.2.4 Identifiable temperatures achieved in structural fires rarely remain above 1040°C (1900°F) for long periods of time. These identifiable temperatures are sometimes called *effective fire temperatures*, because they reflect physical effects that can be defined by specific temperature ranges. The investigator can use the analysis of the melted materials to assist in establishing the minimum temperatures present in specific areas.

6.2.3 Mass Loss of Material.

6.2.3.1 Fires convert fuel and oxygen into combustion products, heat, and light. This process results in mass loss of the fuel (consumption of the material). During a fire, combustible and noncombustible materials may also lose mass due to evaporation, calcination, or sublimation.

6.2.3.2 The mass loss of a material consumed in a fire may be determined by comparing fire-damaged materials to exemplar materials. The edges or surfaces of remaining material may be used to estimate the size and shape of the material before the fire. Materials existing prior to a fire may be determined from duplicate or similar materials not consumed by the fire or from drawings, plans, photographs, or interviews with individuals familiar with conditions prior to the fire.

6.2.3.3 The mass loss of material is often used as an indication of the duration and intensity of the fire. While this may be valid in many instances, it is not valid in all cases. The mass loss rate results from a complex combination of factors involving material properties and fire conditions.

6.2.3.4 The rate of mass loss normally changes throughout the course of a fire. The rate of mass loss is generally dependent on the heat flux to the material surface, fire growth rate, and rate of heat release of the material itself. As the fire grows in size and intensity, the rate of mass loss increases.

6.2.4 Char.

6.2.4.1 Introduction. Charred material is likely to be found in nearly all structural fires. When exposed to elevated temperatures, wood undergoes pyrolysis, a chemical decomposition that drives off gases, water vapor, and various pyrolysis products as smoke. The solid residue that remains is mainly carbon. Char shrinks as it forms, and develops cracks and blisters.

6.2.4.2 Surface Effect of Char. Many surfaces are decomposed in the heat of a fire. The binder in paint will char and darken the color of the painted surface. Wallpaper and the paper surface of gypsum wallboard will char when heated. Vinyl and other plastic surfaces on walls, floors, tables, or counters also will discolor, melt, or char. Wood surfaces will char, but, because of the greater prevalence of wood char, it is treated in further detail in 6.2.4.5. The degree of discoloration and charring can be compared to adjacent areas to find the areas of greatest burning.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.4.3 Appearance of Char. In the past, the appearance of the char and cracks had been given meaning by the fire investigation community beyond what has been substantiated by controlled testing. The presence of large shiny blisters (alligator char) is not evidence that a liquid accelerant was present during the fire, or that a fire spread rapidly or burned with greater intensity. These types of blisters can be found in many different types of fires. There is no justification for the inference that the appearance of large, curved blisters is an indicator of an accelerated fire. Figure 6.2.4.3, showing boards exposed to the same fire, illustrates the variability of char blister.

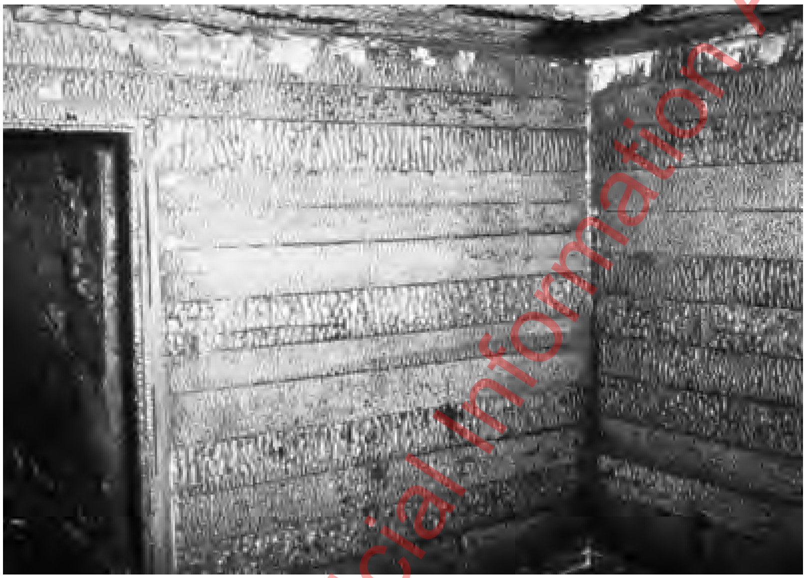


FIGURE 6.2.4.3 Variability of Char Blister.

6.2.4.3.1 It is sometimes claimed that the surface appearance of the char, such as dullness, shininess, colors, or appearance under ultraviolet light sources, has some relation to the use of a hydrocarbon accelerant or the rate of fire growth. There is no scientific evidence that such a correlation exists, and the investigator is advised not to claim indications of accelerant or a rapid fire growth rate on the basis of the appearance of the char.

6.2.4.4 Rate of Wood Charring. The correlation of 2.54 cm (1 in.) in 45 minutes for the rate of charring of wood is based on ventilation-limited burning. Fires may burn with more or less intensity during the course of an uncontrolled fire than in a controlled laboratory fire. Laboratory char rates from exposure to heat from one side vary from 1 cm (0.4 in.) per hour to 25.4 cm (10 in.) per hour. Care needs to be exercised in solely using depth of char measurements to determine the duration of burning. A more in-depth discussion of the appropriate use of depth of char measurements appears in Chapter H17H.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.4.4.1 The rate of charring of wood varies widely depending upon variables, including the following:

(1) Rate and duration of heating
(2) Ventilation effects
(3) Surface area-to-mass ratio
(4) Direction, orientation, and size of wood grain
(5) Species of wood (pine, oak, fir, etc.)
(6) Wood density
(7) Moisture content
(8) Nature of surface coating
(9) Oxygen concentration of the hot gases
(10) Velocity of the impinging gases
(11) Gaps/cracks/crevices and edge effect of materials

6.2.4.4.2 The rate of charring and burning of wood in general has no relation to its age once the wood has been dried. Wood tends to gain or lose moisture according to the ambient temperature and humidity. Thus, old, dry wood is no more combustible than new kiln-dried wood if they have both been exposed to the same atmospheric conditions.

6.2.4.4.3 The investigator is cautioned that no specific time of burning can be determined based solely on depth of char.

6.2.4.5 Depth of Char. Analysis of the depth of charring is more reliable for evaluating fire spread, rather than for the establishment of specific burn times or intensity of heat from adjacent burning materials. The relative depth of char from point to point is the key to appropriate use of charring, locating the places where the damage was most severe due to exposure, ventilation, or fuel placement. The investigator may then deduce the direction of fire spread, with decreasing char depths being farther away from the heat source.

6.2.4.6 Nature of Char. Overall, the use of the nature of char to make determinations about fuels involved in a fire should be done with careful consideration of all the variables that can affect the speed and severity of burning.

6.2.5 Spalling. Spalling is characterized by the loss of surface material resulting in cracking, breaking, and chipping or in the formation of craters on concrete, masonry, rock, or brick.

Source – NFPA 921, Chapter 6, 2008.

Extract

6.2.5.1 Fire-Related Spalling. Fire-related spalling is the breakdown in surface tensile strength of material caused by changes in temperature resulting in mechanical forces within the material. These forces are believed to result from one or more of the following *(see Figure 6.2.5.1)*:

(1) Moisture present in uncured or "green" concrete
(2) Differential expansion between reinforcing rods or steel mesh and the surrounding concrete
(3) Differential expansion between the concrete mix and the aggregate (most common with silicon aggregates)
(4) Differential expansion between the fire-exposed surface and the interior of the slab

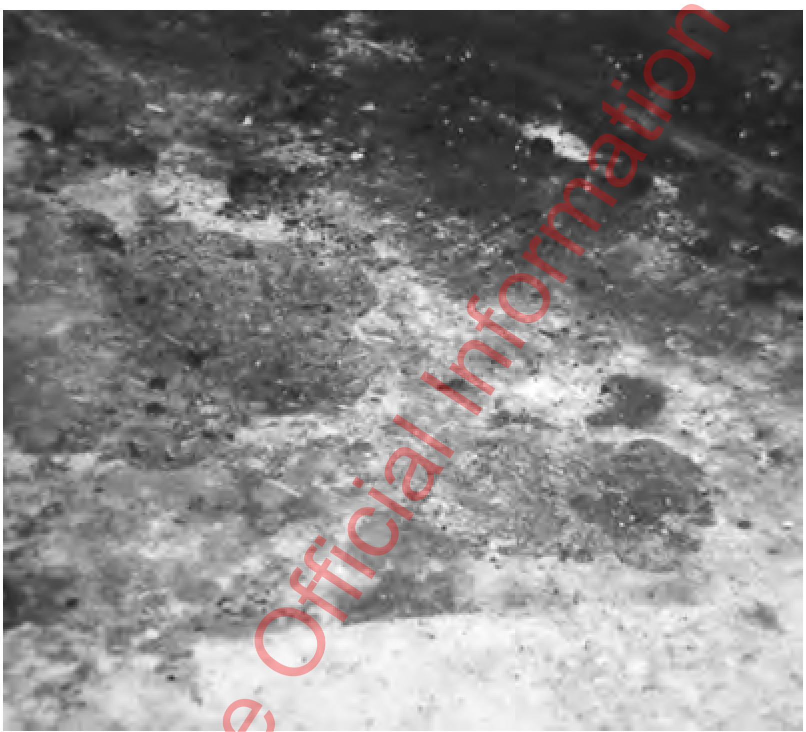


FIGURE 6.2.5.1 Spalled Concrete Floor.

6.2.5.1.1 A mechanism of spalling is the expansion or contraction of the surface while the rest of the mass expands or contracts at a different rate; one example is the rapid cooling of a heated material by water.

6.2.5.1.2 Spalled areas may appear lighter in color than adjacent areas. This lightening can be caused by exposure of clean subsurface material. Adjacent areas may also tend to be darkened by smoke deposition.

Source – NFPA 921, Chapter 6, 2008.

Extract

6.2.5.1.3 Another factor in the spalling of concrete is the loading and stress in the material at the time of the fire. Because these high-stress or high-load areas may not be related to the fire location, spalling of concrete on the underside of ceilings or beams may not be directly over the origin of the fire. *(See Figure 6.2.5.1.3.)*

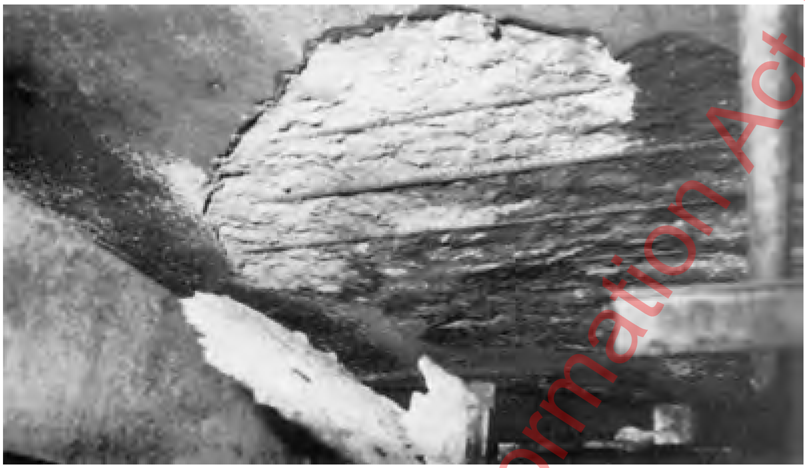


FIGURE 6.2.5.1.3 Spalling on Ceiling.

6.2.5.2 The presence or absence of spalling at a fire scene should not, in and of itself, be construed as an indicator of the presence or absence of liquid fuel accelerant. The presence of ignitible liquids will not normally cause spalling beneath the surface of the liquid. Rapid and intense heat development from an ignitible liquid fire may cause spalling on adjacent surfaces, or a resultant fire may cause spalling on the surface after the ignitible liquid burns away.

6.2.5.3 Non-Fire-Related Spalling. Spalling of concrete or masonry surfaces may be caused by many factors, including heat, freezing, chemicals, abrasions, mechanical movement, shock, force, or fatigue. Spalling may be more readily induced in poorly formulated or finished surfaces. Because spalling can occur from sources other than fires, the investigator should determine whether spalling was present prior to the fire.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.6 Oxidation. Oxidation is the basic chemical process associated with combustion. Oxidation of some non-combustible materials can produce lines of demarcation and fire patterns of use to fire investigators. For these purposes, oxidation may be defined as a combination of oxygen with substances such as metals, rock, or soil that is brought about by high temperatures. Deposition of smoke aerosols containing acidic components may lead to the oxidation of material surfaces and discernible fire patterns. Surfaces may also be oxidized due to deposition of fire suppression agents such as dry or wet chemicals. *(See 6.2.10.)*

6.2.6.1 The effects of oxidation include change of color and change of texture. The higher the temperature and the longer the time of exposure, the more pronounced the effects of oxidation will be. The extent of post-fire oxidation will be a function of the ambient humidity and exposure time.

6.2.6.2 With mild heating, bare galvanized steel may acquire a dull whitish surface due to oxidation of the zinc coating. This oxidation may also eliminate the corrosion protection that the zinc provided. If the unprotected steel is wet for some time, it will rust, which is another form of oxidation. Thus, there can be a pattern of rust compared to non-rusted galvanized steel.

6.2.6.3 When uncoated iron or steel is oxidized in a fire, the surface first acquires a blue-gray dullness. At elevated temperatures, iron may also combine with oxygen to form black oxides. Oxidation can produce thick layers of oxide that can flake off. After the fire, if the metal has been wet, the usual rust-colored oxide may appear.

6.2.6.4 Heavily oxidized steel may exhibit a visual appearance similar to melting. It is frequently not possible to determine by visual observation alone whether the steel has melted. A metallurgical examination of a polished, etched cross-section of the steel is necessary to make a determination of melted steel.

6.2.6.5 On stainless steel surfaces, mild oxidation can result in color fringes, and severe oxidation will produce a dull gray color.

6.2.6.6 Copper forms a dark red or black oxide when exposed to heat. The color is not significant. What is significant is that the oxidation can form a line of demarcation. The thickness of the oxide depends upon the duration and intensity of the heat exposure. The more it is heated, the greater the oxidation.

6.2.6.7 Rocks and soil, when heated to very high temperatures, will often change colors that may range from yellowish to red.

6.2.7 Color Changes. Color changes are a source of information pertaining to the exposure of materials to various temperatures. The above sections have already addressed color changes in a number of specific materials. This section addresses generic color changes applicable to many other materials. Materials have a certain color due to the absorption, reflection, or transmission of light.

6.2.7.1 Color is a subjective quality unless quantitatively measured. People perceive and describe color differently. The intensity, color, and angle of the light source affect the viewer's interpretation of the color of the object. The surface characteristics of the material impact the viewer's color perception. For example, a dark blue car under some lighting conditions may appear black.

Source – NFPA 921, Chapter 17, 2008.

Extract

6.2.7.2 Color changes in general can be brought about by many non-fire factors. When first examining perceived color change evidence, the investigator should consider pre- and post-fire factors as varied as sun or chemical exposures. These exposures may cause dyes and color additives to undergo chemical changes that alter their original color.

6.2.7.3 Material deposited on a translucent surface, such as glass, may exhibit a different color than the same material deposited on an opaque surface. This effect can be observed directly by holding a film negative against a wall, where it may look dark or even black, but the same negative held over a light source will then be observed as lighter and having a visible image.

6.2.7.4 Fabric dyes may be subject to color changes after exposure to a fire. Fabrics may show variations of color from the burned area to a completely unburned area. While the color change is generally related to the heat exposure, without a detailed understanding of the dye breakdown behavior it is difficult to quantify the observation.

6.2.8 Melting of Materials.

6.2.8.1 General. The melting of a material is a physical change caused by exposure to heat. The border between the melted and non-melted portions of a fusible material can produce lines of heat and temperature demarcation that the investigator can use to define fire patterns.

6.2.8.2 Many solid materials soften or melt at elevated temperatures ranging from a little over room temperature to thousands of degrees. A specific melting temperature or range is characteristic for each material. *(See Table 6.2.8.2.)*

Source – NFPA 921, Chapter 17, 2008.

Extract

Table 6.2.8.2 Approximate Melting Temperatures of Common Materials

	Melting Temperatures	
Material	**°C**	**°F**
Aluminum (alloys)[a]	566–650	1050–1200
Aluminum[b]	660	1220
Brass (red)[a]	996	1825
Brass (yellow)[a]	932	1710
Bronze (aluminum)[a]	982	1800
Cast iron (gray)[b]	1350–1400	2460–2550
Cast iron (white)[b]	1050–1100	1920–2010
Chromium[b]	1845	3350
Copper[b]	1082	1981
Fire brick (insulating)[b]	1638–1650	2980–3000
Glass[b]	593–1427	1100–2600
Gold[b]	1063	1945
Iron[b]	1540	2802
Lead[b]	327	621
Magnesium (AZ31B alloy)[a]	627	1160
Nickel[b]	1455	2651
Paraffin[b]	54	129
Plastics (thermo)		
ABS[d]	88–125	190–257
Acrylic[d]	90–105	194–221
Nylon[d]	176–265	349–509
Polyethylene[d]	122–135	251–275
Polystyrene[d]	120–160	248–320
Polyvinylchloride[d]	75–105	167–221
Platinum[b]	1773	3224
Porcelain[b]	1550	2820

Table continued on the next page

Source – NFPA 921, Chapter 17, 2008.

Extract

Table 6.2.8.2 continued

Pot metal[e]	300–400	562–752
Quartz (SiO_2)[b]	1682–1700	3060–3090
Silver[b]	960	1760
Solder (tin)[b]	135–177	275–350
Steel (carbon)[a]	1516	2760
Steel (stainless)[a]	1427	2600
Tin[b]	232	449
Wax (paraffin)[c]	49–75	120–167
White pot metal[e]	300–400	562–752
Zinc[b]	375	707

[a]From Lide, ed., *Handbook of Chemistry and Physics.*
[b]From Baumeister, Avallone, and Baumeister III, *Mark's Standard Handbook for Mechanical Engineers.*
[c]From NFPA *Fire Protection Guide to Hazardous Materials.*
[d]From McGraw-Hill, *Plastics Handbook.*
[e]From Gieck and Gieck, *Engineering Formulas.*

6.2.8.3 Melting temperatures of common metals range from as low as 170°C (338°F) for solder to as high as 1460°C (2660°F) for steel. When the metals or their residues are found in fire debris, some inferences concerning the temperatures in the fire can be drawn.

6.2.8.4 Thermoplastics soften and melt over a range of relatively low temperatures, from around 75°C (167°F) to near 400°C (750°F). Thus, the melting of plastics can give information on temperatures, but mainly where there have been hot gases and little or no flame in that immediate area. *(See Figure 6.2.8.4.)*

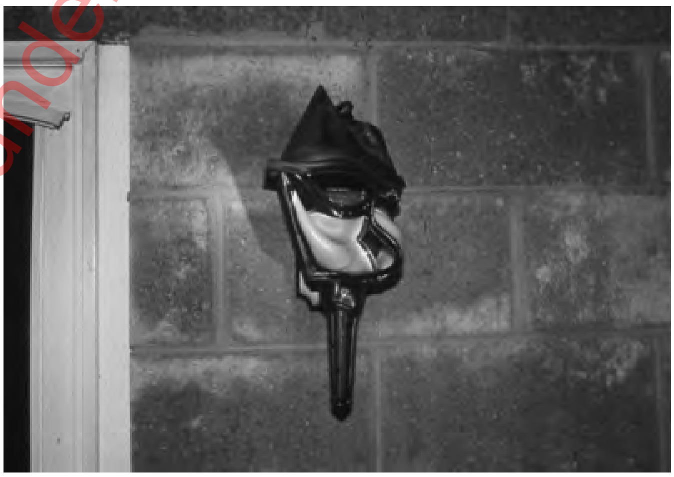


FIGURE 6.2.8.4 Melted Plastic Lighting Fixture, Indicating Heating from Right to Left.

Source – NFPA 921, Chapter 17, 2008.

Extract

6.2.8.5 Glass softens over a range of temperatures. Nevertheless, glass can give useful information on temperatures during a fire.

6.2.8.6 Alloying of Metals. Alloying should be considered when analyzing post-fire metal specimens. The melting of certain metals may not always be caused by fire temperatures higher than the metals' stated melting point; it may be caused by alloying. Alloying refers to the mixing of, generally, two or more metals in which one or more of the metals is in a liquefied state, resulting in an alloy. Metals such as copper and iron (steel) can be affected by alloying with lower melting point metals such as aluminum, zinc, and lead. *(See Table 6.2.8.2.)*

6.2.8.6.1 During a fire, a metal with a relatively low melting point can soften or liquefy and contact other metals with melting temperatures that exceed the temperatures achieved. If a lower-melting-temperature metal, such as zinc, contacts the surface of a higher-melting-temperature metal, such as copper, the two metals can combine to create a zinc-copper alloy (a brass) with an alloy melting temperature lower than copper. In such instances, it is often possible to see the yellow-colored brass.

6.2.8.6.2 The resultant alloy will have a melting point that is less than the higher melting point component in the mixture. In some cases, the alloy can have a melting temperature less than either metal component.

6.2.8.6.3 When metals with high melting temperatures are found to have melted due to alloying, it is not an indication that accelerants or unusually high temperatures were present in the fire.

6.2.9 Thermal Expansion and Deformation of Materials. Many materials change shape temporarily or permanently during fires. Nearly all materials expand when heated. That expansion can affect the integrity of solid structures when they are made from different materials. If one material expands more than another material in a structure, the difference in expansion can cause the structure to fail. Deformation is the change in shape characteristics of an object separate from the other changing characteristics defined elsewhere in this chapter. Deformation can result from a variety of causes ranging from thermal effects to chemical and mechanical effects. In order to make determinations about heat flow based upon deformation, the investigator should determine that the deformation occurred as a result of the fire and is not due to some other cause of deformation.

6.2.9.1 Bending and buckling (deformation) of steel beams and columns occurs when the steel temperature exceeds approximately 538°C (1000°F). At elevated temperatures, steel exhibits a progressive loss of strength. When there is a greater fire exposure, the load required to cause deformation is reduced. Deformation is not the result of melting. A deformed element is not one that has melted during the fire, and therefore the occurrence of such deformation does not indicate that the material was heated above its melting temperature. On the contrary, a deformed as opposed to melted item indicates that the material's temperature did not exceed its melting point. Thermal expansion can also be a factor in the bending of the beam, if the ends of the beam are restrained. *(See Figure 6.2.9.1.)*

Source – NFPA 921, Chapter 6, 2008.

Extract

FIGURE 6.2.9.1 Steel I-Beam Girders Deformed by Heating Under Load.

6.2.9.2 Metal Construction Elements. Studs, beams, columns, and the construction components that are made of high-melting-point metal, such as steel, can be distorted by heating. The higher the coefficient of thermal expansion of the metal, the more prone it is to heat distortion. The amount and location of distortion in a particular metal construction can indicate which areas were heated to higher temperatures or for longer times. In some cases, elongation of beams can result in damage to walls, as shown in Figure 6.2.9.2. This photo demonstrates that the beam inside the basement during the fire was heated above normal ambient temperatures, which led to expansion of the beam. The increased length of the beam pushed out the bricks, causing the wall damage. After the fire, when the beam had cooled, it may have returned to its approximate pre-fire length, but the structural damage to the wall remained as observable evidence of the beam expansion.

FIGURE 6.2.9.2 Damage to an Outside Brick Wall Caused by Thermal Expansion of an I-Beam in the Basement.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.9.3 Piping systems and, specifically, fittings on piping systems may undergo deformation during a fire. These deformations can often be seen as one-way deformations where a fitting, even after complete cooling, does not return to its original shape and dimensions. For example, post-fire, a threaded elbow may be loose on the pipe to which it was originally secured. Due to the compressive and tensile forces of the connection and the heating and cooling exposure to which the connection was exposed, the elbow, which was a tight connection pre-fire, may be loose post-fire. This looseness is caused by the failure of the elbow to return to pre-fire dimensions even after complete cooling. Consideration should be given to the various materials used as sealants in pipe joining.

6.2.9.4 Plastered surfaces are also subject to thermal expansion. Locally heated portions of plaster walls and ceilings may expand and separate from their support lath. In addition to plaster separations from lath, joint compound (sometimes referred to as mud or spackle), joint tape, and patches on gypsum wallboard may fall off.

6.2.10 Deposition of Smoke on Surfaces. Smoke contains particulates, liquid aerosols, and gases. These particulates and liquid aerosols are in motion and may adhere upon collision with a surface. They may also settle out of the smoke over time. Carbon-based fuels produce particles that are predominantly carbon (soot). Petroleum products and most plastics are generally strong soot producers. When flames touch walls and ceilings, particulates and aerosols will commonly be deposited. Smoke deposits can collect on surfaces by settling and deposition.

6.2.10.1 Smoke deposits can collect on cooler surfaces of a building or its contents, often on upper parts of walls in rooms adjacent to the fire. Smoke condensates can be wet and sticky, thin or thick, or dried and resinous. Smoke, especially from smoldering fires, tends to condense on walls, windows, and other cooler surfaces.

6.2.10.2 It should be noted that the color and texture of smoke deposits do not indicate the nature of the fuel or its heat release rate. Chemical analysis of the smoke deposit may indicate the nature of the fuel. For example, smoke from candles may contain paraffin wax, and cigarette smoke may contain nicotine.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.11 Clean Burn. Clean burn is a phenomenon that appears on noncombustible surfaces when the soot and smoke condensate that would normally be found adhering to the surface is burned off. This produces a clean area adjacent to areas darkened by products of combustion, as shown in Figure 6.2.11. Clean burn is produced most commonly by direct flame contact or intense radiated heat. Smoke deposits on surfaces are subject to oxidation. The dark char of the paper surface of gypsum wallboard, soot deposits, and paint can be oxidized by continued flame exposure. The carbon will be oxidized to gases and disappear from the surface.

FIGURE 6.2.11 Clean Burn on Wall Surface.

6.2.11.1 Although they can be indicative of intense heating in an area, clean burn areas by themselves do not necessarily indicate areas of origin. The lines of demarcation between the clean-burned and darkened areas may be used by the investigator to determine direction of fire spread or differences in intensity or time of burning.

6.2.11.2 The investigator should be careful not to confuse the clean burn area with spalling. Clean burn does not show the loss of surface material that is a characteristic of spalling.

6.2.12 Calcination.

6.2.12.1 General. Calcination is used by fire investigators to describe numerous chemical and physical changes that occur in gypsum wallboard surfaces during a fire. Calcination of gypsum wallboard involves driving the free and chemically bound water out of the gypsum as well as other chemical and physical changes to the gypsum component itself. Calcination involves a chemical change of the gypsum to another mineral, anhydrite. Calcined gypsum wallboard is less dense than non-calcined wallboard. The deeper the calcination into the wallboard the greater the total amount of heat exposure (heat flux and duration).

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.12.1.1 Gypsum wallboard has a predictable response to heat. First the paper surface will char and might also burn off. The gypsum on the side exposed to fire changes color from pyrolysis of the organic binder and destiffener in it. With further heating, the color change may extend all the way through, and the paper surface on the backside will char. The face exposed to fire will become whiter as the surface carbon is burned away (clean burn). When the entire thickness of wallboard has turned whitish, there will be no paper left on either face, and the gypsum will be chemically dehydrated and converted to a more crumbly, less dense solid. Such wallboard might stay on a vertical wall but will frequently drop off of an overhead surface, particularly if it has absorbed significant quantities of extinguishment water or post-fire precipitation. Fire-rated gypsum wallboard contains mineral fibers or vermiculite particles embedded in the gypsum to preserve the strength of the wallboard during fire exposure. The fibers add strength to the wallboard even after it has been thoroughly calcined.

6.2.12.1.2 Color changes other than shades of gray may occur after gypsum wall surfaces are exposed to heat. The color itself has no significance to the fire investigator. However, the difference between colors may show lines of demarcation.

6.2.12.1.3 The relationship between the calcined and non-calcined areas on gypsum wallboard can also display visible lines of demarcation on the surface. Significant mass loss and corresponding decrease in density occur within the calcined portion of the gypsum wallboard during the calcination process. Depth of calcination measurements can be plotted to display patterns not visible on the surface. See 17.4.4.

6.2.12.2 General Indications of Calcination. The calcination of gypsum board is an indicator demonstrating the heat exposure sustained by the material. The areas of greatest heat exposure may be indicated by both visual appearance and the depth of calcination. The relative differences in color and depth of calcination from point to point may be used as an indicator to establish the areas of greater or lesser heat exposure due to all fire condition variables, such as area of origin, ventilation, and fuel load.

6.2.13 Window Glass. Many texts have related fire growth history or fuels present to the type of cracking and deposits that resulted on window glass. There are several variables that affect the condition of glass after fire, which include the type and thickness of glass, rate of heating, degree of insulation to the edges of the glass provided by the glazing method, degree of restraint provided by the window frame, history of the flame contact, and cooling history.

6.2.13.1 Breaking of Glass. If a pane of glass is mounted in a frame that protects the edges of the glass from radiated heat of fire, a temperature difference occurs between the unprotected portion of the glass and the protected edge. Experimental research estimates that a temperature difference of about 70°C (126°F) between the center of the pane of glass and the protected edge can cause cracks that start at the edge of the glass. The cracks appear as smooth, undulating lines that can spread and join together. Depending on the degree of cracking, the glass may or may not fall out of its frame.

6.2.13.1.1 If a pane of glass has no edge protection from radiated heat of fire, the glass will break at a higher temperature difference. Also, experimental research suggests that fewer cracks are formed, and the pane is more likely to stay whole.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.13.1.2 Glass that has received an impact will exhibit a characteristic "cobweb" pattern. The cracks will be in straight lines and numerous. The glass may have been broken before, during or after the fire.

6.2.13.1.3 If flame contacts one side of a glass pane while the unexposed side is relatively cool, a stress can develop between the two faces and the glass can fracture between the faces.

6.2.13.1.4 Crazing is a term used to describe a complicated pattern of short cracks in glass. These cracks may be straight or crescent-shaped and may or may not extend through the thickness of the glass. Crazing has been claimed to be the result of very rapid heating of one side of the glass while the other side remains cool. Despite widespread publication of this claim, there is no scientific basis for it. In fact, published research has shown that crazing cannot be caused by rapid heating, but can only be caused by rapid cooling. Regardless of how rapidly it was heated, hot glass will reproducibly craze when sprayed with water. *(See Figure 6.2.13.1.4.)*

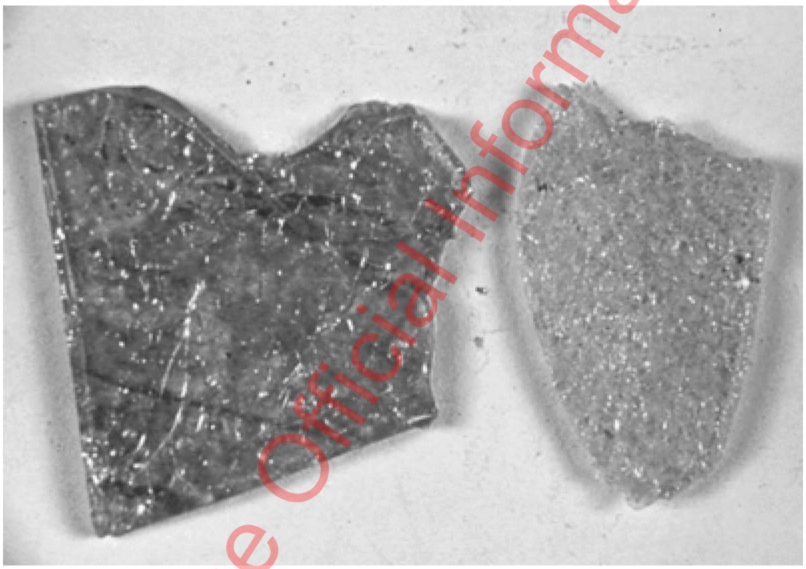


FIGURE 6.2.13.1.4 Crazed Window Glass.

6.2.13.1.5 Occasionally with small-size panes, differential expansion between the exposed and unexposed faces may result in the pane popping out of its frame.

6.2.13.1.6 The pressures developed by fires in buildings generally are not sufficient either to break glass windows or to force them from their frames. Pressures required to break ordinary window glass are in the order of 2.07 kPa to 6.90 kPa (0.3 psi to 1.0 psi), while pressures from fire are in the order of 0.014 kPa to 0.028 kPa (0.002 psi to 0.004 psi). If an overpressure has occurred — such as a deflagration, backdraft, or detonation — glass fragments from a window broken by the pressure will be found some distance from the window. For example, an overpressure of 10.3 kPa (1.5 psi) can cause fragments to travel as far as 30.3 m (100 ft).

6.2.13.1.7 The investigator is urged to be careful not to make conclusions from glass-breaking morphology alone. Both crazing and long, smooth, undulating cracks have been found in adjacent panes.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.13.2 Tempered Glass.

6.2.13.2.1 Tempered glass, whether broken when heated by fire impact or when exploded, will break into many small cube-shaped pieces. Such glass fragments should not be confused with crazed glass. Tempered glass fragments are more uniformly shaped than the complicated pattern of short cracks of crazing.

6.2.13.2.2 Tempered glass is commonly found in applications where safety from breakage is a factor, such as in shower stalls, patio doors, TV screens, motor vehicles, and in commercial and other public buildings.

6.2.13.3 Staining of Glass.

6.2.13.3.1 Glass fragments that are free of soot or condensates have likely been subjected to rapid heating, failure early in the fire, fracture prior to the fire, or flame contact. The proximity of the glass to a heat source and ventilation are factors that can affect the degree of staining.

6.2.13.3.2 The presence of a thick, oily soot on glass, including hydrocarbon residues, has been interpreted as positive proof of the presence or use of liquid accelerant. Such staining can also result from the incomplete combustion of other fuels such as wood and plastics and should not be interpreted as having come from an accelerant.

6.2.14 Collapsed Furniture Springs. The collapse of furniture springs may provide the investigator with clues concerning the direction, duration, or intensity of the fire. However, the collapse of the springs cannot be used to indicate exposure to a specific type of heat or ignition source, such as smoldering ignition or the presence of an ignitible liquid. The results of laboratory testing indicate that the annealing of springs, and the associated loss of tension (tensile strength), is a function of the application of heat. These tests reveal that short-term heating at high temperatures and long-term heating at moderate temperatures over 400°C (750°F) can result in the loss of tensile strength and in the collapse of the springs. Tests also reveal that the presence of a load or weight on the springs while they are being heated increases the loss of tension.

6.2.14.1 The value of analyzing the furniture springs is in comparing the differences in the springs to other areas of the mattress, cushion, or frame. Comparative analysis of the springs can assist the investigator in developing hypotheses concerning the relative exposure to a particular heat source. For example, if at one end of the cushion or mattress the springs have lost their strength, and at the other end they have not, then hypotheses may be developed concerning the location of the heat source. The hypotheses should take into consideration other circumstances, effects (such as ventilation), and evidence at the scene concerning duration or intensity of the fire, area of origin, direction of heat travel, or relative proximity of the heat source. The investigator should also consider that bedding, pillows, and cushions may shield the springs, or provide an additional fuel load. The portion with the loss of spring strength may indicate more exposure to heat than those areas without the loss of strength. The investigator should also consider the condition of the springs prior to the fire.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.15 Distorted Lightbulbs. Incandescent lightbulbs can sometimes show the direction of heat impingement. As the side of the bulb facing the source of heating is heated and softened, the gases inside a bulb of greater than 25 W can begin to expand and bubble out the softened glass. This has been traditionally, albeit misleadingly, called a *pulled* lightbulb, though the action is really a response to internal pressure rather than a pulling. The bulged or pulled portion of the bulb will be in the direction of the source of the heating, as shown in Figure 6.2.15.

FIGURE 6.2.15 A Typical "Pulled" Bulb Showing That the Heating Was from the Right Side.

6.2.15.1 Because they contain a vacuum, bulbs of 25 watts or less can be pulled inward on the side in the direction of the source of heating.

6.2.15.2 Often these light bulbs will survive fire extinguishment efforts and can be used by the investigator to show the direction of fire travel. In evaluating a distorted light bulb, the investigator should be careful to ascertain that the bulb has not been turned in its socket or that the socket itself has not turned as a result of coming loose during or after the fire.

6.2.16 Rainbow Effect. Oily substances, which do not mix with water, float and create diffraction patterns on the surface of water. This results in a "rainbow" or "sheen" appearance. Such rainbow effects are common at fire scenes. Although ignitible liquids will create a rainbow effect, the observation of a rainbow effect should not be interpreted as an indication of the presence of ignitible liquids unless confirmed by a laboratory analysis. Building materials, such as asphalt, plastics, and wood produce oily substances upon pyrolysis that can produce rainbow effects.

6.2.17 Victim Injuries. A body will exhibit a material response to exposure to heat and fire. The skin, fat, muscle, and bones will develop a sequential response to heat exposure. Even heavily damaged bodies can be analyzed for body position, orientation to heat sources, and differential exposure and protection that should be correlated with burn patterns of the body and scene.

Source – NFPA 921, Chapter 6, 2004

Extract

6.2.17.1 Skin can change color or physical shape, and it can burn. The color changes can vary from reddening to the black of char. Skin can tighten, shrink, and pull apart. Splits in the skin, as a result of exposure to fire, are superficial and distinguishable from traumatic penetrating injuries that deform and bulge along the wound tract. Skin can blister from either pre-mortem or post-mortem exposure.

6.2.17.2 Body fat can melt and burn as a liquid fuel. The burning of body fat typically requires the presence of a porous wick-like material such as cellulose fabric, wood, carpet, or other absorbent/carbonized materials.

6.2.17.3 Muscle can change shape, char, and burn. Heat causes dehydration and shortening of tendons and muscles. Bulkier flexor muscles, such as the biceps in the arms and quadriceps in the legs, shorten and contract, causing a body position known as the pugilistic posture. Shorter muscles of the torso cause arching of the neck and back. The pugilistic posture is a common post-mortem response of muscle to heat and is not indicative of a behavioral response to events prior to or during the fire. Deviations from the pugilistic posture should be correlated with the scene to determine if circumstances such as fallen debris, entrapment, or body position (e.g., motor vehicle accidents pinning the body with dashboard or steering wheel) prevented the pugilistic response. Other considerations could be criminal attempts to restrain the body (arms behind the back, ligatures, preexisting traumatic injury, dismemberment, etc.), where the circumstances prevented or altered the expected pugilistic position. Tissues of the body are a fuel load and can continue to burn after surrounding materials self-extinguish.

6.2.17.4 In a fire, bones can change color, change composition, char, and fragment. The color change within bones is related to pyrolysis and is not an indicator of temperatures encountered in a fire. Calcination of the bone can occur when the organic components are burned. The small bones of the extremities, such as feet, hands, fingers, and toes, can appear to be consumed. However, these small bones may have fallen off or fragmented when the surrounding tissues were consumed. As a result, the debris around and under the body should be sifted in an effort to retrieve the small bones and fragments.

6.2.17.5 The skull can exhibit a fragmented, or fractured, appearance regardless of the presence or absence of pre-existing traumatic injury. This fragmentary appearance can be caused by numerous actions: the burning off of organic material that renders the bone brittle, trauma, impact of a fireman's hose stream on the body, impacting debris, vertical falling of the body through furniture, flooring, or spatial levels, or post-fire movement. Prior to movement, the head should be stabilized and/or a protective bag or wrapping placed around it to minimize further fragment loss. Additional cranial fragments found around the head or body should be collected, as they can retain evidence of traumatic injury from gunshot wounds, blunt-force trauma, or sharp-force trauma. Forensic evaluations of these remains are necessary to determine the cause of death. All cranial fragments and teeth should be collected.

6.2.17.6 The body is evidence and should be examined within the original scene context, if practicable. Unlike other materials in the fire, a body is unique in that during the exposure to the fire, the victim can have purposely changed locations, or positions, prior to death. The investigator should carefully document the location, orientation, and condition of the body. The relationship of the victim to other objects or victims should be documented. The area around the victim should be documented as to significant fuels or collapsed material, which could have caused prolonged burning, protection from the fire, or impact damage to the body.

Source – NFPA 921, Chapter 6, 2008

Extract

6.2.17.7 Autopsy reports and photographs provide useful information regarding burn damage. If possible, the fire investigator should attend the autopsy, as certain fire effects that could be significant to the fire investigator may not be significant to the official who examines the body to determine cause and manner of death. The autopsy can provide an opportunity for better examination and documentation of the fire effects to the body. The investigator can correlate the autopsy findings with burn patterns at the scene.

6.2.17.8 Individual victim variables such as age, weight, and health can affect how the body burns and what may survive after burning. Infants and children have developing bones and extra bones that later join to form a mature adult bone. Developing juvenile bones are less dense and may be more fragile and susceptible to damage than adult bones. Mature adult bones are denser and have a higher resistance to fragmenting during the fire. Elderly individuals lose bone density with age (osteoporosis), and their bones are more easily fragmented from heat and recovery. Obese individuals possess higher amounts of body fat than thin or emaciated bodies, thereby contributing more fuel for burning of the body.

6.2.17.9 Victims who survive the fire, but suffer injuries, should also be documented as soon as possible. The nature of their actions within the fire, their clothing, and their injuries should be documented. Interviews and photographing of injuries and clothing can provide immediate documentation. Medical records may be difficult to acquire at a later date.

6.3 Fire Patterns. A fire pattern is the visible or measurable physical changes or identifiable shapes formed by a fire effect or group of fire effects.

6.3.1 Introduction. Fire effects are the underlying data that are used by the investigator to identify fire patterns. The circumstances of every fire are different from every other fire because of the differences in the structures, fuel loads, ignition factors, airflow, ventilation, and many other variables. This discussion, therefore, cannot cover every possible variation in fire patterns and how they come about. The basic principles are covered here, and the investigator should apply them to the particular fire incident under investigation.

6.3.1.1 Dynamics of Pattern Production. The recognition, identification, and proper analysis of fire patterns depend on an understanding of the dynamics of fire development and heat and flame spread. This recognition, identification, and proper analysis require an understanding of the way that conduction, convection, and radiation produce the fire effects and the nature of flame, heat, and smoke movement within a structure. *(See Chapter 5.)*

6.3.1.2 Lines or Areas of Demarcation. Lines or areas of demarcation are the borders defining the differences in certain heat and smoke effects of the fire on various materials. They appear between the affected area and adjacent, less-affected areas.

6.3.1.2.1 The production of lines and areas of demarcation depends on a combination of variables: the material itself, the rate of heat release of the fire, fire suppression activities, temperature of the heat source, ventilation, and the amount of time that the material is exposed to the heat. For example, a wooden wall may display the same heat exposure patterns from exposure to a low-temperature heat source for a long period of time as to a high-temperature heat source for a shorter period of time. The investigator should keep this concept in mind while analyzing the nature of fire patterns.

6.3.1.2.2 The patterns seen by an investigator can represent much of the history of the fire. Each time another fuel package is ignited or the ventilation to the fire changes, the rate of energy production and heat distribution will change. Any burning item can produce a plume and thus a fire pattern. Determining which pattern was produced at the point of origin by the first material ignited usually becomes more difficult as the size and duration of the fire increases.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.2 Causes of Fire Patterns. There are three basic causes of fire patterns: heat, deposition, and consumption. These causes of patterns are defined largely by the fire dynamics discussed in Section 5.5. A systematic analysis of fire patterns can be used to lead back to the heat source that produced them. Some patterns may be interpreted as defining fire intensity (heat/fuel) or spread (movement). See Section 6.4.

6.3.2.1 Plume-Generated Patterns. Most fire patterns are generated directly by fire plumes, which are three-dimensional. Fire patterns represent demarcation lines of fire effects upon materials created by the three-dimensional (conical) shape of the fire plume being cut (truncated) by an intervening two-dimensional surface such as a ceiling or a wall. When the plume intersects with surfaces it creates effects that are interpreted as patterns (conical sections). The rate of heat release of the burning fuel has a profound effect on the shape of the fire patterns produced. These fire patterns include the following:

(1) V patterns
(2) Inverted cone patterns
(3) Hourglass patterns
(4) U-shaped patterns
(5) Pointer and arrow patterns
(6) Circular-shaped patterns

6.3.2.1.1 As the buoyant column of flames, hot gases, and smoke rising above a fire in the plume are cooled by air entrainment, the plume temperatures approach that of the surrounding air (decreased temperatures with increasing height in the plume). Therefore, the production of fire patterns is most prominent when the surface displaying the patterns has been exposed to plume temperatures near or above its minimum pyrolysis temperature. The presence of a physical barrier, such as a ceiling, will contribute to the lateral extension of the plume boundary in a ceiling jet.

6.3.2.1.2 When no ceiling exists over a fire, and the fire is far from walls, the hot gases and smoke of the unconfined plume continue to rise vertically until they ultimately cool to the ambient air temperature. At that point, the smoke and hot gases will stratify and diffuse in the air. Such conditions exist for an unconfined fire outdoors. The same conditions can exist in a building fire at the very early stages of a fire, when the fire has a low heat release rate, when the plume is small, or if the fire is in a very large-volume space with a high ceiling such as an atrium.

6.3.2.1.3 The plume width varies with the size of the base of the fire and will increase over time as the fire spreads. A narrow base pattern will develop from a small surface area fire, and a wide base pattern will develop from a fire with a large surface area. *(See Figure 6.3.2.1.3.)*

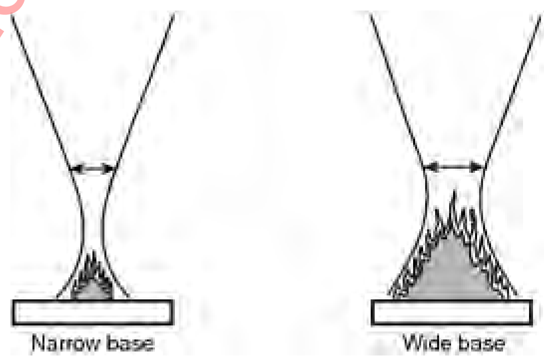


FIGURE 6.3.2.1.3 Effects of Fire Base on Fire Pattern Width.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.2.1.4 An incipient stage fire may produce a fire pattern that has the appearance of an inverted cone. As the heat release rate and flame height increase, this inverted cone pattern may evolve into a subsequent pattern that is more columnar in appearance. Likewise, the growing fire can cause the columnar pattern to evolve into conical patterns such as a V pattern, U pattern, or hourglass pattern. The first patterns will be observable only if the fire goes out, whether from suppression, lack of oxygen, or fuel depletion. For this reason, observation of patterns gives the investigator insight into the fire development. It must also be understood that the lack of an observable inverted cone, hourglass, or columnar pattern after the fire does not mean that one was not present earlier in the fire's growth. If the fire achieves flashover and full room involvement, the patterns formed early in the growth of the fire are often changed by the intense convective and radiant heat transfer.

6.3.2.2 Ventilation-Generated Patterns. Ventilation of fires and hot gases through windows, doors, or other openings in a structure greatly increases the velocity of the flow over combustible materials. In addition, well-ventilated fires burn with higher heat release rates that can increase the rate of char and spall concrete or deform metal components. Areas of great damage are indicators of a high heat release rate, ventilation effects, or long exposure. Such areas, however, are not always the point of fire origin. For example, fire could spread from slow-burning fuels to rapid-burning fuels, with the latter producing most of the fire damage.

6.3.2.2.1 Airflow over coals or embers can raise temperatures, and more heat is transferred as the velocity of the hot gas increases. These phenomena can generate enough heat to spall concrete, melt metals, or burn holes through floors. If a building burns extensively and collapses, embers in debris can produce holes in floors. Once a hole is made, air can flow through the hole, and the burning rate can increase. Careful interpretation of these patterns should be exercised, because they may be mistaken for patterns originating from ignitible liquids.

6.3.2.2.2 When a door is closed on a fire-involved compartment, hot gases (being lighter) can escape through the space at the top of the closed door, resulting in charring. Cool air may enter the compartment at the bottom of the door, as in HFigure 6.3.2.2.2(a)H. In a fully developed room fire where the hot gases extend to the floor, the hot gases may escape under the door and cause charring under the door and possibly through the threshold, as in HFigure 6.3.2.2.2(b)H. Charring can also occur if glowing debris falls against the door either on the inside or the outside, as in HFigure 6.3.2.2.2(c)H. Ignitible liquids burning under wood doors may cause charring of the doors.

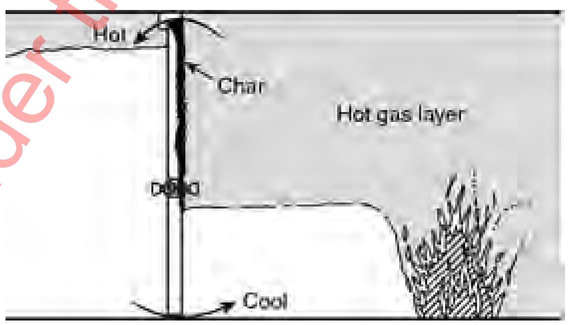


FIGURE 6.3.2.2.2(a) Airflow Around Door.

Source – NFPA 921, Chapter 6, 2008

Extract

FIGURE 6.3.2.2.2(a) Airflow Around Door.

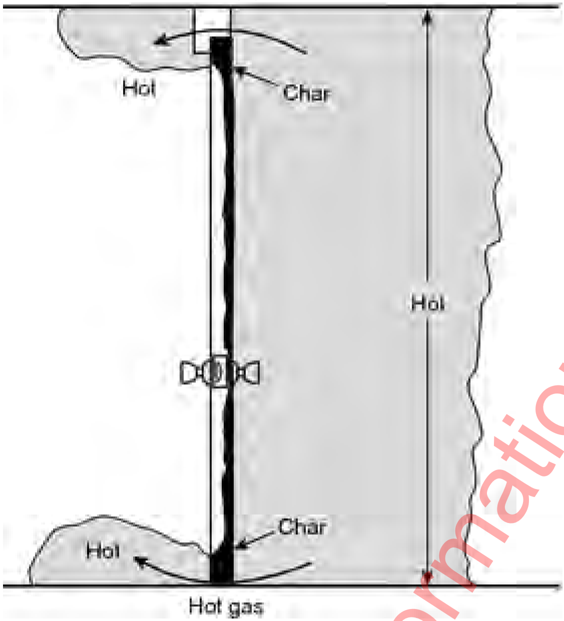


FIGURE 6.3.2.2.2(b) Hot Gases Under Door.

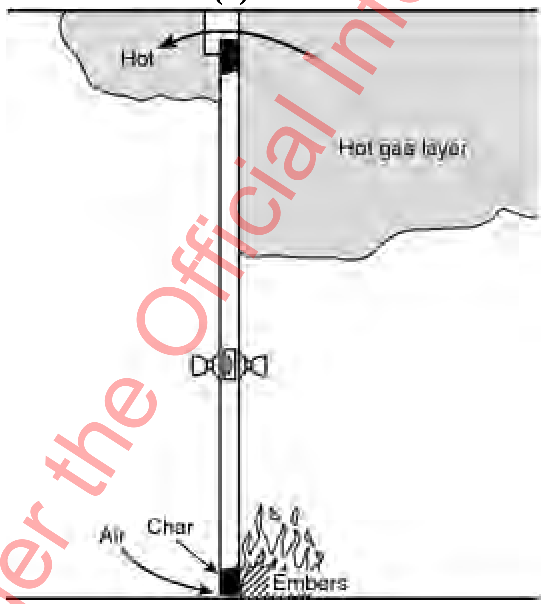


FIGURE 6.3.2.2.2(c) Glowing Embers at Base of Door.

6.3.2.2.3 Effects of Room Ventilation on Pattern Magnitude and Location.

6.3.2.2.3.1 The ventilation of the room has a significant effect on the growth and heat release rate of a fire, and for this reason greatly affects pattern formation.

6.3.2.2.3.2 Besides affecting the fire intensity, ventilation can affect the location, shape, and magnitude of fire patterns. Where fresh air ventilation is available to a fire through open windows and doors, it is common to find locally heavy damage effects on combustible items close to the ventilation opening. These patterns may not indicate a point of origin.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.2.3 Hot Gas Layer–Generated Patterns. The radiant flux from the hot gas layer can produce damage to the upper surfaces of contents and floor covering materials. This process commonly begins as the environment within the room approaches flashover conditions. Similar damage to floor surfaces from radiant heat frequently occurs in adjacent spaces immediately outside rooms that are fully involved in fire. Damage to hallway floors and porches are examples. Protected surfaces may not exhibit any damage. At this time in the fire development, a line of demarcation representing the lower extent of the hot gas layer may form on vertical surfaces. The degree of damage generally will be uniform except where there is drop down, where there is burning of isolated items that are easily ignited, or where there are protected areas.

6.3.2.4 Full Room Involvement–Generated Patterns. If a fire progresses to full room involvement *(see 5.10.2.1 through 5.10.28)*, damage found at low levels in the room down to and including the floor can be more extensive due to the effects of radiant flux and the convected heat from the descending hot gas layer and the contribution of an increasing number of burning fuel packages. The radiant heat flux has the greatest impact on surfaces with a direct "view" of the hot gas layer. As the hot gas layer descends to floor level, damage will significantly increase. Damage can include charring of the undersides of furniture, burning of carpet and floor coverings under furniture and in corners, burning of baseboards, and burning on the undersides of doors. Full room involvement can result in holes burned through carpet and floor coverings. The effects of protected areas and floor clutter on low burn patterns should be considered *(see 6.3.3.2.8)*. Although the degree of damage will increase with time, the extreme conditions of the full room involvement can produce major damage in a few minutes, depending on ventilation and fuels present.

6.3.2.5 Suppression-Generated Patterns. Water or other agents used for fire suppression are capable of producing or altering patterns. Hose streams are capable of altering the spread of the fire and creating fire damage in places where the fire would not move in the absence of the hose stream. Additionally, fire department ventilation operations can influence fire patterns. Some fire departments use positive pressure ventilation (PPV) fans that can create patterns that may be difficult to interpret, particularly if the investigator is unaware of PPV use. The history of suppression-generated patterns can only be understood through communication with the responding fire suppression personnel.

6.3.3 Locations of Patterns. Fire patterns may be found on any surface that has been exposed to the effects of the fire or its by-products. These surfaces include interior surfaces, external surfaces and structural members, and outside exposures surrounding the fire scene. Interior surfaces commonly include walls, floors, ceilings, doors, windows, furnishings, appliances, machinery, equipment, other contents, personal property, confined spaces, attics, closets, and the insides of walls. Exterior surfaces commonly include walls, eaves, roofs, doors, windows, gutters and downspouts, utilities (e.g., meters, service drops), porches, and decks. Outside exposures commonly include outbuildings, adjacent structures, trees and vegetation, utilities (e.g., poles, lines, meters, fuel storage tanks, and transformers), vehicles, and other objects. Patterns can also be used to determine the height at which burning may have begun within the structure.

6.3.3.1 Walls and Ceilings. Fire patterns are often found on walls and ceilings. As the hot gas zone and the flame zone of the fire plume encounter these obstructions, patterns are produced that investigators may use to trace a fire's origin. *(See Sections 5.5 and 5.6.)*

6.3.3.1.1 Walls. Patterns on walls may appear as lines of demarcation on the surfaces of the walls or may be manifested as deeper burning. Once the surface coverings of a wall are destroyed by burning, the underlying construction can also display various patterns. These patterns are most commonly V patterns, U patterns, hourglass patterns, and spalling. Surfaces behind wall coverings, even when the covering is still in place, can sometimes also display patterns.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.3.1.2 Ceilings. The investigator should examine patterns that occur on ceilings or the underside of such horizontal surfaces as tabletops or shelves. The buoyant nature of fire gases concentrates the heat energy at horizontal surfaces above the heat source. Therefore, the patterns that are created on the underside of such horizontal surfaces can indicate the locations of heat sources. Although areas immediately over the source of heat and flame will generally experience heating before the other areas to which the fire spreads, circumstances can occur where fuel at the origin burns out quickly, but the resulting fire spreads to an area where a larger supply of fuel can ignite and burn for a longer period of time. This process can cause more damage to the ceiling in that area than in the area immediately over the origin.

6.3.3.1.2.1 These horizontal patterns are roughly circular. Portions of circular patterns are often found where walls meet ceilings or shelves and at the edges of tabletops and shelves. The investigator should determine the approximate center of the circular pattern and investigate below this center point for a heat source.

6.3.3.1.2.2 Fire damage can be found inside walls and ceilings as a result of heat transfer through surfaces. It is possible for the heat of a fire to be conducted through a wall or ceiling surface and to ignite wooden structural members within the wall or ceiling.

6.3.3.1.2.3 The ability of the surface to withstand the passage of heat over time is called its finish rating. The finish rating of a surface material only represents the performance of the material in a specific laboratory test (e.g., as shown in UL 263, *Standard for Safety Fire Tests of Building Construction and Materials*) and not necessarily the actual performance of the material in a real fire. Knowledge of the concept can be of value to an investigator's overall fire spread analysis.

6.3.3.1.2.4 This heat transfer process can be observed by the charring of the wooden structural element covered by the protective membrane, shown in Figure 6.3.3.1.2.4.

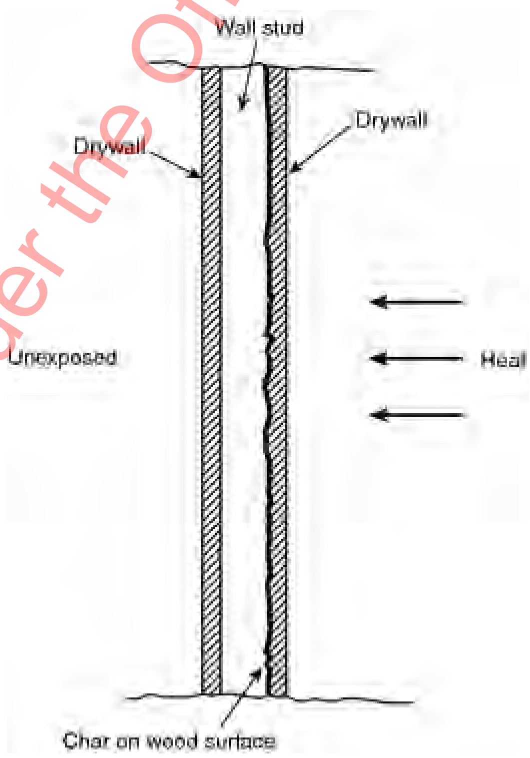


FIGURE 6.3.3.1.2.4 Charring of Wooden Structural Elements by Heat Conduction Through Wall Surface Material.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.3.2 Floors. The investigators should examine patterns that occur on floor coverings and floors. The transition through flashover to full room involvement is associated with a radiant heat flux that exceeds approximately 20 kW/m^2 (2 W/cm^2) at floor level, a typical value for the radiant ignition of common combustible materials. Post-flashover or full room involvement conditions can typically produce fluxes in excess of 170 kW/m^2 and may create, modify, or obliterate patterns.

6.3.3.2.1 Since 1970, carpeting and rugs manufactured or imported to be sold in the United States have been resistant to ignition or fire spread. Typically, cigarettes or matches dropped on carpets will not set them on fire. ASTM D 2859, *Standard Test Method for Flammability of Finished Textile Floor Covering Materials* (Methenamine Pill Test), describes the test used to measure the ignition characteristics of carpeting from a small ignition source. Carpeting and rugs passing the pill test will have very limited ability to spread flame or char in a horizontal direction when exposed to small ignition sources such as a cigarette or match.

6.3.3.2.2 Fire will not spread across a room on the surface of these carpets or rugs without the input of additional energy, such as from a fire external to the carpet or fuel burning on the carpet, in which case the fire spread on the carpet will terminate at a point where the radiant energy from the exposing fire is less than the minimum needed to support flame spread on the carpet (critical radiant flux). Carpet can be expected to ignite and burn when exposed to flashover conditions because the radiant heat flux that produces flashover exceeds the carpet's critical radiant flux.

6.3.3.2.3 Burning between seams or cracks of floorboards or around door thresholds, sills, and baseboards may or may not indicate the presence of an ignitible liquid. Standard tests involving flooring materials such as ASTM E 648, *Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*, regularly produce burning between seams or cracks of floorboard assemblies from radiant heating alone. The knowledge of the pre-fire condition of floorboards, sills, and baseboards can assist in this assessment.

6.3.3.2.4 Full room involvement can also produce burning of floors or around door thresholds, sills, and baseboards due to radiation, the presence of hot combustible fire gases, or air sources (ventilation) provided by the gaps in construction. These gaps can provide sufficient air for combustion of, on, or near floors *(see 6.3.2.2)*.

6.3.3.2.5 Holes in floors may be caused by glowing combustion, radiation, or an ignitible liquid. The surface below a liquid remains cool (or at least below the boiling point of the liquid) until the liquid is consumed. Holes in the floor from burning ignitible liquids may result when the ignitible liquid has soaked into the floor or accumulated below the floor level. Evidence other than the hole or its shape is necessary to confirm the cause of a given pattern.

6.3.3.2.6 Fire-damaged vinyl floor tiles often exhibit curled tile edges, exposing the floor beneath. The curling of tile edges can frequently be seen in non-fire situations and is due to natural shrinkage and loss of plasticizer. In a fire, the radiation from a hot gas layer will produce the same patterns. These patterns can also be caused by ignitible liquids, although confirmation of the presence of ignitible liquids requires laboratory analysis.

6.3.3.2.7 The collection of samples and laboratory verification of the presence or absence of ignitible liquid residues may assist the investigator in developing hypotheses and drawing conclusions concerning the development of floor patterns.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.3.2.8 Unburned areas present after a fire can reveal the location of items that protected the floor or floor covering from radiation damage or smoke staining.

6.3.3.2.9 Outside Surfaces. External surfaces of structures can display fire patterns. In addition to the regular patterns, both vertical and horizontal external surfaces can display burn-through. All other variables being equal, these burn-through areas can identify areas of intense or long-duration burning.

6.3.3.2.10 Drop Down (Fall Down). Burning debris can fall and burn upward, creating a new pattern from this heat source. This occurrence is known as *drop down*. Drop down can ignite other combustible materials, producing low burn patterns.

6.3.4 Location of Objects. Certain types of patterns can be used to locate the positions of objects as they were during a fire.

6.3.4.1 Heat Shadowing. Heat shadowing results from an object blocking the travel of radiant heat from its source to a target material on which the pattern is produced. The object blocking the travel of the heat energy may be a solid, liquid, or gas, combustible or noncombustible. Any object that absorbs or reflects the heat energy may cause the production of a pattern on the material it protects. *(See Figure 6.3.4.1.)*

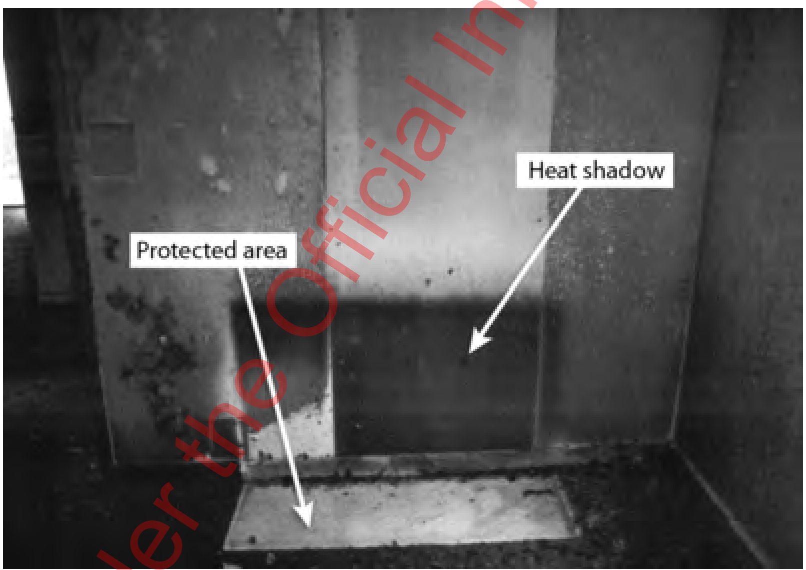


FIGURE 6.3.4.1 Heat Shadow and Protected Areas (USFA Fire Pattern Project).

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.4.1.1 Heat shadowing can change, mask, or inhibit the production of identifiable lines of demarcation that may have appeared on that material. Patterns produced by the heat shadowing, may, however, assist the fire investigator in the process of reconstruction during origin determination.

6.3.4.2 Protected Areas. Closely related in appearance to the resulting pattern of heat shadowing is a protected area. A protected area results from an object preventing the products of combustion from depositing on the material that the object protects, or prevents the protected material from burning. The object may be a solid or liquid, combustible or noncombustible. Any object that prevents the deposition of the products of combustion, or prevents the burning of the material, may produce a protected area. Figure 6.3.4.2 provides an example.

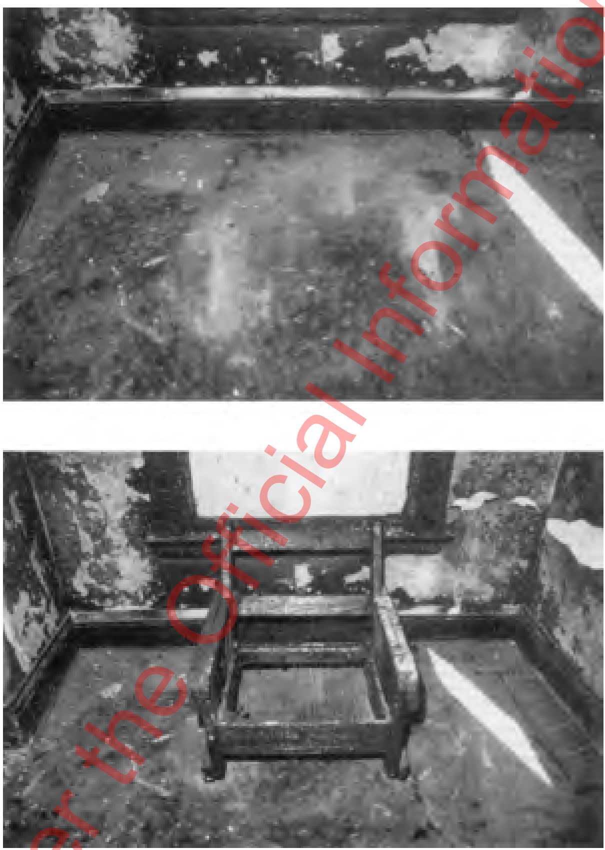


FIGURE 6.3.4.2 Photograph on Top, Showing Protected Area; Photograph at Bottom, Showing How the Chair Was Positioned During the Fire.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.5 Penetrations of Horizontal Surfaces. Penetration of horizontal surfaces, from above or below, can be caused by radiant heat, direct flame impingement, or localized smoldering with or without the effects of ventilation.

6.3.5.1 Penetrations in a downward direction are often considered unusual because the more natural direction of heat movement is upward because of the buoyancy of heated gases. In fully involved compartments, however, hot gases may be forced through small, pre-existing openings in a floor, resulting in a penetration. Penetrations may also arise as the result of intense burning under furniture items such as polyurethane mattresses, couches, or chairs. Flaming or smoldering under collapsed floors or roofs can also cause floor penetrations.

6.3.5.2 Whether a hole burned into a horizontal surface was created from above or below may be identified by an examination of the sloping sides of the hole. Sides that slope downward from above toward the hole are indicators that the fire was from above. Sides that are wider at the bottom and slope upward toward the center of the hole indicate that the fire was from below. During the course of the fire it is possible for both upward and downward burning to occur through a hole. The investigator should keep in mind that only the last burning direction through the hole may be evident. *(See Figure 6.3.5.2.)*

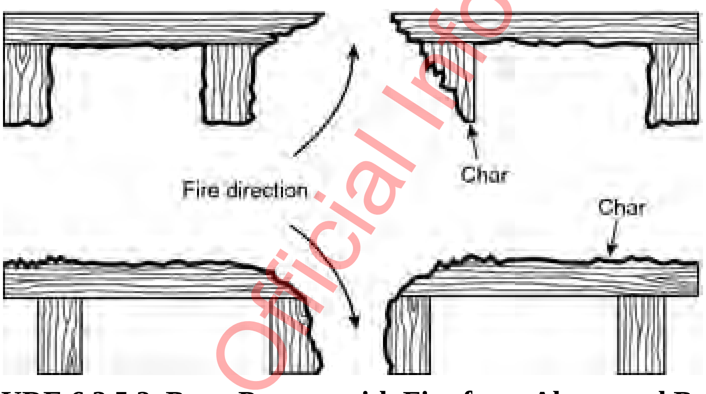


FIGURE 6.3.5.2 Burn Pattern with Fire from Above and Below.

6.3.5.3 Structural elements, such as studs or joists, can influence the patterns created by fire penetrating up or down or laterally through a building surface. For example, a fire that moves upward through a floor may exhibit patterns significantly influenced by the joists, as opposed to a fire that moves downward through the same floor. The investigator should keep in mind that only the last burning direction through the surface may be evident.

6.3.6 Depth of Char Patterns with Fuel Gases. Flash fires involving fuel gases can produce widely distributed, even charring. However, in areas of pocketed fuel gas, deeper charring can occur. In close proximity to the point of continuing gas leakage, deeper charring may exist, as burning may continue there after the original quantity of fugitive gas is consumed. This charring may be highly localized because of the pressurized gas jets that can exist at the immediate point of leakage and may assist the investigator in locating the leak.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.7 Pattern Geometry. Various patterns having distinctive geometry or shape are created by the effects of fire and smoke exposure on building materials and contents. In order to identify them for discussion and analysis, they have been described in the field by terms that are indicative of their shapes. While these terms generally do not relate to the manner in which the pattern was formed, the descriptive nature of the terminology makes the patterns easy to recognize. The discussion that follows will refer to patterns by common names and provide some information about how they were formed and how they can be interpreted. Additional information can be found in 6.3.2. Because the interpretation of all possible fire patterns cannot be traced directly to scientific research, the user of this guide is cautioned that alternative interpretations of a given pattern are possible. In addition, patterns other than those described may be observed.

6.3.7.1 V Patterns on Vertical Surfaces. The V-shaped pattern is created by flames, convective or radiated heat from hot fire gases, or smoke within the fire plume. *(See 6.3.2.1.)* The V pattern often appears as lines of demarcation (*see 6.3.1.2*) defining the borders of the fire effects as shown in Figure 6.3.7.1(a) and Figure 6.3.7.1(b).

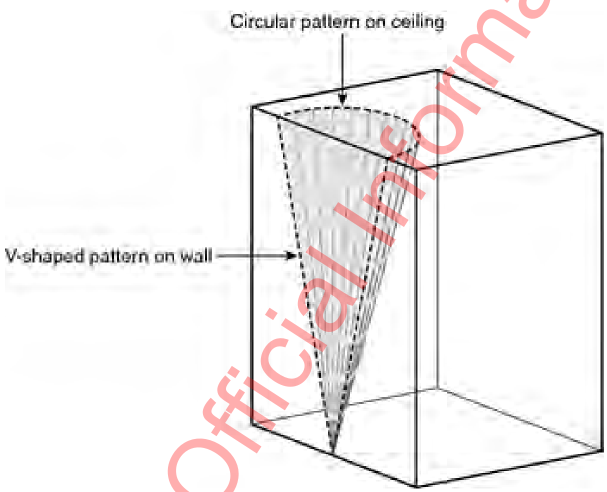


FIGURE 6.3.7.1(a) Idealized Formation of V Pattern and Circular Pattern.

FIGURE 6.3.7.1(b) V Pattern Showing Wall and Wood Stud Damage.

Source – NFPA 921, Chapter 6, 2004

Extract

6.3.7.1.1 The angle of the V-shaped pattern is dependent on several variables *(see 6.3.2.1)*, including the following:

(1) Heat release rate (HRR)
(2) Geometry of the fuel
(3) Effects of ventilation
(4) Combustibility of the surface on which the pattern appears
(5) Presence of horizontal surfaces such as ceilings, shelves, table tops, or the overhanging construction on the exterior of a building *(See 6.3.2.1.)*

6.3.7.1.2 The angle of the borders of the V pattern does not indicate the speed of fire growth or rate of heat release of the fuel alone; that is, a wide V does not indicate a slowly growing ("slow") fire and a narrow V does not indicate a rapidly growing ("fast") fire.

6.3.7.2 Inverted Cone (Triangular) Patterns. Inverted cones are commonly caused by the vertical flame plumes not reaching the ceiling. The characteristic two-dimensional shape is triangular with the base at the bottom. *[See Figure 6.3.7.2(a) and Figure 6.3.7.2(b).]*

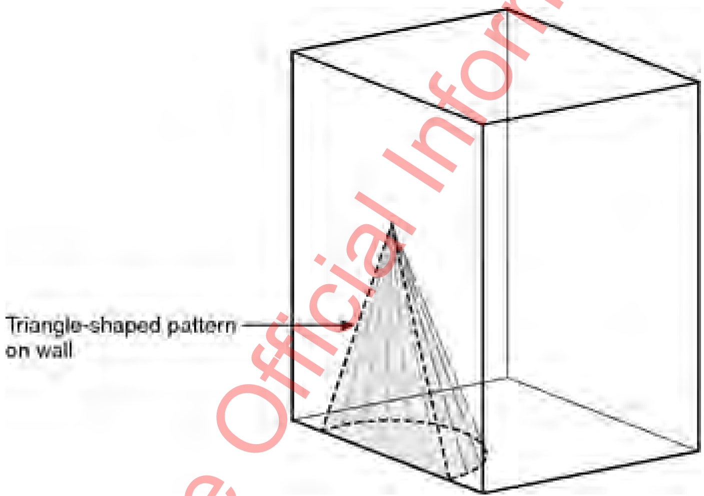


FIGURE 6.3.7.2(a) Idealized Formation of an Inverted Cone Pattern.

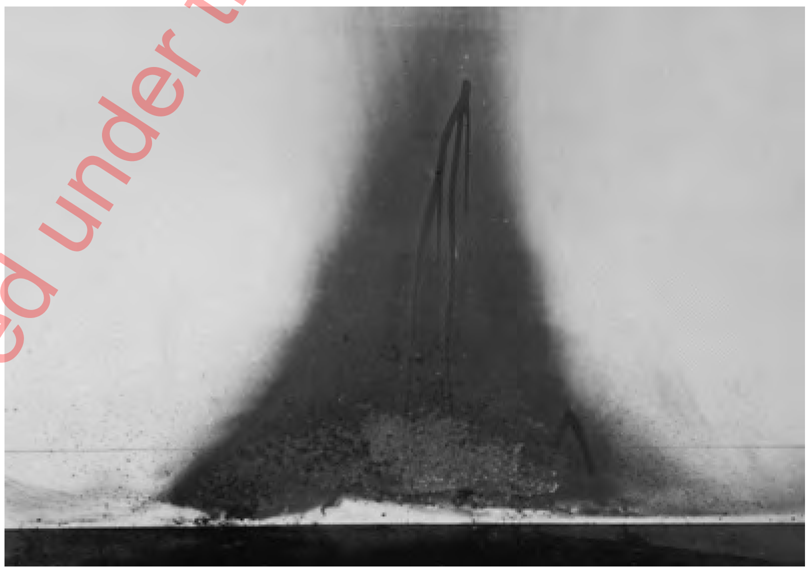


FIGURE 6.3.7.2(b) Inverted Cone Pattern Produced by Burning a Small Pile of Newspapers.

Source – NFPA 921, Chapter 6, 2004

Extract

6.3.7.2.1 Interpretation of Inverted Cone Patterns. Inverted cone patterns are manifestations of relatively short-lived or low HRR fires that do not fully evolve into floor-to-ceiling flame plumes or have flame plumes that are not vertically restricted

6.3.7.2.2 Inverted cone patterns have been interpreted as proof of ignitible liquid fires, but any fuel source (leaking fuel gas, Class A fuels, etc.) that produces flame zones that do not become vertically restricted by a horizontal surface, such as a ceiling or furniture, can produce inverted cone patterns.

6.3.7.2.3 Inverted Cone Patterns with Natural Gas. The burning of leaking natural gas tends to produce inverted cone patterns, especially if the leakage occurs from below floor level and escapes above at the intersection of the floor and a wall, as in HFigure 6.3.7.2.3H. The subsequent burning often does not reach the ceiling and is manifested by a characteristic triangular inverted cone pattern shape.

FIGURE 6.3.7.2.3 Inverted Cone Pattern Fueled by a Natural Gas Leak Below the Floor Level.

6.3.7.3 Hourglass Patterns. The plume is a hot gas zone shaped like a V with a flame zone at its base. The flame zone is shaped like an inverted V. When the hot gas zone intersects a vertical surface, the typical V pattern is formed. If the fire itself is very close to or in contact with the vertical surface, the resulting pattern will show the effects of both the hot gas zone and the flame zone together as a large V above an inverted V. The inverted V is generally smaller and may exhibit more intense burning or clean burn. The overall pattern that results is called an hourglass.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.7.4 U-Shaped Patterns. U patterns are similar to the more sharply angled V patterns but display gently curved lines of demarcation and curved rather than angled lower vertices. *(See Figure 6.3.7.4.)* The lowest lines of demarcation of the U patterns are generally higher than the lowest lines of demarcation of corresponding V patterns that are closer to the heat source.

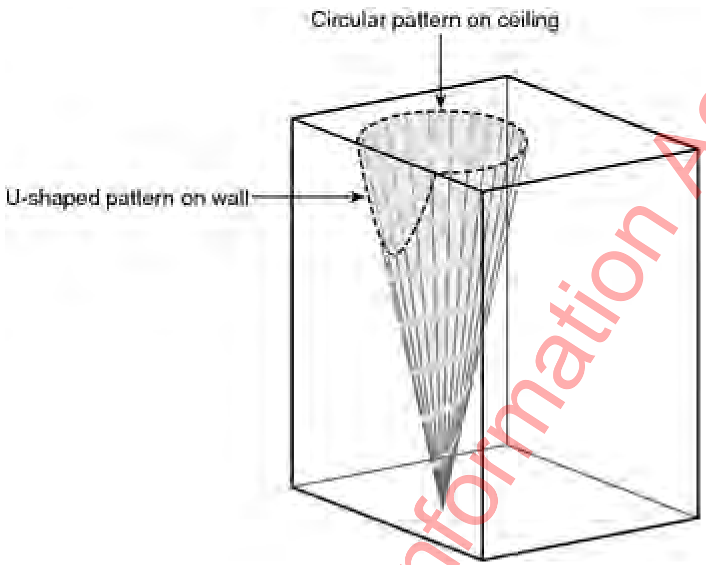


FIGURE 6.3.7.4 Idealized Formation of U-Shaped Pattern.

6.3.7.5 Truncated Cone Patterns. Truncated cone patterns, also called truncated plumes, are three-dimensional fire patterns displayed on both horizontal and vertical surfaces. *(See Figure 6.3.7.5(a) and Figure 6.3.7.5(b).)* It is the intersection or truncating of the natural cone-shaped or hourglass-shaped plume by these vertical and horizontal surfaces that causes the patterns to be displayed. Many fire patterns, such as V patterns, U patterns, circular patterns, and "pointer or arrow" patterns, are related directly to the three-dimensional cone of heat created by the fire.

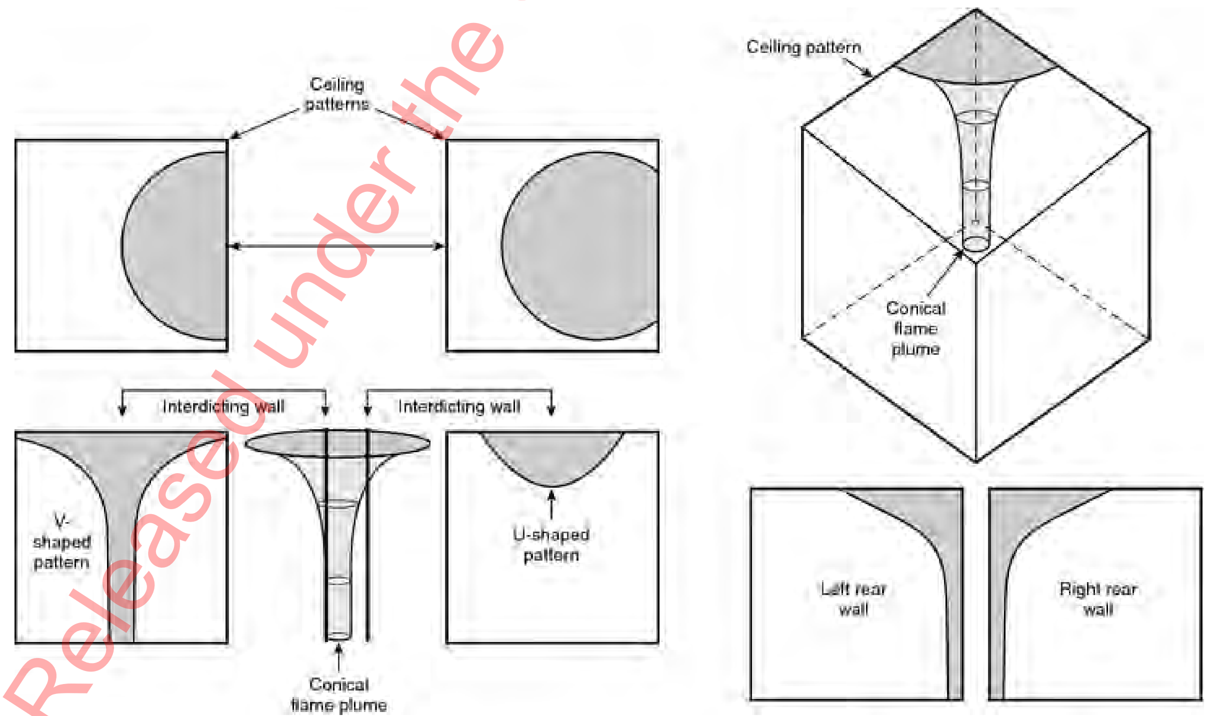


FIGURE 6.3.7.5(a) Idealized Truncated Cone Pattern Formation.

Source – NFPA 921, Chapter 6, 2008

Extract

FIGURE 6.3.7.5(b) Truncated Cone Pattern Displayed on Perpendicular Walls.

6.3.7.5.1 Due to air entrainment, the width of the plume cone increases with increasing height. When the fire plume encounters an obstruction to its vertical movement, such as the ceiling of a room, the hot gases move horizontally. Thermal damage to a ceiling will generally extend beyond the circular area attributed to a "truncated cone" due to this horizontal movement. The truncated cone pattern combines two-dimensional patterns such as V-shaped patterns on vertical surfaces, with circular patterns displayed on horizontal surfaces. The combination of more than one two-dimensional pattern on perpendicular, vertical, and horizontal surfaces reveals the plume's three-dimensional shape.

6.3.7.6 Pointer and Arrow Patterns. These fire patterns may be on a series of combustible elements such as wooden wall studs whose surface sheathing has been destroyed by fire. The direction of fire spread along a wall can often be identified and traced back toward its source by an examination of the relative heights and burned-away shapes of the wall studs left standing after a fire. In general, shorter and more severely charred studs will be closer to a source of heat than taller studs. The heights of the remaining studs increase as distance from a source of fire increases. The difference in height and severity of charring may be observed and documented, as shown in Figure 6.3.7.6.

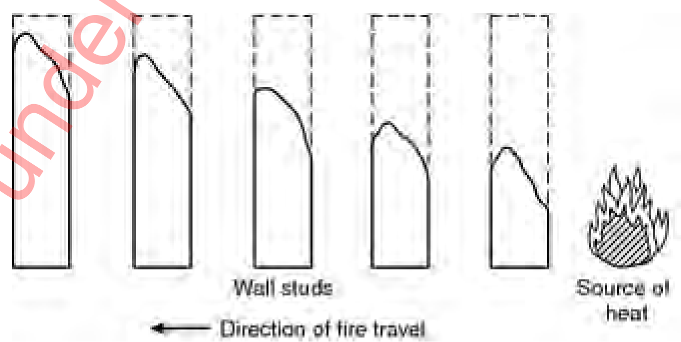


FIGURE 6.3.7.6 Wood Wall Studs Showing Decreasing Damage as Distance from Fire Increases.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.7.6.1 The shape of the studs' cross section will tend to produce "arrows" pointing back toward the general area of the source of heat. This is caused by the burning off of the sharp angles of the edges of the studs on the sides toward the heat source that produces them, as shown in Figure 6.3.7.6.1.

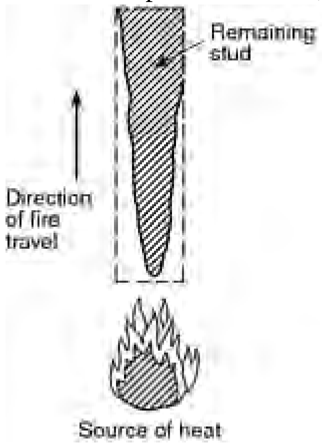


FIGURE 6.3.7.6.1 Cross-Section of Wood Wall Stud Pointing Toward the Heat Source.

6.3.7.6.2 More severe charring can be expected on the side of the stud closest to the heat source.

6.3.7.7 Circular-Shaped Patterns. Patterns on the underside of horizontal surfaces, such as ceilings, tabletops, and shelves, can appear in roughly circular shapes. The farther the heat source is from the wall, the more circular the patterns may appear. Portions of circular patterns can appear on the underside of surfaces that partially block the heated gases or fire plumes. This appearance can occur when the edge of the surface receiving the pattern does not extend far enough to show the entire circular pattern or when the edge of the surface is adjacent to a wall. Within the circular pattern, the center may show more heat degradation, such as deeper charring. By locating the center of the circular pattern, the investigator may find a valuable clue to the source of greatest heating, immediately below.

6.3.7.8 Irregular Patterns. Irregular, curved, or "pool-shaped" patterns on floors and floor coverings should not be identified as resulting from ignitible liquids on the basis of visual appearance alone. In cases of full room involvement, patterns similar in appearance to ignitible liquid burn patterns can be produced when no ignitible liquid is present.

6.3.7.8.1 The lines of demarcation between the damaged and undamaged areas of irregular patterns range from sharp edges to smooth gradations, depending on the properties of the material and the intensity of heat exposure. Denser materials like oak flooring will generally show sharper lines of demarcation than polymer (e.g., nylon) carpet. The absence of a carpet pad often leads to sharper lines.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.7.8.2 Irregular patterns are common in situations of post-flashover conditions, long extinguishing times, or building collapse. These patterns may result from the effects of hot gases, flaming and smoldering debris, melted plastics, or ignitible liquids. If the presence of ignitible liquids is suspected, supporting evidence in the form of a laboratory analysis should be sought. It should be noted that many plastic materials release hydrocarbon fumes when they pyrolyze or burn. These fumes may have an odor similar to that of petroleum products and can be detected by combustible gas indicators when no ignitible liquid accelerant has been used. A "positive" reading should prompt further investigation and the collection of samples for more detailed chemical analysis. It should be noted that pyrolysis products, including hydrocarbons, can be detected in laboratory analysis of fire debris in the absence of the use of accelerants. It can be helpful for the laboratory, when analyzing carpet debris, to burn a portion of the comparison sample and run a gas chromatographic-mass spectrometric analysis on both samples. By comparing the results of the burned and unburned comparison samples with those from the fire debris sample, it may be possible to determine whether or not hydrocarbon residues in the debris sample were products of pyrolysis or residue of an accelerant. In any situation where the presence of ignitible liquids is suggested, the effects of flashover, airflow, hot gases, melted plastic, and building collapse should be considered.

6.3.7.8.3 When overall fire damage is limited and small, or isolated irregular patterns are found, further examination should be conducted for supporting evidence of ignitible liquids. *[See Figure 6.3.7.8.3(a) and Figure 6.3.7.8.3(b).]* Even in these cases, radiant heating may cause the production of patterns on some surfaces that can be misinterpreted as liquid burn patterns. *[See Figure 6.3.7.8.3(c).]*

FIGURE 6.3.7.8.3(a) Irregular Burn Patterns on a Floor of a Room Burned in a Test Fire in Which No Ignitible Liquids Were Used.

Source – NFPA 921, Chapter 6, 2004

Extract

FIGURE 6.3.7.8.3(b) Irregularly Shaped Pattern on Carpet Resulting from Poured Ignitible Liquid; Burned Match Can be Seen at Lower Left.

FIGURE 6.3.7.8.3(c) "Pool-Shaped" Burn Pattern Produced by a Cardboard Box Burning on an Oak Parquet Floor.

6.3.7.8.4 Pooled ignitible liquids that soak into flooring or floor covering materials as well as melted plastic can produce irregular patterns. These patterns can also be produced by localized heating or fallen fire debris. *[See Figure 6.3.7.8.4(a) and Figure 6.3.7.8.4(b).]*

FIGURE 6.3.7.8.4(a) Non-Accelerated Test Burns Demonstrating Melting, Dripping, Pooling, and Burning of Melted Polyurethane Foam Mattress.

Source – NFPA 921, Chapter 6, 2008

Extract

FIGURE 6.3.7.8.4(b) Non-Accelerated Test Burns Demonstrating Melting, Dripping, Pooling, and Burning of Melted Upholstered Chair Padding.

6.3.7.8.5 The term *pour pattern* implies that a liquid has been poured or otherwise distributed, and therefore, is demonstrative of an intentional act. Because fire patterns resulting from burning ignitible liquids are not visually unique, the use of the term pour pattern and reference to the nature of the pattern should be avoided. The correct term for this fire pattern is an *irregularly shaped fire pattern*. The presence of an ignitible liquid should be confirmed by laboratory analysis. The determination of the nature of an irregular pattern should not be made by visual interpretation of the pattern alone. See Figure 6.3.7.8.5(a) and Figure 6.3.7.8.5(b) for examples of fire patterns on floors.

FIGURE 6.3.7.8.5(a) Fire Patterns on Floor Resulting from Fully Developed (Post-Flashover) Fire in Full Scale Test Burn of Residential Structure. Floor Was Carpeted and Room Had Typical Residential Furnishings; No Ignitible Liquids Were Present.

Source – NFPA 921, Chapter 6, 2008

Extract

FIGURE 6.3.7.8.5(b) Fire Patterns on Linoleum Floor Resulting from Fully Developed (Post-Flashover) Fire in Full-Scale Test Burn of Residential Structure; No Ignitible Liquids Were Present.

6.3.7.8.6 Liquids Versus Melted Solids. Many plastic materials will burn. Thermoplastics react to heating by first liquefying, and then, when they burn as liquids, they produce irregularly shaped or circular patterns. When found in unexpected places, such patterns can be erroneously identified as ignitible liquid patterns and associated with an incendiary fire cause. The investigator should be careful to identify properly the fuel sources for any irregularly shaped or circular patterns.

6.3.7.9 Doughnut-Shaped Patterns. A doughnut-shaped pattern, where an irregularly shaped burn area surrounds a less burned area, may result from an ignitible liquid. When a liquid causes this pattern, shown in Figure 6.3.7.9(a), it is due to the effects of the liquid cooling the center of the pool as it burns, while flames at the perimeter of the doughnut produce charring of the floor or floor covering. When this condition is found, further examination should be conducted for supporting evidence of ignitible liquids, especially on the interior of the pattern. See Figure 6.3.7.9(b).

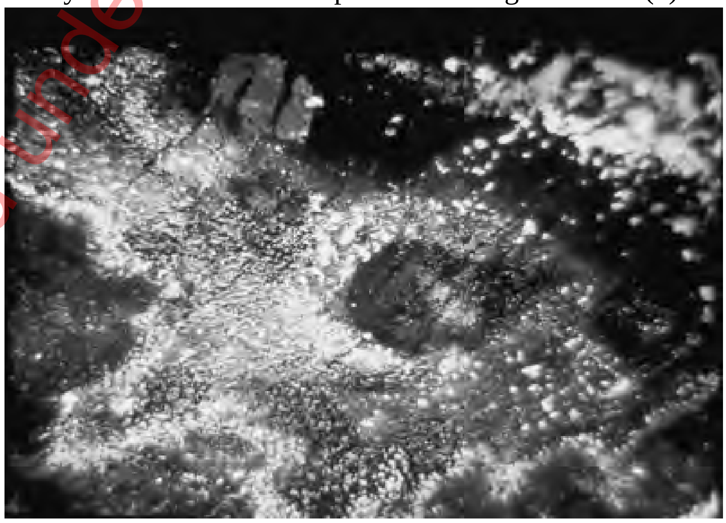


FIGURE 6.3.7.9(a) Doughnut-Shaped Fire Pattern on a Carpeted Floor.

Source – NFPA 921, Chapter 6, 2008

Extract

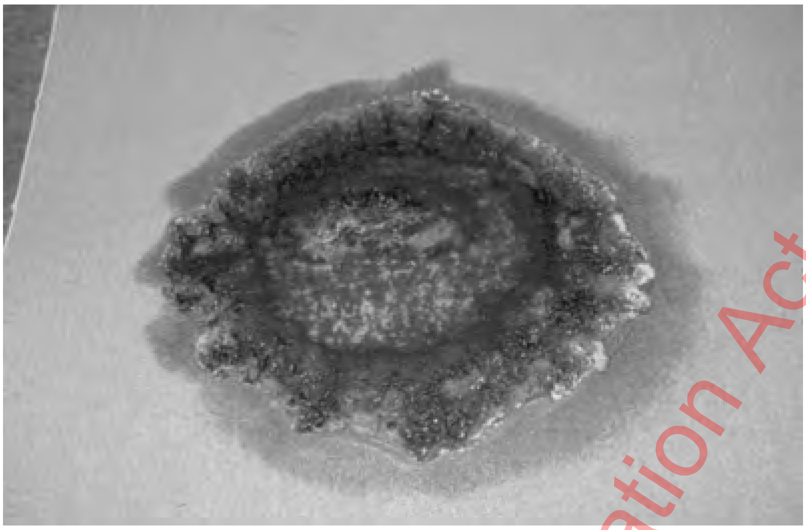


FIGURE 6.3.7.9(b) Doughnut-Shaped Fire Pattern on a Carpeted Floor Burn Test.

6.3.7.10 Linear Patterns. Patterns that have overall linear or elongated shapes can be called *linear patterns*. Linear patterns usually appear on horizontal surfaces.

6.3.7.10.1 Trailers. In many incendiary fires, when fuels are intentionally distributed or "trailed" from one area to another, the elongated patterns may be visible. Such fire patterns, known as "trailers," can be found along floors to connect separate fire sets, or up stairways as shown in Figure 6.3.7.10.1. Fuels used for trailers may be ignitible liquids, solids, or combinations of these.

FIGURE 6.3.7.10.1 Trailer Running Up a Stairway.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.7.10.2 Protected Floor Areas. Often when the floor area is cleared of debris to examine damage, long, wide, straight patterns will be found, showing areas of extensive heat damage bounded on each side by undamaged or less damaged areas. These patterns often have been interpreted to be "trailers." While this is possible, the presence of furniture, stock, counters, or storage may result in these linear patterns. These patterns may also result from wear on floors and the floor covering due to high traffic. Irregularly shaped objects on the floor, such as clothing or bedding, may also provide protection and produce patterns that may be inaccurately interpreted.

6.3.7.10.3 Fuel Gas Jets. Jets of ignited fuel gases, such as LP-Gas or natural gas, can produce linear patterns or lines of demarcation, particularly on noncombustible surfaces.

6.3.7.11 Area Patterns. Some patterns may appear to cover entire rooms or large areas without any readily identifiable source. These patterns are often formed when the fuels that create them are above the lower flammable limit and widely dispersed before ignition, or when the movement of the fire through the areas is very rapid, as in a flash fire.

6.3.7.11.1 Flashover and Full Room Involvement. In the course of a flashover transition, fire spreads rapidly to all exposed combustible materials as the fire progresses to full room involvement. *(See 5.10.2.6.)* This process can produce relatively uniform depths of char or calcination. If the fire is terminated before full room involvement, relatively uniform burning can be evident on vertical surfaces above the bottom of the hot layer. When the fire has progressed to full room involvement, the area pattern may be uneven and may extend to the floor. The uniformity described in this section may not be consistent throughout the room or space. Some exposed surfaces may exhibit little or no damage due to the ventilation effects or the locations of furnishings or fixtures that may prevent charring, darkening, or discoloration of wall and ceiling surfaces.

6.3.7.11.2 Flash Fires. The ignition of gases or vapors of liquids does not necessarily always cause explosions. Whether an explosion occurs depends on the location and concentration of diffuse fuels and on the geometry, venting, and strength of the confining structure.

6.3.7.11.2.1 If the diffuse fuels are near the lower flammable or lower explosive limit and there is no explosion, the fuels may burn as a flash fire, and there may be little or no subsequent burning. In the instance where the first fuel to be ignited is a diffuse fuel–air mixture, the area of greatest destruction may not, and generally does not, coincide with the area where the heat source ignites the mixture. The greatest destruction will occur where the flash fire from the burning mixture encounters a secondary fuel load that is capable of being ignited by the momentary intense temperature in the flame front. Likewise, once secondary ignition occurs, the dynamics of the fire spread will be dictated by the compartment and fuel geometry and the relative heat release rates of these secondary fuels. The relatively short duration of the burning may have little impact on the flashover in the compartment as compared to the burning of the secondary fuels. Therefore, origin determination of such a flash fire can be supported by accurate witness observations and the analysis of the potential ignition sources in the areas where the vapor or gas could have existed. When the analysis of fire patterns is the only means of determining the origin, the investigator should be aware that the resultant ignition of secondary fuels and compartment flashover could have altered or obliterated the subtle patterns created by the flash fire.

Source – NFPA 921, Chapter 6, 2008

Extract

6.3.7.11.2.2 The difficulty in detecting patterns caused by flash fires is the result of the total consumption of available fuel without significantly raising the temperatures of other combustibles. In this case, the fire patterns may be superficial and difficult to trace to any specific point of ignition as in Figure 6.3.7.11.2.2. In addition, separate areas of burning from pocket fuel gas may exist and further confuse the tracing of fire spread.

FIGURE 6.3.7.11.2.2 Blistering of Varnish on Door and Slight Scorching of Draperies, the Only Indications of the Natural Gas Flash Fire.

6.3.7.12 Saddle Burns. *Saddle burns* are distinctive U- or saddle-shaped patterns that are sometimes found on the top edges of floor joists. They are caused by fire burning downward through the floor above the affected joist. Saddle burns display deep charring, and the fire patterns are highly localized and gently curved. These patterns are often created by the burning of ignitible liquids. They also may be created by radiant heat from a burning material in close proximity to the floor, including materials that may melt and burn on the floor (e.g., polyurethane foam). Ventilation caused by floor openings may also contribute to the development of these patterns, shown in Figure 6.3.7.12.

FIGURE 6.3.7.12 Saddle Burn in a Floor Joist.

Source – NFPA 921, Chapter 6, 2008

Extract

6.4 Fire Pattern Analysis.
Fire pattern analysis is the process of identifying and interpreting fire patterns to determine how the patterns were created and their significance.

6.4.1 Types of Fire Patterns. There are two basic types of fire patterns: movement patterns and intensity patterns. These types of patterns are defined by the fire dynamics discussed in Section 5.10. Often a systematic use of more than one type of fire pattern at a fire scene can be used in combination to lead back to the heat source that produced them. Some patterns may display aspects defining both movement and intensity (heat/fuel).

6.4.1.1 Fire Spread (Movement) Patterns. Flame, heat, and smoke produce patterns as a result of fire growth, fire spread, and heat movement patterns are produced by the growth, spread, and the flow of products of combustion away from an initial heat source. If accurately identified and analyzed, these patterns can be traced back to the origin of the heat source that produced them.

6.4.1.2 Heat (Intensity) Patterns. Flames and hot gases produce patterns as a result of the response of materials to heat exposure. The various heat effects on materials can produce lines of demarcation. These lines of demarcation may be helpful to the investigator in determining the characteristics and quantities of fuel materials, as well as the direction of fire spread.

Source – NFPA 921, Chapter 6, 2008

4. Fire Cause Determination

NFPA 921, Chapter 18 – Fire Cause Determination

Extract

18.1 General.

18.1.1 The focus of this chapter is on determining the cause of a fire or explosion incident. The determination of the cause of a fire or explosion involves consideration of the circumstances, conditions, or agencies that bring together a fuel, ignition source, and oxidizer (such as air or oxygen).

18.1.2 The determination of the cause of a fire requires the identification of those materials, circumstances, and factors that were necessary for the fire to have occurred. Those materials, circumstances, and factors include, but are not limited to, the device, appliance, or equipment involved in the ignition, the presence of a competent ignition source, the type and form of the material first ignited, and the failures (e.g., high temperature thermostat on an appliance that fails to operate), circumstances (e.g., failure to monitor a cooking pot on a stove), or human actions (e.g., failure to shut off an appliance, failure to connect electrical wiring tightly in a receptacle resulting in high resistance connection, failure to activate fire suppression equipment, or an intentional act) that allowed the materials, circumstances, and factors to come together to allow the fire to occur.

18.1.3 An individual investigator may not have responsibility for, or be required to address, all of the issues described in this section. A particular investigation may or may not require that all of these issues be addressed.

18.1.4 The cause of any particular fire may involve several circumstances and factors. For example, consider a fire that starts when a blanket is ignited by an incandescent lamp in a closet. The various factors include having a lamp hanging down too close to the shelf, putting combustibles too close to the lamp, and leaving the lamp on while not using the closet. The absence of any one of those factors would have prevented the fire. The function of the investigator is to identify those materials and circumstances that contribute to the fire. For more complex situations, techniques such as fault trees *(see 20.3.1)* and failure mode and effects analysis *(see 20.3.2)* are systematic methods for the analysis of systems, which can help determine the cause of a fire.

Source – NFPA 921, Chapter 18, 2008.

Extract

18.2 Process of Elimination.

18.2.1 Any determination of fire cause should be based on evidence rather than on the absence of evidence; however, when the origin of a fire is clearly defined, it may be possible to make a credible determination regarding the cause of the fire, even when there is no physical evidence of the ignition source identified after the fire. This finding may be accomplished through the testing of alternate hypotheses involving other potential ignition sources, provided that the conclusion regarding the remaining ignition source is consistent with all known facts *(see Chapter 4, Basic Methodology)*. A clearly defined origin exists when it is known conclusively to the exclusion of all other potential origins. The process of elimination is not to be used indiscriminately. Whenever the origin is not clearly defined, this process is inappropriate and cannot be used. Some of the conditions and circumstances that prevent the origin from being clearly defined include the degree or extent of damage (such as those conditions found in fully developed compartment fires), or the adverse effects of fire suppression activities (such as fire scenes where excessive overhaul has occurred). In conditions and circumstances such as these examples, the origin is not likely to be clearly defined. As such, the use of this methodology is inappropriate. The positive identification of the origin is the most significant factor in determining whether the process of elimination is appropriate. If the origin cannot be positively identified to the exclusion of all other potential origins, no inferences regarding the ignition source should be made.

18.2.2 For example, an investigator may be able to logically infer that the ignition source came from an open flame, even if the device producing the open flame is not found at the scene. This conclusion may be properly reached as long as the analysis producing the conclusion follows the scientific method as discussed in Chapter H4H.

18.2.3 Elimination, which actually involves the developing, testing, and rejection of alternate hypotheses, becomes more difficult as the degree of destruction in the compartment of origin increases, and it is not possible in many cases. Whenever an investigator proposes the elimination of a particular system or appliance as the ignition source on the basis of appearance or visual observation, the investigator should be able to explain how the appearance or condition of that system or appliance would be different from what is observed, if that system or appliance were the ignition source for the fire.

18.2.4 There are times when visual differences do not exist; for example, when a heat-producing device or appliance ignites combustibles that are placed too close to it, the device itself may appear no different than if something else were the ignition source.

18.2.5 The "elimination of all accidental causes" to reach a conclusion that a fire was incendiary is a finding that can rarely be justified scientifically, using only physical data; however, the "elimination of all causes other than the application of an open flame" is a finding that may be justified in limited circumstances, where the area of origin is clearly defined and all other potential heat sources at the origin can be examined and credibly eliminated. It is recognized that in cases where a fire is ignited by the application of an open flame, there may be no evidence of the ignition source remaining.

18.2.6 In a determination of an accidental cause, the same precautions regarding elimination of other potential ignition sources should be carefully considered. For example, the determination that an appliance is the ignition source in a fire is not simply related to its being at the origin. Prior to an appliance being identified as the ignition source, the method or mode of failure should be established. It is equally important that the material first ignited and the ignition sequence also be identified, especially to establish a fire cause in the absence of the physical evidence of an ignition source.

Source - NFPA 921, Chapter 18, 2008.

Extract

18.3 Source and Form of Heat of Ignition.

18.3.1 The source of ignition energy will be at or near the point of origin, although in some circumstances the two may appear not to coincide. Sometimes the sources of ignition will remain at the point of origin in recognizable form, whereas other times the source may be altered greatly, destroyed, consumed, or moved. Nevertheless, the source should be identified in order for the cause to be proven. There are occasions when there is no physical evidence of the ignition source and where the source can only be inferred. However, these occasions are limited to those circumstances where the area of origin is clearly defined. *(See 18.2.5.)*

18.3.2 A competent ignition source will have sufficient temperature and energy and will be in contact with the fuel long enough to raise it to its ignition temperature.

18.3.3 The ignition process involves the following three components: generation, transmission, and heating, as described in 18.3.3(A) through 18.3.3(C).
(A) The competent ignition source will generate a level of energy sufficient to raise the fuel to its ignition temperature, and will be capable of transmitting that level of energy to the fuel.
(B) Transmission of sufficient energy raises the fuel to its ignition temperature. Where the energy source is in direct contact with the fuel, such as the contact of an overheated wire with its insulation, the transfer is a direct conduction from the source to the fuel. Where there is a separation, however, there should be a form of energy transport. This transport can be by contact with the flaming gases from a burning item, by radiation from the flame or surfaces or gases heated by that flame, or a combination of heating by the flow of hot gases and radiation.
(C) Heating of the potential fuel will occur by the energy that reaches it. Each fuel reacts differently to the energy that impacts on it. Some energy may be reflected, and some energy may be transmitted through the material. Some is dispersed through the material, and some heats the material, causing its temperature to rise. The term *thermal inertia* is used to describe the response of a material to the energy impacting on it. Thermal inertia is defined as the product of thermal conductivity, density, and specific heat (or heat capacity). *(See 5.2.1.)* These three properties determine the manner in which a material will transmit heat from the exposed surface to its core or to an unexposed surface, and distribute and absorb heat within the element itself. The surface temperature of a material with a low thermal inertia (such as foam plastic) will rise much more quickly when exposed to energy from a high-temperature source than will a material with higher thermal inertia (such as wood paneling). Thin materials will also heat more quickly from a given source of energy.

18.3.4 Once the area and possibly the point of origin are identified, the investigator should identify all heat-producing devices, appliances, or equipment that could have caused the ignition. Heat-producing devices can include fixed and portable heaters, gas-fired or electric appliances, furnaces, water heaters, wood stoves, lamps, internal combustion engines, clothes dryers, open flames, and incendiary devices.

18.3.5 The investigator should also look for devices, appliances, or equipment that may have malfunctioned or failed. Such devices include many of the foregoing, plus electrical service equipment, receptacles, kitchen and laundry appliances, motors, transformers, and heavy machinery.

18.3.6 Sources of ignition for gases or vapors include arcs from motors with brushes, arcs from switches that are not explosionproof, gas or electric pilots, or flames in gas appliances.

Source - NFPA 921, Chapter 18, 2008.

Extract

18.3.6.1 Flammable gases or liquid vapors, such as those from gasoline, may travel a considerable distance before reaching an ignition source. Only under specific conditions will ignition take place, the most important condition being concentration within the flammable limits and an ignition source of sufficient energy located in the flammable mixture. This separation of the fuel source and the origin of the fire can cause confusion.

While a review of surface and autoignition temperatures may suggest that cigarettes are a competent ignition source for ignitible liquids and gases, in reality, cigarettes make poor ignition sources for most ignitible liquids and gases. There are many coupled factors that have been proposed as responsible for the lack of ignition for most ignitible liquids and gases, including flammability limits (oxygen-depleted conditions at cigarette tip), surface temperature, residence time and ignition delay, burning velocity, minimum ignition energy, quenching distance, and insulating effect of cigarette ash.

18.3.7 Information should be obtained from owners or occupants, when possible, about what heat-producing devices, appliances, or equipment, all potential ignition sources, were in the area of origin, how and when they were used, and recent activities in the area. That type of gathering of information is especially important when the source of ignition does not survive the fire. The information would also be helpful in alerting an investigator to small or easily overlooked items when examining the area of origin. When electrical energy sources are considered as potential producers of the heat of ignition, the investigator should refer to Chapter 8.

18.4 First Material Ignited.

18.4.1 The first material ignited (initial fuel) is that which first sustains combustion beyond the igniting source. For example, the wood of the match would not be the initial fuel, but paper, ignitible liquid, or draperies would be, if the match were used to ignite them. The physical configuration of the fuel plays a significant role in its ability to be ignited. A nongaseous fuel with a high surface-to-mass ratio is much more readily ignitible than a fuel with a low surface-to-mass ratio. Examples of high surface-to-mass fuels include dusts, fibers, and paper. If the initial fuel has a high surface-to-mass ratio, then the intensity and duration characteristics for a heat source become less stringent. The higher the surface-to-mass ratio of the fuel, the less energy the heat source should produce to ignite the fuel, although the ignition temperature is the same. Gases and vapors are fully dispersed (in effect, an extremely high surface-to-mass ratio) and can be ignited by a low heat energy source instantly.

18.4.2 The initial fuel could be part of a device that malfunctions or fails. Examples include insulation on a wire that is heated to its ignition temperature by excessive current, or the plastic housing or cover on an overheating coffee maker.

18.4.3 The initial fuel might be something too close to a heat-producing device. Examples are clothing against an incandescent lamp or a radiant heater, wood framing too close to a wood stove or fireplace, or combustibles too close to an engine exhaust manifold or catalytic converter.

18.4.4 Identifying the initial fuel is important for understanding the events that caused the fire. For example, if the remains of a match were found on the burned surface of a wood end table in the area of origin, the match almost certainly would not have sufficient energy to ignite the solid wood surface. Maybe the match had been blown out and dropped there by an occupant. Was there any paper or other light-weight fuel that could have carried flame to a chair or other fuels? Remember that the initial fuel must be capable of being ignited within the limitations of the ignition source. The components in most buildings are not susceptible to ready ignition by heat sources, low energy, low temperature, or short duration. For example, flooring, drywall, structural lumber, wood cabinets, and carpeting do not ignite unless they are exposed to a substantial heat source. The investigator needs to identify easily ignited items that, once ignited, could provide the heat source to damage or involve these harder-to-ignite items. *(See 5.3.1.)*

Source - NFPA 921, Chapter 18, 2008.

Extract

18.4.5 Unusual residues might remain from the initial fuel. Those residues could arise from thermite, magnesium, or other pyrotechnic materials.

18.4.6 Gases and vapors can be the initial fuel and can cause confusion because the point of ignition can be some distance away from where sustained fire starts in the structure or furnishings. Also, flash fire may occur with sustained burning of light density materials, such as curtains, that are located away from the initial vapor-fuel source. When ignition causes a low-order explosion, it is obvious that a gas, vapor, or dust is involved. Layered vapors of gasoline might not ignite violently so that, unless evidence of the accelerant is found, the source of ignition many feet from where the puddle burned might be difficult to associate with the fire. *(See 5.3.2 and 5.3.3.)*

18.5 Ignition Sequence.

18.5.1 A fuel by itself or an ignition source by itself does not create a fire. Fire results from the combination of fuel and an ignition source. Therefore, the investigator should be cautious about deciding on a cause of a fire just because a readily ignitible fuel and potential ignition source are present. The sequence of events that allow the source of ignition and the fuel to get together establishes the cause.

18.5.2 Defining the ignition sequence requires determining events and conditions that might have occurred or might have been created in the past. Furthermore, the order in which those past events occurred might have to be determined. Consider a fire in a restaurant kitchen that started when a deep-fat fryer ignited and spread fire through the kitchen. The cause is more than simply “the deep-fat fryer overheated.” In this example, the investigator should seek to find an answer to the following questions as part of data gathering, hypothesis development, and hypothesis testing, in determining the fire cause as well as in affixing responsibility:

(1) Was the control thermostat turned up too high?
(2) Did the control contact stick?
(3) Why did the high temperature cutoff not prevent overheating?
(4) Was there a kitchen exhaust hood present?
(5) Was there a fire suppression system present?
(6) Was a power supply shutoff provided?
(7) Were the requirements of the manufacturer met?

18.5.2.1 The factors mentioned in 18.5.2(1) through 18.5.2(7) could make a difference between a minor incident and a large hostile fire. In each fire investigation, the various contributing factors should be investigated and included in the ultimate explanation of the ignition sequence. Furthermore, the investigator should be prepared to discuss generally the proper operation of the appliance, the safety elements built into the appliance, and the failure modes that would be necessary for the fire to have occurred.

Source - NFPA 921, Chapter 18, 2008.

Extract

18.5.3 The investigator should use the scientific method (see Chapter H4H) as the method for data gathering, hypothesis development, and hypothesis testing regarding the consideration of potential ignition sources. This process of consideration actually involves the development and testing of alternate hypotheses. In this case, a separate hypothesis is developed considering each individual heat source in the area of origin as a potential ignition source. Systematic evaluation (hypothesis testing) is then conducted with the elimination of those hypotheses that are not supportable (or refuted) by the facts discovered through further examination. The investigator is cautioned not to eliminate a heat source merely because there is no obvious evidence for it. For example, the investigator should not eliminate the electric heater because there is no arcing in the wires or because the contacts are not stuck. There may be other methods by which the heater could have been the ignition source other than a system failure, such as combustible materials being stored too close to it. Obviously, arson is not eliminated because a lab did not find accelerant in the evidence. Potential ignition sources should be eliminated from consideration only if there is definite evidence that they could not be the ignition source for the fire. For example, an electric heater can easily be eliminated from consideration if it was not plugged in.

18.6 Opinions.
When forming opinions from hypotheses about fires or explosions, the investigator should set standards for the level of certainty in those opinions. The following lists two levels of confidence that have significance with respect to opinions:

(1) *Probable.* This level of certainty corresponds to being more likely true than not. At this level of certainty, the likelihood of the hypothesis being true is greater than 50 percent.

(2) *Possible.* At this level of certainty, the hypothesis can be demonstrated to be feasible but cannot be declared probable. If two or more hypotheses are equally likely, then the level of certainty must be “possible.”

18.6.1 Use of the scientific method dictates that any hypothesis formed from an analysis of the data collected in an investigation must stand the challenge of reasonable examination, by the investigator testing his hypothesis or by the examination of others. *(See Chapter 4.) [See Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579, 113 S. Ct. 2786 (1993).]*

18.6.2 Ultimately, the decision as to the level of certainty in data collected in the investigation or of any hypothesis drawn from an analysis of the data rests with the investigator. The final opinion is only as good as the quality of the data used in reaching that opinion. If the level of certainty of the opinion is only “possible” or “suspected,” the cause should be listed as undetermined. Only when the level of certainty is considered probable can a fire cause be classified as accidental, incendiary, or natural.

Source - NFPA 921, Chapter 18, 2008.

5. Examination and Removal of Fire Debris

NFPA 921, Chapter 16 – Physical Evidence

Extract

16.1 General.
During the course of any fire investigation, the fire investigator is likely to be responsible for locating, collecting, identifying, storing, examining, and arranging for testing of physical evidence. The fire investigator should be thoroughly familiar with the recommended and accepted methods of processing such physical evidence.

16.2 Physical Evidence.

16.2.1 Physical evidence, defined generally, is any physical or tangible item that tends to prove or disprove a particular fact or issue. Physical evidence at the fire scene may be relevant to the issues of the origin, cause, spread, or the responsibility for the fire.

16.2.2 The decision on what physical evidence to collect at the incident scene for submission to a laboratory or other testing facility for examination and testing, or for support of a fact or opinion, rests with the fire investigator. This decision may be based on a variety of considerations, such as the scope of the investigation, legal requirements, or prohibition. *(See Section 13.2.)* Additional evidence may also be collected by others, including other investigators, insurance company representatives, manufacturer's representatives, owners, and occupants. The investigator should also be aware of standards and procedures relating to evidentiary issues and those issues related to spoliation of evidence.

16.3 Preservation of the Fire Scene and Physical Evidence.

16.3.1 General. Every attempt should be made to protect and preserve the fire scene as intact and undisturbed as possible, with the structure, contents, fixtures, and furnishings remaining in their pre-fire locations. Evidence such as the small paper match shown in Figure 16.3.1 could easily be destroyed or lost in an improperly preserved fire scene.

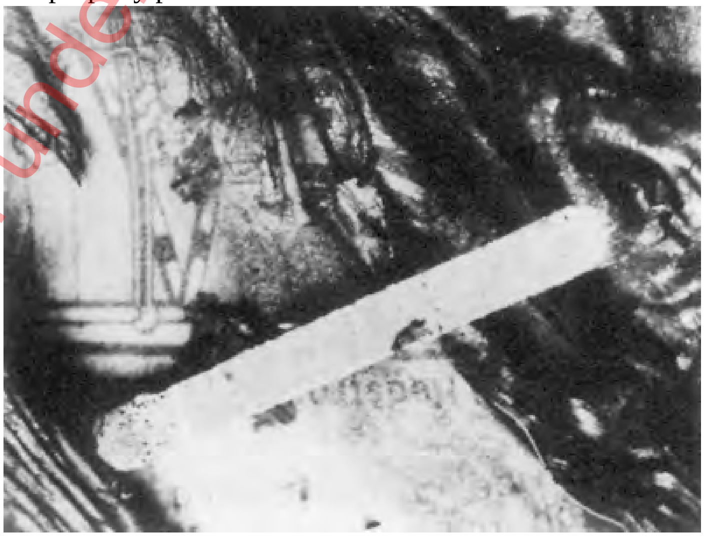


FIGURE 16.3.1 Physical Evidence at a Fire Scene.

Source – NFPA 921, Chapter 16, 2008.

Extract

16.3.1.1 Generally, the cause of a fire or explosion is not known until near the end of the investigation. Therefore, the evidentiary or interpretative value of various pieces of physical evidence observed at the scene may not be known until, at, or near the end of the fire scene examination, or until the end of the complete investigation. As a result, the entire fire scene should be considered physical evidence and should be protected and preserved. Consideration should be given to temporarily placing removed ash and debris into bags, tarps, or other suitable containers labeled as to the location from which it was removed. This way, if components from an appliance or an incendiary device are found to be missing they can be more easily found in a labeled container.

16.3.1.2 The responsibility for the preservation of the fire scene and physical evidence does not lie solely with the fire investigator, but should begin with arriving fire-fighting units or police authorities. Lack of preservation may result in the destruction, contamination, loss, or unnecessary movement of physical evidence. Initially, the incident commander and, later, the fire investigator should secure or ensure the security of the fire scene from unnecessary and unauthorized intrusions and should limit fire suppression activities to those that are necessary.

16.3.1.3 Evidence at the fire scene should be considered not only in a criminal context, such as in traditional forensic evidence (e.g., weapons, bodily fluids, footprints), nor should it be limited to arson-related evidence, items, or artifacts, such as incendiary devices or containers. Potential evidence at the fire scene and surrounding areas can include the physical structure, the contents, the artifacts, and any materials ignited or any material on which fire patterns appear.

16.3.2 Fire Patterns as Physical Evidence. The evidentiary and interpretative use of fire patterns may be valuable in the identification of a potential ignition source, such as an incendiary device in an arson fire or an appliance in an accidental fire. Fire patterns are the visible or measurable physical effects that remain after a fire. These include thermal effects on materials, such as charring, oxidation, consumption of combustibles, smoke and soot deposits, distortion, melting, color changes, changes in the character of materials, structural collapse, and other effects. *(See Section 6.3.)*

16.3.3 Artifact Evidence. Artifacts can be the remains of the material first ignited, the ignition source, or other items or components in some way related to the fire ignition, development, or spread. An artifact may also be an item on which fire patterns are present, in which case the preservation of the artifact is not for the item itself but for the fire pattern that is contained thereon.

16.3.4 Protecting Evidence.

16.3.4.1 There are a number of methods that can be utilized to protect evidence from destruction. Some methods include posting a fire fighter or police officer as a sentry to prevent or limit access to a building, a room, or an area; use of traffic cones or numerical markers to identify evidence or areas that warrant further examination; covering the area or evidence with tarpaulins prior to overhaul; or isolating the room or area with rope, caution tape, or police line tape. The investigator may benefit from supervising overhaul and salvage operations.

16.3.4.2 Items found at the fire scene, such as empty boxes or buckets, may be placed over an artifact. However, these items may not clearly identify the artifact as evidence that should be preserved by fire fighters or others at the fire scene. If evidence is not clearly identified, it may be susceptible to movement or destruction at the scene.

16.3.5 Role and Responsibilities of Fire Suppression Personnel in Preserving the Fire Scene.

16.3.5.1 Generally, fire officers and fire fighters have been instructed during basic fire training that they have a responsibility at the fire scene regarding fire investigation.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.3.5.1.1 In most cases, this responsibility is identified as recognizing the indicators of incendiarism, such as multiple fires, the presence of incendiary devices or trailers, and the presence of ignitible liquids at the area of origin *(see Section 22.2)*. While this is an important aspect of their responsibilities in the investigation of the fire cause, it is only a small part.

16.3.5.1.2 Prompt control and extinguishment of the fire protects evidence. The ability to preserve the fire scene is often an important element in the investigation. Even when fire officers and fire fighters are not responsible for actually determining the origin or cause of the fire, they play an integral part in the investigation by preserving the fire scene and physical evidence.

16.3.5.2 Preservation. Once an artifact or other evidence has been discovered, preliminary steps should be taken to preserve and protect the item from loss, destruction, or movement. The person making the discovery should notify the incident commander as soon as practical. The incident commander should notify the fire investigator or other appropriate individual or agency with the authority and responsibility for the documentation and collection of the evidence.

16.3.5.3 Caution in Fire Suppression Operations. Fire crews should avoid causing unnecessary damage to evidence when using straight-stream hoselines, pulling ceilings, breaking windows, collapsing walls, and performing overhaul and salvage.

16.3.5.3.1 Use of Water Lines and Hose Streams. When possible, fire fighters should use caution with straight-stream applications, particularly at the base of the fire, because the base of the fire may be the area of origin. Evidence of the ignition source can sometimes be found at the area of origin. The use of hoselines, particularly straight-stream applications, can move, damage, or destroy physical evidence that may be present.
(A) The use of water hoselines for overhaul operations such as washing down, or for opening up walls or ceilings, should also be restricted to areas away from possible areas of origin.
(B) The use of water should be controlled in areas where the investigator may wish to look at the floor for possible fire patterns. When draining the floor of standing water, the drain hole should be located so as to have the least impact on the fire scene and fire patterns.

16.3.5.3.2 Overhaul.
(A) It is during overhaul that any remaining evidence not damaged by the fire is susceptible to being destroyed or displaced. Excessive overhaul of the fire scene prior to the documentation and analysis of fire patterns can affect the investigation, including failure to determine the area of origin.
(B) While the fire fighters have a responsibility to control and extinguish the fire and then check for fire extension, they are also responsible for the preservation of evidence. These two responsibilities may appear to be in conflict and, as a result, it is usually the evidence that is affected during the search for hidden fire. However, if overhaul operations are performed in a systematic manner, both responsibilities can be met successfully.

16.3.5.3.3 Salvage. The movement or removal of artifacts from a fire scene can make the reconstruction difficult for the investigator. If the investigator cannot determine the pre-fire location of the evidence, the analytical or interpretative value of the evidence may be lost. Moving, and particularly removing, contents and furnishings or other evidences at the fire scene should be avoided until the documentation, reconstruction, and analysis are completed.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.3.5.3.4 Movement of Knobs and Switches. Fire fighters should refrain from turning knobs and operating switches on any equipment, appliances, or utility services at the fire scene. The position of components, such as the knobs and switches, may be a necessary element in the investigation, particularly in developing fire ignition scenarios or hypotheses. These components, which are often constructed of plastics, can become very brittle when subjected to heating. Their movement may alter the original post-fire state and may cause the switch to break or to become impossible to relocate in its original post-fire position. *(See 24.5.3.)*

16.3.5.3.5 Use of Power Tools. The use of gasoline- or diesel-powered tools and equipment should be controlled carefully in certain locations. The refueling of any fuel-powered equipment or tools should be done outside the perimeter of the fire scene. Whenever fuel-powered equipment is used on the fire scene, its use and location should be documented and the investigator advised.

16.3.5.3.6 Limiting Access of Fire Fighters and Other Emergency Personnel. Access to the fire scene should be limited to those persons who need to be there. This precaution includes limiting fire fighters and other emergency or rescue personnel to those necessary for the task at hand. When possible, the activity or operation should be postponed until the evidence has been documented, protected, evaluated, and collected.

16.3.6 Role and Responsibilities of the Fire Investigator. If the fire fighters have not taken the preliminary steps to preserve or protect the fire scene, then the fire investigator should assume the responsibility for doing so. Then, depending on the individual's authority and responsibility, the investigator should document, analyze, and collect the evidence.

16.3.7 Practical Considerations. The precautions in this section should not be interpreted as requiring the unsafe or infinite preservation of the fire scene. It may be necessary to repair or demolish the scene for safety or for other practical reasons. Once the scene has been documented by interested parties and the relevant evidence removed, there is no reason to continue to preserve the scene. The decision as to when sufficient steps have been taken to allow the resumption of normal activities should be made by all interested parties known at that time.

16.4 Contamination of Physical Evidence.
Contamination of physical evidence can occur from improper methods of collection, storage, or shipment. Like improper preservation of the fire scene, any contamination of physical evidence may reduce the evidentiary value of the physical evidence.

16.4.1 Contamination of Evidence Containers.
16.4.1.1 Unless care is taken, physical evidence may become contaminated through the use of contaminated evidence containers. For this reason, the fire investigator should take every reasonable precaution to ensure that new and uncontaminated evidence containers are stored separately from used containers or contaminated areas.

16.4.1.2 One practice that may help to limit a possible source of cross-contamination of evidence collection containers, including steel paint cans or glass jars, is to seal them immediately after receipt from the supplier. The containers should remain sealed during storage and transportation to the evidence collection site. An evidence collection container should be opened only to receive evidence at the collection point, at which time it should be resealed pending laboratory examination.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.4.2 Contamination During Collection. Most contamination of physical evidence occurs during its collection. This is especially true during the collection of liquid and solid accelerant evidence. The liquid and solid accelerant may be absorbed by the fire investigator's gloves or may be transferred onto the collection tools and instruments.

16.4.2.1 Avoiding cross-contamination of any subsequent physical evidence, therefore, becomes critical to the fire investigator. To prevent such cross-contamination, the fire investigator can wear disposable plastic gloves or place his or her hands into plastic bags during the collection of the liquid or solid accelerant evidence. New gloves or bags should always be used during the collection of each subsequent item of liquid or solid accelerant evidence.

16.4.2.2 An alternative method to limit contamination during collection is to utilize the evidence container itself as the collection tool. For example, the lid of a metal can may be used to scoop the physical evidence into the can, thereby eliminating any cross-contamination from the fire investigator's hands, gloves, or tools.

16.4.2.3 Similarly, any collection tools or overhaul equipment such as brooms, shovels, or squeegees utilized by the fire investigator need to be cleaned thoroughly between the collection of each item of liquid or solid accelerant evidence to prevent similar cross-contamination. The fire investigator should be careful, however, not to use waterless or other types of cleaners that may contain volatile solvents.

16.4.3 Contamination by Fire Fighters. Contamination is possible when fire fighters are using or refilling fuel-powered tools and equipment in an area where an investigator later tests for the presence or omission of an ignitible liquid. Fire fighters should take the necessary precautions to ensure that the possibility of contamination is kept to a minimum, and the investigator should be informed when the possibility of contamination exists.

16.5 Methods of Collection.

16.5.1 General. The collection of physical evidence is an integral part of a properly conducted fire investigation.

16.5.1.1 The method of collection of the physical evidence is determined by many factors, including the following:

(1) *Physical State.* Whether the physical evidence is a solid, liquid, or gas
(2) *Physical Characteristics.* The size, shape, and weight of the physical evidence
(3) *Fragility.* How easily the physical evidence may be broken, damaged, or altered
(4) *Volatility.* How easily the physical evidence may evaporate

Regardless of which method of collection is employed, the fire investigator should be guided by ASTM standards as well as by the policies and procedures of the laboratory that will examine or test the physical evidence.

16.5.2 Documenting the Collection of Physical Evidence.

16.5.2.1 Physical evidence should be thoroughly documented before it is moved. This documentation can be best accomplished through field notes, written reports, sketches, and diagrams, with accurate measurements and photography. The diagramming and photography should always be accomplished before the physical evidence is moved or disturbed. The investigator should strive to maintain a list of all evidence removed and of who removed it.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.5.2.2 The purpose of such documentation is twofold. First, the documentation should assist the fire investigator in establishing the origin of the physical evidence, including not only its location at the time of discovery, but also its condition and relationship to the fire investigation. Second, the documentation should also assist the fire investigator in establishing that the physical evidence has not been contaminated or altered. *(See 15.2.6.8.)*

16.5.3 Collection of Traditional Forensic Physical Evidence. Traditional forensic physical evidence includes, but is not limited to, finger and palm prints, bodily fluids such as blood and saliva, hair and fibers, footwear impressions, tool marks, soils and sand, woods and sawdust, glass, paint, metals, handwriting, questioned documents, and general types of trace evidence. Although usually associated with other types of investigations, these types of physical evidence may also become part of a fire investigation. The recommended methods of collection of such traditional forensic physical evidence vary greatly. As such, the fire investigator should consult with the forensic laboratory that will examine or test the physical evidence.

16.5.4 Collection of Evidence for Accelerant Testing. An accelerant is any fuel or oxidizer, often an ignitible liquid, used to initiate a fire or increase the rate of growth or speed the spread of fire. Accelerant may be found in any state: gas, liquid, or solid. Evidence for accelerant testing should be collected and tested in accordance with ASTM E 1387, *Standard Test Method for Ignitible Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography*, or with ASTM E 1618, *Standard Test Method for Ignitible Liquid Residues in Extracts from Fire Debris by Gas Chromatography–Mass Spectrometry*.

16.5.4.1 Liquid Accelerant Characteristics. Liquid accelerants have unique characteristics that are directly related to their collection as physical evidence. These characteristics include the following:

(1) Liquid accelerants are readily absorbed by most structural components, interior furnishings, and other fire debris.
(2) Generally, liquid accelerants float when in contact with water (alcohol is a noted exception).
(3) Liquid accelerants have remarkable persistence (survivability) when trapped within porous material.

16.5.4.2 Canine/Handler Teams. When a canine/handler team is used to detect possible evidence of accelerant use, the handler should be allowed to decide what areas (if any) of a building or site to examine. Prior to any search, the handler should carefully evaluate the site for safety and health risks such as collapse, falling, toxic materials, residual heat, and vapors, and should be the final arbiter of whether the canine is allowed to search. It should also be the handler's decision whether to search all of a building or site, even areas not involved in the fire. The canine/handler team can assist with the examination of debris (loose or packaged) removed from the immediate scene as a screening step to confirm whether the appropriate debris has been recovered for laboratory analysis.

16.5.4.3 Collection of Liquid Samples for Ignitible Liquid Testing. When a possible ignitible liquid is found in a liquid state, it can be collected using any one of a variety of methods. Whichever method is employed, however, the fire investigator should be certain that the evidence does not become contaminated. If readily accessible, the liquid may be collected with a new syringe, eye dropper, pipette, siphoning device, or the evidence container itself. Sterile cotton balls or gauze pads may also be used to absorb the liquid. This method of collection results in the liquid becoming absorbed by the cotton balls or gauze pads. The cotton balls or gauze pads and their absorbed contents then become the physical evidence that should be sealed in an airtight container and submitted to the laboratory for examination and testing.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.5.4.4 Collection of Liquid Evidence Absorbed by Solid Materials. Often, liquid accelerant evidence may be found only where the liquid accelerant has been absorbed by solid materials, including soils and sands. This method of collection merely involves the collection of these solid materials with their absorbed contents. The collection of these solid materials may be accomplished by scooping them with the evidence container itself or by cutting, sawing, or scraping. Raw, unsealed, or sawed edges, ends, nail holes, cracks, knot holes, and other similar areas of wood, plaster, sheet rock, mortar, or even concrete are particularly good areas to sample. If deep penetration is suspected, the entire cross-section of material should be removed and preserved for laboratory evaluation. In some solid material, such as soil or sand, the liquid accelerant may absorb deeply into the material. The investigator should therefore remove samples from a greater depth. In those situations where liquid accelerants are believed to have become trapped in porous material, such as a concrete floor, the fire investigator may use absorbent materials such as lime, diatomaceous earth, or non-self-rising flour. This method of collection involves spreading the absorbent onto the concrete surface, allowing it to stand for 20 to 30 minutes, and securing it in a clean, airtight container. The absorbent is then extracted in the laboratory. The investigator should be careful to use clean tools and containers for the recovery step, because the absorbent is easily contaminated. A sample of the unused absorbent should be preserved separately for analysis as a comparison sample.

16.5.4.5 Collection of Solid Samples for Accelerant Testing. Solid accelerant may be common household materials and compounds or dangerous chemicals. Because some incendiary materials remain corrosive or reactive, care should be taken in packaging to ensure that the corrosive residues do not attack the packaging container. In addition, such materials should be handled carefully by personnel for their own safety.

16.5.4.6 Comparison Samples. When physical evidence is collected for examination and testing, it is often necessary to also collect comparison samples.

16.5.4.6.1 The collection of comparison samples is especially important in the collection of materials that are believed to contain liquid or solid accelerant. For example, the comparison sample for physical evidence consisting of a piece of carpeting believed to contain a liquid accelerant would be a piece of the same carpeting that does not contain any of the liquid accelerant. Comparison samples allow the laboratory to evaluate the possible contributions of volatile pyrolysis products to the analysis and also to estimate the flammability properties of the normal fuel present.

16.5.4.6.2 When collected for the purpose of identifying the presence of accelerant residue, the comparison sample should be collected from an area that the investigator believes is free of such accelerants, such as under furniture or in areas that have not been involved in the fire. Assuming that the comparison sample tests negative for ignitible liquids, any ignitible liquids that are found in the suspect sample can be shown to be foreign to the area when the suspect sample was taken.

16.5.4.6.3 It is recognized that comparison samples may be unavailable due to the condition of the fire scene. It is also recognized that comparison samples are frequently unnecessary for the valid identification of ignitible liquid residue. The determination of whether comparison samples are necessary is made by the laboratory analyst, but because it is usually impossible for an investigator to return to a scene to collect comparison samples, they should be collected at the time of the initial investigation.

16.5.4.6.4 If mechanical or electrical equipment is suspected in the fire ignition, exemplar equipment may be identified and collected or purchased as a comparison sample.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.5.4.7.4 Canine Teams. Properly trained and validated ignitible liquid detection canine/handler teams have proven their ability to improve fire investigations by assisting in the location and collection of samples for laboratory analysis for the presence of ignitible liquids. The proper use of detection canines is to assist with the location and selection of samples.

16.5.4.7.1 In order for the presence or absence of an ignitible liquid to be scientifically confirmed in a sample, that sample should be analyzed by a laboratory in accordance with 16.5.3. Any canine alert not confirmed by laboratory analysis should not be considered validated.

16.5.4.7.2 Research has shown that canines have responded or have been alerted to pyrolysis products that are not produced by an ignitible liquid and have not always responded when an ignitible liquid accelerant was known to be present. If an investigator feels that there are indicators of an accelerant, samples should be taken even in the absence of a canine alert.

16.5.4.7.3 The canine olfactory system is believed capable of detecting gasoline at concentrations below those normally cited for laboratory methods. The detection limit, however, is not the sole criterion or even the most important criterion for any forensic technique. Specificity, the ability to distinguish between ignitible liquids and background materials, is even more important than sensitivity for detection of any ignitible liquid residues. Unlike explosive- or drug-detecting dogs, these canines are trained to detect substances that are common to our everyday environment. The techniques exist today for forensic laboratories to detect submicroliter quantities of ignitible liquids, but because these substances are intrinsic to our mechanized world, merely detecting such quantities is of limited evidential value.

16.5.4.7.4 Current research does not indicate which individual chemical compounds or classes of chemical compounds are the key “triggers” for canine alerts. Research reveals that most classes of compounds contained in ignitible liquids may be produced from the burning of common synthetic materials. Laboratories that use ASTM standards (*see Section 16.10*) have minimum standards that define those chemical compounds that must be present in order to make a positive determination. The sheer variety of pyrolysis products present in fire scenes suggests possible reasons for some unconfirmed alerts by canines. The discriminatory ability of the canine to distinguish between pyrolysis products and ignitible liquids is remarkable but not infallible.

16.5.4.7.5 The proper objective of the use of canine/handler teams is to assist with the selection of samples that have a higher probability of laboratory confirmation than samples selected without the canine’s assistance.

16.5.4.7.6 Canine ignitible liquid detection should be used in conjunction with, and not in place of, the other fire investigation and analysis methods described in this guide.

16.5.5 Collection of Gaseous Samples. During certain types of fire and explosion investigations, especially those involving fuel gases, it may become necessary for the fire investigator to collect a gaseous sample. The collection of gaseous samples may be accomplished by several methods.

16.5.5.1 The first method involves the use of commercially available mechanical sampling devices. These devices merely draw a sample of the gaseous atmosphere and contain it in a sample chamber or draw it through a trap of charcoal- or polymer-adsorbing material for later analysis.

16.5.5.2 Another method is the utilization of evacuated air-sampling cans. These cans are specifically designed for taking gaseous samples.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.5.6 Collection of Electrical Equipment and System Components. Before attempting to collect electrical equipment or components from circuits of a power distribution system, the fire investigator should verify that all sources of electricity are off or disconnected. All safety procedures described in Chapter H12H should be followed. Electrical equipment and components may be collected as physical evidence to assist the fire investigator in determining whether the component was related to the cause of the fire.

16.5.6.1 Electrical components, after being involved in a fire, may become brittle and subject to damage if mishandled. Therefore, methods and procedures used in collection should preserve, as far as practical, the condition in which the physical evidence was found. Before any electrical component is collected as physical evidence, it should be thoroughly documented, including being photographed and diagrammed. Electrical wiring can usually be cut easily and removed. This type of evidence may consist of a short piece, a severed or melted end, or it might be a much longer piece, including an unburned section where the wiring's insulation is still intact. The fire investigator should collect the longest section of wiring practicable so that any remaining insulation can also be examined. Before wires are cut, a photograph should be taken of the wire(s), and then both ends of the wire should be tagged and cut so that they can be identified as one of the following:

(1) The device or appliance to which it was attached or from which it was severed
(2) The circuit breaker or fuse number or location to which the wire was attached or from which it was severed
(3) The wire's path or the route it took between the device and the circuit protector.

16.5.6.2 Electrical switches, receptacles, thermostats, relays, junction boxes, electrical distribution panels, and similar equipment and components are often collected as physical evidence. It is recommended that these types of electrical evidence be removed intact, in the condition in which they were found.

16.5.6.3 When practical, it is recommended that any fixtures housing such equipment and components be removed without disturbing the components within them. Electrical distribution panels, for example, should be removed intact. An alternative method, however, would be the removal of individual fuse holders or circuit breakers from the panel. If the removal of individual components becomes necessary, the fire investigator should be careful not to operate or manipulate them while being careful to document their position and their function in the overall electrical distribution system.

16.5.6.4 If the investigator is unfamiliar with the equipment, he or she should obtain assistance from someone knowledgeable regarding the equipment, prior to disassembly or on-scene testing, to prevent damage to the equipment or components.

16.5.7 Collection of Appliances or Small Electrical Equipment. Whenever an appliance or other type of equipment is believed to be part of the ignition scenario, it is recommended that the fire investigator have it examined or tested. Appliances may be collected as physical evidence to support the fire investigator's determination that the appliance was or was not the cause of the fire. This type of physical evidence may include many diverse items, from the large (e.g., furnaces, water heaters, stoves, washers, dryers) to the small (e.g., toasters, coffee pots, radios, irons, lamps).

16.5.7.1 Where practical, the entire appliance or item of equipment should be collected intact as physical evidence. This includes any electrical power cords or fuel lines supplying or controlling it.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.5.7.2 Where the size or damaged condition of an appliance or item of equipment makes it impractical to be removed in its entirety, it is recommended that it be secured in place for examination and testing. Often, however, only a single component or group of components in an appliance or item of equipment may be collected as physical evidence. The fire investigator should strive to ensure that the removal, transportation, and storage of such evidence maintains the physical evidence in its originally discovered condition. *(See 11.3.5 on spoliation.)*

16.6 Evidence Containers.

16.6.1 General. Once collected, physical evidence should be placed and stored in an appropriate evidence container.

16.6.1.1 Like the collection of the physical evidence itself, the selection of an appropriate evidence container also depends on the physical state, physical characteristics, fragility, and volatility of the physical evidence. The evidence container should preserve the integrity of the evidence and should prevent any change to or contamination of the evidence. Evidence should not be packed directly in loose packing materials, such as "peanuts" or shredded paper, but first placed in a proper bag or container to avoid the loss of small items. Alternatively, the packing material can be placed in bags and packed around the evidence.

16.6.1.2 Evidence containers may be common items, such as envelopes, paper bags, plastic bags, glass containers, or metal cans, or they may be containers specifically designed for certain types of physical evidence. The investigator's selection of an appropriate evidence container should be guided by the policies and procedures of the laboratory that will examine or test the physical evidence or the use to which the evidence will be subjected.

16.6.2 Liquid and Solid Accelerant Evidence Containers. It is recommended that containers used for the collection of liquid and solid accelerant evidence be limited to four types. These include metal cans, glass jars, special evidence bags, and common plastic evidence bags. The fire investigator should be concerned with preventing the evaporation of the accelerant and preventing its contamination. It is important, therefore, that the container used be completely sealed to prohibit such evaporation or contamination.

16.6.2.1 Metal Cans. The recommended container for the collection of liquid and solid accelerant evidence is an unused, clean metal can, as shown in Figure 16.6.2.1. In order to allow space for vapors to collect, the can should be not more than two-thirds full.

FIGURE 16.6.2.1 Various Types of Metal Cans.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.6.2.1.1 The advantages of using metal cans include their availability, economic price, durability, and ability to prevent the evaporation of volatile liquids.

16.6.2.1.2 The disadvantages, however, include the inability to view the evidence without opening the container, the space requirements for storage, and the tendency of the container to rust when stored for long periods of time. If metal cans are used to store bulk quantities of volatile liquids, such as gasoline, high storage temperatures [above 38°C (100°F)] can produce sufficient vapor pressure to force the lid open and cause loss of sample. For such samples, glass jars may be more appropriate.

16.6.2.2 Glass Jars. Glass jars can also be used for the collection of liquid and solid accelerant evidence. It is important that the jars not have glued cap liners or rubber seals, especially when bulk liquids are collected. The glue often contains traces of solvent that can contaminate the sample, and rubber seals can soften or even dissolve in the presence of liquid accelerants or their vapors, allowing leakage or loss of the sample. In order to allow space for vapor samples to be taken during examination and testing, the glass jar should be not more than two-thirds full.

16.6.2.2.1 The advantages of using glass jars include their availability, their low price, the ability to view the evidence without opening the jar, the ability to prevent the evaporation of volatile liquids, and their lack of deterioration when stored for long periods of time.

16.6.2.2.2 The disadvantages, however, include their tendency to break easily and their physical size, which often prohibits the storage of large quantities of physical evidence.

16.6.2.3 Special Evidence Bags. Special bags, designed specifically for liquid and solid accelerant evidence, can also be used for collection. Unlike common plastic evidence bags, these special evidence bags do not have a chemical composition that can cause erroneous test results during laboratory examination and during testing of the physical evidence contained in such bags.

16.6.2.3.1 The advantages of using special evidence bags include their availability in a variety of shapes and sizes, their economic price, the ability to view the evidence without opening the bag, their ease of storage, and the ability to prevent the evaporation of volatile liquids.

16.6.2.3.2 The disadvantages, however, are that they are susceptible to being damaged easily, resulting in the contamination of the physical evidence contained in them, and they may be difficult to seal adequately.

16.6.2.4 Common Plastic Bags. While they are not generally usable for volatile evidence, common (polyethylene) plastic bags can be used for some evidence packaging. They can be used for packaging incendiary devices or solid accelerant residues, but they could be permeable, allowing for loss and contamination.

16.6.2.4.1 The advantages of using common plastic bags include their availability in a variety of shapes and sizes, their economic price, the ability to view the evidence without opening the bag, and their ease of storage.

16.6.2.4.2 The disadvantages, however, are their susceptibility to easy damage (tearing and penetration), resulting in the contamination of the physical evidence contained in them, and their marked inability to retain light hydrocarbons and alcohols, resulting in loss of the sample, misidentification, or cross-contamination between containers in the same box.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.7 Identification of Physical Evidence.
All evidence should be marked or labeled for identification at the time of collection, as required by ASTM E 1188, *Standard Practice for Collection and Preservation of Information and Physical Items by a Technical Investigator*, and ASTM E 1459, *Standard Guide for Physical Evidence Labeling and Related Documentation*.

16.7.1 Recommended identification includes the name of the fire investigator collecting the physical evidence, the date and time of collection, an identification name or number, the case number and item designation, a description of the physical evidence, and where the physical evidence was located. This can be accomplished directly on the container (*see Figure 16.7.1*) or on a preprinted tag or label that is then securely fastened to the container.

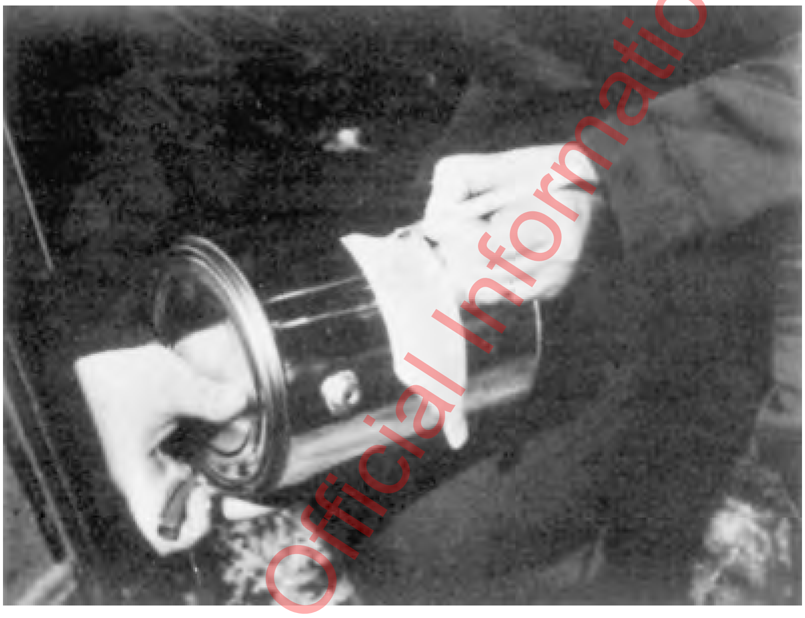


FIGURE 16.7.1 Marking of the Evidence Container.

16.7.2 The fire investigator should be careful that the identification of the physical evidence cannot be easily damaged, lost, removed, or altered. The fire investigator also should be careful that the placement of the identification, especially adhesive labels, does not interfere with subsequent examination or testing of the physical evidence at the laboratory.

16.8 Transportation and Storage of Physical Evidence.
Transportation of physical evidence to the laboratory or testing facility can be done either by hand delivery or by shipment.

16.8.1 Hand Delivery. Whenever possible, it is recommended that physical evidence be hand delivered for examination and testing. Hand delivery minimizes the potential of the physical evidence becoming damaged, misplaced, or stolen.

16.8.1.1 During such hand delivery, the fire investigator should take every precaution to preserve the integrity of the physical evidence. It is recommended that the physical evidence remain in the immediate possession and control of the fire investigator until arrival and transfer of custody at the laboratory or testing facility.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.8.2.1.2 The individual evidence container should be packaged securely within the shipping container. A letter of transmittal should be included. The letter of transmittal is a written request for laboratory examination and testing. It should include the name, address, and telephone number of the fire investigator; a detailed listing of the physical evidence being submitted for examination and testing; the nature and scope of the examination and testing desired; and any other information required, depending on the nature and scope of the examination and testing requested. This letter of transmittal may also include the facts and circumstances of the incident yielding the physical evidence.

16.8.2.1.3 The sealed package should be shipped by registered United States mail or any commercial courier service. The fire investigator should, however, always request return receipts and signature surveillance.

16.8.2.2 Shipping Electrical Evidence. In addition to the procedures described in 16.8.2.1, the investigator should be aware that some electrical equipment with sensitive electromechanical components may not be suitable for shipment. Examples include certain circuit breakers, relays, or thermostats. The fire investigator should consult personnel at laboratory or testing facilities for advice on how to transport the evidence.

16.8.2.3 Shipping of Volatile or Hazardous Materials. The fire investigator is cautioned about shipping volatile or hazardous materials. The investigator should ensure that such shipments are made in accordance with applicable federal, state, and local laws. When dealing with volatile evidence, it is important that the evidence be protected from extremes of temperature. Freezing or heating of the volatile materials may affect lab test results. Generally, the lower the temperature at which the evidence is stored, the better the volatile sample will be preserved, but it should not be allowed to freeze.

16.8.3 Storage of Evidence. Physical evidence should be maintained in the best possible condition until it is no longer needed. It should always be protected from loss, contamination, and degradation. Heat, sunlight, and moisture are the chief sources of degradation of most kinds of evidence. Dry and dark conditions are preferred, and the cooler the better. Opening of sealed evidence bags containing evidence not intended for accelerant testing will allow moisture to evaporate, will better preserve metallic items, and can prevent molding of organic items such as wet clothing. Refrigeration of volatile evidence is strongly recommended. If a sample is being collected for fire-debris analysis, it may be frozen, since freezing will prevent microbial and other biological degradation. However, freezing may interfere with flash point or other physical tests and may burst water-filled containers.

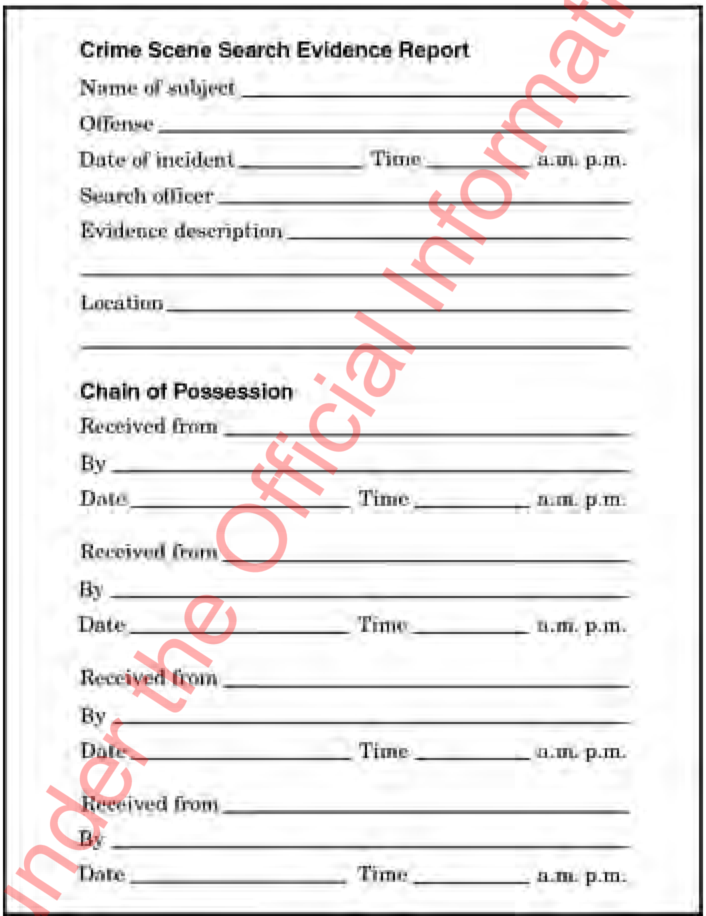
Source - NFPA 921, Chapter 16, 2008.

Extract

16.9 Chain of Custody of Physical Evidence.

16.9.1 The value of physical evidence entirely depends on the fire investigator's efforts to maintain the security and integrity of that physical evidence from the time of its initial discovery and collection to its subsequent examination and testing. At all times after its discovery and collection, physical evidence should be stored in a secured location that is designed and designated for this purpose. Access to this storage location should be limited in order to limit the chain of custody to as few persons as possible. Wherever possible, the desired storage location is one that is under the sole control of the fire investigator.

16.9.2 When it is necessary to pass chain of custody from one person to another, it should be done using a form on which the receiving person signs for the physical evidence. Figure 16.9.2 shows an example of such a form.



Crime Scene Search Evidence Report

Name of subject ____________________

Offense ____________________

Date of incident __________ Time __________ a.m. p.m.

Search officer ____________________

Evidence description ____________________

____

Location ____________________

____

Chain of Possession

Received from ____________________

By ____________________

Date __________ Time __________ a.m. p.m.

Received from ____________________

By ____________________

Date __________ Time __________ a.m. p.m.

Received from ____________________

By ____________________

Date __________ Time __________ a.m. p.m.

Received from ____________________

By ____________________

Date __________ Time __________ a.m. p.m.

FIGURE 16.9.2 Chain of Custody Form.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.10 Examination and Testing of Physical Evidence.
Once collected, physical evidence is usually examined and tested in a laboratory or other testing facility. Physical evidence may be examined and tested to identify its chemical composition; to establish its physical properties; to determine its conformity or lack of conformity to certain legal standards; to establish its operation, inoperation, or malfunction; to determine its design sufficiency or deficiency, or other issues that will provide the fire investigator with an opportunity to understand and determine the origin of a fire, the specific cause of a fire, the contributing factors to a fire's spread, or the responsibility for a fire. The investigator should consult with the laboratory or other testing facility to determine what specific services are provided and what limitations are in effect.

16.10.1 Laboratory Examination and Testing. A wide variety of standardized tests are available, depending on the physical evidence and the issue or hypothesis being examined or tested. Such tests should be performed and carried out by procedures that have been standardized by some recognized group. Such conformance better ensures that the results are valid and that they will be comparable to results from other laboratories or testing facilities.

16.10.1.1 It should be noted that the results of many laboratory examinations and tests may be affected by a variety of factors. These factors include the abilities of the person conducting or interpreting the test, the capabilities of the particular test apparatus, the maintenance or condition of the particular test apparatus, sufficiency of the test protocol, and the quality of the sample or specimen being tested. Fire investigators should be aware of these factors when using the interpretations of test results.

16.10.1.2 If it is determined that testing might alter the evidence, interested parties should be notified prior to testing to allow them an opportunity to object or be present at the testing. Guidance regarding notification can be found in ASTM E 860, *Standard Practice for Examining and Testing Items That Are or May Become Involved in Product Liability Litigation. (See also 16.5.4.6.)*

16.10.2 Test Methods. The following is a listing of selected analytical methods and tests that are applicable to certain fire investigations. When utilizing laboratories to perform any of these tests, investigators should be aware of the quality of the laboratory results that can be expected.

16.10.2.1 Gas Chromatography (GC). This test method separates the mixtures into their individual components and then provides a graphical representation of each component and its relative amount. This method is useful for mixtures of gases or liquids that can be vaporized without decomposition. GC is sometimes a preliminary test that may indicate the need for additional testing to specifically identify the components. For most petroleum distillate accelerants, GC provides adequate characterization if conducted according to accepted methods. These methods are described in ASTM E 1387, *Standard Test Method for Ignitible Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography*.

16.10.2.2 Mass Spectrometry (MS). This test method is usually employed in conjunction with gas chromatography. This method further analyzes the individual components that have been separated during gas chromatography. Methods of GC/MS analysis are described in ASTM E 1618, *Standard Test Method for Ignitible Liquid Residues in Extracts from Fire Debris by Gas Chromatography–Mass Spectrometry*.

16.10.2.3 Infrared Spectrophotometer (IR). This test method can identify some chemical species by their ability to absorb infrared light in specific wavelength regions.

16.10.2.4 Atomic Absorption (AA). This test method identifies the individual elements in nonvolatile substances such as metals, ceramics, or soils.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.10.2.5 X-Ray Fluorescence. This test analyzes for metallic elements by evaluating an element's response to X-ray photons.

16.10.2.6 Flash Point by Tag Closed Tester (ASTM D 56). This test method, from ASTM D 56, *Standard Test Method for Flash Point by Tag Closed Tester,* covers the determination of the flash point, by tag closed tester, of liquids having low viscosity and a flash point below 93°C (200°F). Asphalt and those liquids that tend to form a surface film under test conditions and materials that contain suspended solids are tested using the Pensky-Martens (*see 16.10.2.8*) closed tester.

16.10.2.7 Flash and Fire Points by Cleveland Open Cup (ASTM D 92). This test method, from ASTM D 92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup*, covers determination of the flash and fire points of all petroleum products (except oils) and those products having an open-cup flash point below 79°C (175°F).

16.10.2.8 Flash Point by Pensky-Martens Closed Tester (ASTM D 93). This test method, from ASTM D 93, *Standard Test Method for Flash Point by Pensky-Martens Closed Cup Tester*, covers the determination of the flash point by Pensky-Martens closed-cup tester of fuel oils, lubricating oils, suspensions of solids, liquids that tend to form a surface film under test conditions, and other liquids.

16.10.2.9 Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus (ASTM D 1310). This test method, from ASTM D 1310, *Standard Test Method for Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus*, covers the determination by tag open-cup apparatus of the flash point and fire point of liquids having flash points between -18°C and 163°C (0°F and 325°F) and fire points up to 163°C (325°F).

16.10.2.10 Flash Point by Setaflash Closed Tester (ASTM D 3828). This test method, from ASTM D 3828, *Standard Test Methods for Flash Point by Small Scale Closed Tester*, covers procedures for the determination of flash point by a Setaflash closed tester. Setaflash methods require smaller specimens than the other flash point tests.

16.10.2.11 Autoignition Temperature of Liquid Chemicals (ASTM E 659). This test method, from ASTM E 659, *Standard Test Method for Autoignition Temperature of Liquid Chemicals*, covers the determination of hot- and cool-flame autoignition temperatures of a liquid chemical in air at atmospheric pressure in a uniformly heated vessel.

16.10.2.12 Heat of Combustion of Hydrocarbon Fuels by Bomb Calorimeter (Precision Method) (ASTM D 4809). This test method, from ASTM D 4809, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)*, covers the determination of the heat of combustion of hydrocarbon fuels. It is designed specifically for use with aviation fuels when the permissible difference between duplicate determinations is of the order of 0.1 percent. It can be used for a wide range of volatile and nonvolatile materials where slightly greater differences in precision can be tolerated.

16.10.2.13 Flammability of Apparel Textiles (ASTM D 1230). This test method, from ASTM D 1230, *Standard Test Method for Flammability of Apparel Textiles*, covers the evaluation of the flammability of textile fabrics as they reach the consumer for or from apparel other than children's sleepwear or protective clothing.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.10.2.14 Cigarette Ignition Resistance of Mock-up Upholstered Furniture Assemblies (ASTM E 1352). This test method, from ASTM E 1352, *Standard Test Method for Cigarette Ignition Resistance of Mock-up Upholstered Furniture Assemblies*, is intended to cover the assessment of the resistance of upholstered furniture mock-up assemblies to combustion after exposure to smoldering cigarettes under specified conditions.

16.10.2.15 Cigarette Ignition Resistance of Components of Upholstered Furniture (ASTM E 1353). This test method, from ASTM E 1353, *Standard Test Methods for Cigarette Ignition Resistance of Components of Upholstered Furniture*, is intended to evaluate the ignition resistance of upholstered furniture component assemblies when exposed to smoldering cigarettes under specified conditions.

16.10.2.16 Flammability of Finished Textile Floor-Covering Materials (ASTM D 2859). This test method, from ASTM D 2859, *Standard Test Method for Flammability of Finished Textile Floor Covering Materials*, covers the determination of the flammability of finished textile floor covering materials when exposed to an ignition source under controlled laboratory conditions. It is applicable to all types of textile floor coverings regardless of the method of fabrication or whether they are made from natural or manmade fibers. Although this test method may be applied to unfinished material, such a test is not considered satisfactory for the evaluation of a textile floor-covering material for ultimate consumer use.

16.10.2.17 Flammability of Aerosol Products (ASTM D 3065). This test method, from ASTM D 3065, *Standard Test Methods for Flammability of Aerosol Products*, covers the determination of flammability hazards for aerosol products.

16.10.2.18 Surface Burning Characteristics of Building Materials (ASTM E 84). This test method, from ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, for the comparative surface burning behavior of building materials, is applicable to exposed surfaces, such as ceilings or walls, provided that the material or assembly of materials, by its own structural quality or the manner in which it is tested and intended for use, is capable of supporting itself in position or being supported during the test period. This test is conducted with the material in the ceiling position. This test is not recommended for use with cellular plastic.

16.10.2.19 Fire Tests of Roof Coverings (ASTM E 108). This test method, from ASTM E 108, *Standard Test Method for Fire Tests of Roof Coverings*, covers the measurement of relative fire characteristics of roof coverings under simulated fire originating outside the building. It is applicable to roof coverings intended for installation on either combustible or noncombustible decks, when applied as intended for use.

16.10.2.20 Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source (ASTM E 648). This test method, from ASTM E 648, *Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*, describes a procedure for measuring the critical radiant flux of horizontally mounted floor covering systems exposed to a flaming ignition source in graded radiant heat energy environment in a test chamber. The specimen can be mounted over underlayment or to a simulated concrete structural floor, bonded to a simulated structural floor, or otherwise mounted in a typical and representative way.

16.10.2.21 Room Fire Experiments (ASTM E 603). This guide, ASTM E 603, *Standard Guide for Room Fire Experiments*, covers full-scale compartment fire experiments that are designed to evaluate the fire characteristics of materials, products, or systems under actual fire conditions. It is intended to serve as a guide for the design of the experiment and for the interpretation of its results. ASTM E 603 may be used as a guide for establishing laboratory conditions that simulate a given set of fire conditions to the greatest extent possible.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.10.2.22 Concentration Limits of Flammability of Chemicals (ASTM E 681). This test method, from ASTM E 681, *Standard Test Method for Concentration Limits of Flammability of Chemicals*, covers the determination of the lower and upper concentration limits of flammability of chemicals having sufficient vapor pressure to form flammable mixtures in air at 1 atmosphere pressure at the test temperature. This method may be used to determine these limits in the presence of inert dilution gases. No oxidant stronger than air should be used.

16.10.2.23 Measurement of Gases Present or Generated During Fires (ASTM E 800). Analytical methods for the measurement of carbon monoxide, carbon dioxide, oxygen, nitrogen oxides, sulfur oxides, carbonyl sulfide, hydrogen halide, hydrogen cyanide, aldehydes, and hydrocarbons are described in ASTM E 800, *Standard Guide for Measurement of Gases Present or Generated During Fires*, along with sampling considerations. Many of these gases may be present in any fire environment. Several analytical techniques are described for each gaseous species, together with advantages and disadvantages of each. The test environment, sampling constraints, analytical range, and accuracy often dictate use of one analytical method over another.

16.10.2.24 Heat and Visible Smoke Release Rates for Materials and Products (ASTM E 906). This test method, from ASTM E 906, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products*, can be used to determine the release rates of heat and visible smoke from materials and products when exposed to different levels of radiant heat using the test apparatus, specimen configurations, and procedures described in this test method.

16.10.2.25 Pressure and Rate of Pressure Rise for Combustible Dusts (ASTM E 1226). This test method, from ASTM E 1226, *Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts*, can be used to measure composition limits of explosibility, ease of ignition, and explosion pressures of dusts and gases.

16.10.2.26 Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter (ASTM E 1354). This test method, from ASTM E 1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, is a bench-scale laboratory instrument for measuring heat release rate, radiant ignitibility, smoke production, mass loss rate, and certain toxic gases of materials.

16.10.2.27 Ignition Properties of Plastics (ASTM D 1929). This test method, from ASTM D 1929, *Standard Test Method for Determining Ignition Temperature of Plastics*, covers a laboratory determination of the self-ignition and flash-ignition temperatures of plastics using a hot-air ignition furnace.

16.10.2.28 Dielectric Withstand Voltage (Mil-Std–202F Method 301). This test method, from Mil-Std–202F, *Test Method for Electronic and Electrical Components*, also called high-potential, over-potential, voltage-breakdown, or dielectric-strength test, consists of the application of a voltage higher than rated voltage for a specific time between mutually insulated portions of a component part or between insulated portions and ground.

16.10.2.29 Insulation Resistance (Mil-Std–202F Method 302). This test, from Mil-Std–202F, *Test Method for Electronic and Electrical Components*, measures the resistance offered by the insulating members of a component part to an impressed direct voltage tending to produce a leakage current through or on the surface of these members.

Source - NFPA 921, Chapter 16, 2008.

Extract

16.10.3 Sufficiency of Samples. Fire investigators often misunderstand the abilities of laboratory personnel and the capabilities of their scientific laboratory equipment. These misconceptions usually result in the fire investigator's collecting a quantity of physical evidence that is too small to examine or test.

16.10.3.1 Certainly, the fire investigator will not always have the opportunity to determine the quantity of physical evidence he or she can collect. Often, the fire investigator can collect only that quantity that is discovered during his or her investigation.

16.10.3.2 Each laboratory examination or test requires a certain minimum quantity of physical evidence to facilitate proper and accurate results. The fire investigator should be familiar with these minimum requirements. The laboratory that examines or tests the physical evidence should be consulted concerning these minimum quantities.

16.10.4 Comparative Examination and Testing.

16.10.4.1 During the course of certain fire investigations, the fire investigator may wish to have appliances, electrical equipment, or other products examined to determine their compliance with recognized standards. Such standards are published by the American Society for Testing and Materials, Underwriters Laboratories Inc., and other agencies.

16.10.4.2 Another method of comparative examination and testing involves the use of an exemplar appliance or product. Utilizing an exemplar allows the testing of an undamaged example of a particular appliance or product to determine whether it was capable of causing the fire. The sample should be the same make and model as the product involved in the fire.

16.11 Evidence Disposition.

16.11.1 The fire investigator is often faced with disposing of evidence after an investigation has been completed. The investigator should not destroy or discard evidence unless proper authorization is received. Circumstances may require that evidence be retained for many years and ultimately may be returned to the owner.

16.11.2 Criminal cases such as arson require that the evidence be kept until the case is adjudicated. During the trial, evidence submitted — such as reports, photographs, diagrams, and items of physical evidence — will become part of the court record and will be kept by the courts. Volatile or large physical items may be returned to the investigator by the court. There may be other evidence still in the investigator's possession that was not used in the trial. Once all appeals have been exhausted, the investigator may petition the court to either destroy or distribute all of the evidence accordingly. A written record of authorization to dispose of the evidence should be kept. The criminal investigator should be mindful of potential civil cases resulting from this incident, which may require retention of the evidence beyond the criminal proceedings.

Source - NFPA 921, Chapter 16, 2008.

6. Fire and Explosion Deaths and Injuries

NFPA 921, Chapter 23 – Fire and Explosion Deaths and Injuries

Extract

23.1 General.
Fire and explosions exact a high toll in deaths and injuries, and the investigator must be prepared to make special efforts when they occur. Since fire and explosion injuries can lead to death hours, days, or even weeks after the event, every fire and explosion that involves serious injuries should be investigated in the same way as a fire and explosion that has immediate fatalities. While there is considerable overlap between fire deaths and fire injuries, they will be considered separately.

23.2 Death Scene Considerations.
There are a number of considerations to be made before the investigation of a fatal fire or explosion even begins that can have a significant impact on the length and success of the investigation. Any time a fire death occurs, or a death resulting from injuries received as a result of a fire or explosion occurs, an autopsy should be performed.

23.2.1 Fire Suppression. Fire suppression personnel should be made aware that the use of straight-stream hose streams can disturb fragile evidence such as clothing and can alter a badly charred body. As soon as a body is discovered, and it is determined that the victim is beyond medical aid, every effort should be made to minimize fire-fighting operations in close proximity to the victim, including foot traffic, hoselines, and equipment. Of course, if there is any chance of resuscitation, the survival of the victim must take priority. It might be thought advantageous to remove a body as soon as it is found so that operations are not impeded, but it is beneficial to the entire fire-death investigation if the body is left in place until it can be properly documented and examined. Only severe emergency conditions, such as imminent collapse of the building or uncontrollable fire in the vicinity, should force premature removal of the body.

23.2.2 Documentation.

23.2.2.1 As soon as conditions permit, photographic documentation of the body or body parts and their surroundings should be carried out. If the body has to be moved due to emergency considerations, a few photographs may make the difference between a successful investigation and failure. The photographs should be taken on color, 35 mm, large-format still film or digital medium, with a good-quality camera and a suitable electronic flash. Video recordings or instant-photo films may not provide adequate detail but may be used as a supplement or in the absence of other images. Either slides or prints are suitable, but print negatives expedite the process of making prints for court displays. Because fire patterns or blast effects on clothing and on the body may be important evidence, photographs should be taken of all exposed surfaces of the body before the debris is disturbed and then again during searching and layering operations. The body should be photographed while it is being moved, to record any changes incurred during the removal process. In this situation, videotaping may be beneficial. The body should also be photographed once inside the body bag. After the body is removed, the location where it was found should be photographed, and photographs should be taken of the body before it is unclothed, as well as after removal of clothing. Any burns or other injuries should be photographed in close-up with a suitable scale in the field of view.

Source – NFPA 921, Chapter 23, 2008.

Extract

23.2.2.2 Diagrams and sketches should supplement photos. Diagrams can show hidden details. They can record the dimensions of features of the scene and can document distances between the body (and its extremities) and furnishings, walls, doors, windows, and other features *(see Figure 23.2.2.2)*. The outline of the body should be recorded on a diagram and should be traced on the floor in chalk, tape, or string so that it can be referred to in later stages of the scene examination.

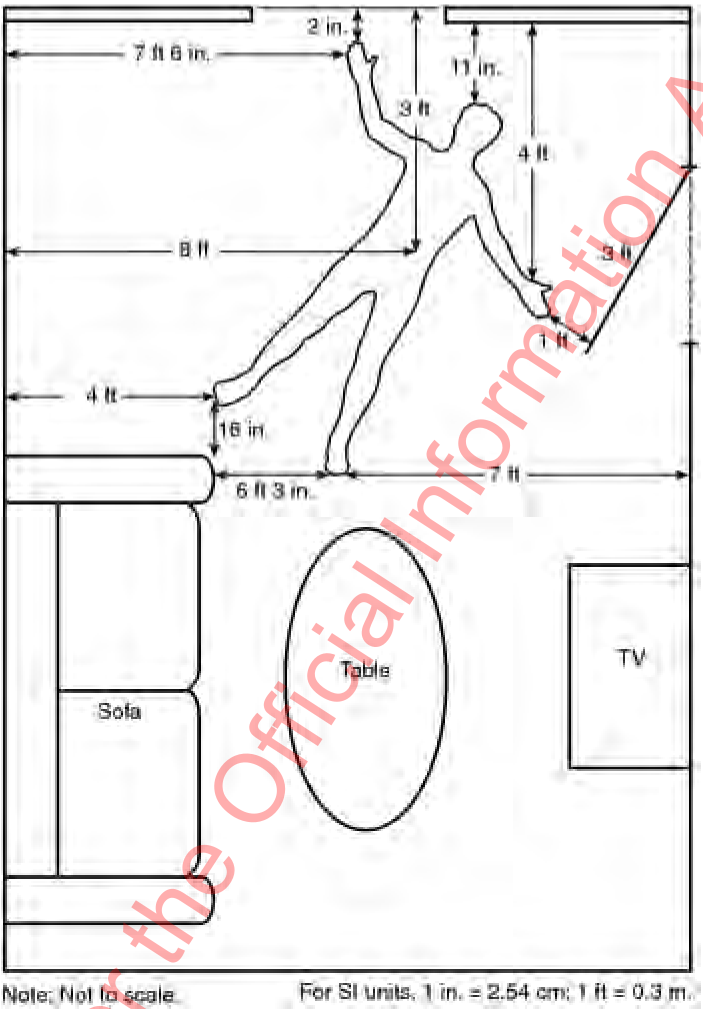


FIGURE 23.2.2.2 Diagram Showing Location of Body in Relationship to Room and Furnishings.

23.2.3 Notification. In death investigations, there are legal and procedural requirements for notifying the authorities, including police, coroner, medical examiner, and forensic lab, that vary from jurisdiction to jurisdiction. These requirements may involve both civil and criminal agencies, and the investigator should understand these steps prior to beginning the investigation.

23.2.4 Recovery of Bodies and Evidence. A proper death investigation is a team effort, and may involve the investigator, homicide detective, and forensic pathologist. All parties should be prepared to work side by side at the scene to ensure that all critical evidence is recovered, whether the death is determined to be accidental or otherwise. If there are indications of foul play or if the body is very badly burned, the investigator should consider special assistance in the form of a criminalist (forensic scientist) with crime scene experience, a forensic odontologist, or a forensic anthropologist.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.2.4.1 The search for evidence tends to focus on the body with a realization that, in any death investigation, critical evidence is often recovered within arm's reach of the body. The body is a convenient reference point, but it should be remembered that evidence may be elsewhere in the vicinity, so a careful search must be made of the entire room or area. To aid in the search, this area should be marked off into sectors by string, tape, rope, or chalk, as shown in Figure 23.2.4.1. A grid system may be developed to conduct the investigation by dividing the scene into specific areas. The search in each grid needs to be documented and the evidence from each grid identified. The geometry of the scene may determine the grid system, such as by floor or by room. Other methods include spiral, strip, or area searches. Regardless of the method used, the assigned search areas should overlap to ensure complete coverage.

FIGURE 23.2.4.1 An Example of a Room That Has Been Marked Off into Sectors.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.2.4.2 The sequence of events of death, fire, explosion, and collapse may be revealed by the sequence of layers in the debris (ceiling, furniture, body, floor covering, etc.) and by noting where the fire damage has occurred. An unburned body found on an unburned sofa beneath a collapsed ceiling and roof structure is a lot different than a burned body found under a burned sofa with a ceiling collapsed on top. The search through each sector proceeds through the layers of debris as they are found. The debris from each sector can be removed to a location where a more detailed search can be carried out by other searchers, using sieving through a series of sifting screens. Such screens are typically made of 1 in., 0.50 in., 0.25 in., and window screen wire mesh (hardware cloth) fitted to wooden or metal frames.

23.2.4.3 When the body is removed (often after the detailed search has been carried out in the sectors surrounding it), the body should be placed in a new, unused, sealed body bag. All debris associated with or adhering to the body should be transported in the body bag and preserved for trace evidence, volatiles, weapons, projectiles, and the like. The area under the body should then be carefully searched for evidence that has fallen loose while the body was being moved.

23.3 Death-Related Pathological and Toxicological Examination.
There are a number of examinations that can be conducted on the victim that may yield information of value to an investigator.

23.3.1 X-rays. X-rays made of the entire body and all associated debris can be extremely beneficial. These can be supplemented with dental x-rays and detail x-rays of anatomic features (broken bones, wounds, etc.). Fluoroscopy, while convenient, does not capture the same detail as an x-ray and provides no permanent image.

23.3.2 Carbon Monoxide Levels. Carbon monoxide levels in blood and tissue are the most common postmortem tests because they can reveal a lot about the cause of death. Carbon monoxide causes a cherry-pink coloration to the skin that may not be visible in dark-skinned individuals or ones that are heavily soot covered. The coloration may be visible in the skin, lips, and nipples, as well as in the liquid blood, in areas of postmortem lividity, and in the internal organs. The coloration in internal organs will remain when the organ is preserved in formalin, when normal tissue turns a muddy gray-brown color. The carbon monoxide saturation in the blood (carboxyhemoglobin, percent COHb) and tissue may be measured by a chemical assay or by a gas chromatographic method. If possible, carbon monoxide saturation should be measured for every fire victim.

23.3.3 Presence of Other Toxic Products. The presence of toxic products such as hydrogen cyanide or hydrogen chloride (from combustion products) or other organic or inorganic poisons is determined by chemical or instrumental analysis of blood, brain, or organ tissue. The levels of alcohol, pharmaceutical drugs, or drugs of abuse are determined by gas chromatography/mass spectrometry, liquid chromatography, or immunoassay techniques. Most of these assays are carried out on liquid blood, but in severely burned bodies, there may not be enough liquid blood, so other body fluids or tissue samples may be used. Blood samples must be drawn from a blood vessel and not from the abdominal cavity if their analysis is to be reliable.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.3.4 Smoke and Soot Exposure. Evidence of smoke or soot in the lungs, bronchi, and trachea (even esophagus) is one of the most significant factors in confirming that the victim was alive and breathing smoke during the fire. This finding requires that the trachea be transected over its entire length. Soot in mouth or nasal openings alone may be the result of soot settling in openings and not of breathing. Knowing the position of the body when found may be critical to a correct interpretation. Soot may also be swallowed and found in the esophagus and stomach.

23.3.5 Burns. Burns may be induced by antemortem exposure to flames, hot surfaces, radiant heat, or hot gases or by postmortem radiant, convected, or conducted heat in the fire environment. Antemortem burns trigger a vital response, including reddening and blistering, which involves cellular and chemical changes that may be detected after death. Burns that occur immediately prior to death may not have time to exhibit a vital response and may not be distinguishable from postmortem burns. Blistering can be produced postmortem.

23.3.5.1 Postmortem effects are dominated first by shrinkage due to dehydration of the muscle tissue. This shrinkage causes flexion, since the flexor muscles of the body are usually more massive that the extensor muscles. This flexion can produce the so-called *pugilistic attitude*. The crouching stance with flexed arms, legs, and fingers is not the result of any pre-fire physical activity (such as self-defense or escape), but a direct result of the fire. Bone fractures can result from such muscle contraction or as the result of extensive direct exposure to heat and flames.

23.3.5.2 Blood can seep from ears, nose, and mouth as a result of heating. Blood found external to the body can indicate antemortem physical trauma. Blood can percolate into the epidural space between skull and the dura (the tough lining of the skull), but not, as a rule, into the subdural space between the brain and the dura. This subdural hematoma results from injury only.

23.3.6 Consumption of the Body by Fire.

23.3.6.1 The investigator should remember that the body is part of the fuel load of a burning room. That is why the burn patterns on the body and any consumption of it have to be considered within the context of the entire scene and not in isolation. Aside from the clothing, there are three major combustible constituents to the body. Skin and muscle tissue is not a good fuel, but it will burn if heated enough to dehydrate it and if then exposed to enough direct flame to consume it. It will char and undergo glowing combustion if enough additional heat is provided. Fat is the best fuel on the body. Animal fat has a heat of combustion (DHc) of over 30 MJ/kg. It can be dehydrated by a modest flame, and then melted or rendered to support flames. While not readily combustible, bone adds to the fuel by supplying marrow and tissue as fuel. Living bone will shrink and shatter when heated, while its surface undergoes degradation to a flaky or powdery form, but it does not readily oxidize to calcium oxide. The skull can fracture (typically along the suture lines) or disintegrate when heated.

23.3.6.2 Human bodies do not combust spontaneously. If fire conditions are appropriate, the body fat can render from a dead body to sustain a small but persistent flaming fire. If the body fat can be absorbed onto the rigid, absorbent char of upholstery, clothing, bedding, or carpet, the flames can be sustained in the manner of an oil lamp. The flames then promote dehydration and combustion of muscle tissues and internal organs and reduce bones to a flaky mass over a period of many hours. The fire thus sustained is small enough that other combustible fuels in the vicinity may not ignite by radiant or convected heat. The end result is a body most heavily burned away in the area where the most body fat is located (the torso), leaving the lower legs, arms, and often the head relatively unburned.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.4 Fundamental Issues of Death Investigations.
There are a number of fundamental issues that may confront the investigator involved in a death related to fire or explosion. These are listed in 23.4.1 through 23.4.6.

23.4.1 Remains Identification. In a very badly damaged body, the determination as to the remains being human or animal may not be as simple a matter as would first appear. Animals having the same mass as an adult, such as pigs, deer, or even large dogs, can be mistaken for human remains (and vice versa). Badly charred remains of children or infants are even harder to identify, because their smaller mass and reduced calcification allow more destruction. While it is difficult to destroy the remains of an adult human in a structure or even vehicle fire, remains of infants can be consumed so completely as to defy identification. This critical identification may require the services of a physical or forensic anthropologist who is familiar with the anatomical characteristics of all species.

23.4.2 Victim Identification. The identification of victims can be carried out by a variety of means, depending on the extent of fire damage to the body. Identification by visual observation is most unreliable, for exposure to even a moderate fire induces tissue swelling and tightening of skin by shrinkage. Color changes to face and hair can make identification of a person and sometimes even estimation of age and race difficult. Visual observation should be used only as a starting point.

23.4.2.1 Clothing and personal effects should be used, like visual identification, only as a starting point. It is far too easy for clothes, wallets, rings, watches, and other personal effects (even dental plates) to be substituted onto another person prior to a fire. Fingerprints can be used with almost complete certainty if record prints are available for the person thought to be the victim. If even a small portion of unburned friction ridge skin remains on a fingertip, that may bear enough individual characteristics to permit comparison.

23.4.2.2 X-rays provide one of the surest means of identifying even badly burned bodies. The mass of the head tends to protect the teeth from most fire damage, and dental x-rays may be secured if even a tentative identification is made. The jaws must be resected and x-rays made by a qualified odontologist to replicate the positions and angles of whatever clinical antemortem x-rays are available. The shape and locations of fillings, bridges, and implants are then used to make the identification. In some cases, unusual root shapes or other irregularities have been used in the absence of dental work. X-rays of other parts of the body may yield previous fractures or other injuries or surgical procedures that can verify an identification. There are also custom-made joint implants, prostheses, and even pacemakers that can be identified.

23.4.2.3 Serological or DNA typing can be conducted if family members are available to provide reference samples. These techniques can be used on even fragmentary remains if they have not been completely charred, and they are nearly as reliable a form of personal identification as fingerprints.

23.4.3 Cause of Death. The cause of death may be defined as the event, injury, or illness that caused the sequence of changes that ultimately brought about death. Examples of causes of death include smoke inhalation, burn (incineration), gunshot, trauma (explosion, structural collapse), but may be heart attack or illness (chronic or acute).

23.4.4 Manner of Death. The manner of death describes the general course of events or circumstances that brought about the cause of death (accidental, homicidal, suicidal, natural, or undetermined).

Source - NFPA 921, Chapter 23, 2008.

Extract

23.4.5 Victim Activity.

23.4.5.1 An attempt should be made to determine the victim's activity before, during, and after the onset of the fire or explosion and at the time of death, including whether the person was alive and conscious. Factors that can assist the investigator in making these determinations include the following:

(1) Location of the body (in bed, at exit)
(2) Position of the body (in chair, hiding)
(3) Clothing on the body (pajamas, work clothes)
(4) Burn patterns on the clothing
(5) Burn patterns on the body
(6) Items found with the body (e.g., keys, telephone, flashlight, fire extinguisher, personal property)
(7) Blast damage to the body (e.g., pressure, impact, and shrapnel)

23.4.5.2 The patterns of damage on the clothing and the body should be considered in context with the total fire or explosion patterns in the room or area. Apparent inconsistencies should be examined. Burn patterns to the clothing (e.g., cigarette burns) may reveal a history of involvement with previous fires. Burn patterns to the clothing or the body may indicate that an attempt had been made to fight the fire or may be evidence of firesetting. The relationship between the death and the fire should be investigated, because not all fire-related deaths are directly caused by heat, flame, or smoke. Examples include a person smoking a cigarette on a sofa who dies of a heart attack, a person jumping from a window to escape a fire, fatal trauma from building collapse, suicide, and homicide prior to the fire.

23.4.6 Postmortem Changes.

23.4.6.1 Upon death, the circulation of blood ceases and the blood begins to settle in the blood vessels and capillaries into the lowest available portions of the body in response to gravity, over a period of hours. This settling produces a purple or red coloration in the tissues, called *lividity* or *livor mortis*. In the first few hours after death, if the body is moved and its position altered, lividity disappears from one area and will develop in the new lowest area. After 6 to 9 hours, lividity becomes fixed and no longer shifts if the body is moved. The areas of lividity can appear red if the victim died with a significant COHb level, because of the bright red color of blood with a high COHb saturation. The presence, absence, and pattern of areas of lividity can help establish the position of the body after death and can reveal whether it has been moved or repositioned after death.

23.4.6.2 Over a period of hours after death, chemical changes in the muscle tissue cause it and the joints to stiffen in place. This is called *rigor mortis*. It develops first in the hands and feet, progressively involving the limbs, torso, and head. Its onset depends on the temperature of the body (and its environment) and the physical activity of the victim just before death. After 12 to 24 hours, the rigor passes, leaving the joints and muscles limber. Loss of the rigor proceeds from extremities to torso and head over a several hour period. Extreme muscular activity just prior to death and high environmental temperatures may hasten the onset (and often the loss) of rigor. Experienced forensic pathologists may use the progressive onset and loss of rigor to help establish an approximate time of death. Rigidity (and contraction) of muscles caused by exposure to fire is not the same as rigor mortis and does not leave the body over time.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.5 Mechanism of Death.
The combustion products arising from a fire are many and their effects on healthy individuals varied; however, none are without toxicological effects. The inhalation of these products or contact with skin or eyes can result in deleterious biological effects, such as immediate irritation of the eyes and respiratory tract or systemic effects that influence other functions of the body. These products include carbon monoxide, carbon dioxide, nitrogen oxides, halogen acids (hydrochloric, hydrofluoric, and hydrobromic acids), hydrogen cyanide, acrolein, benzene, particulates (ash, soot), and aerosols (complex organic molecules resulting from pyrolysis products).

23.5.1 Carbon Monoxide. Carbon monoxide (CO) is produced at some level in virtually every fire. All carbon-based fuels (e.g., wood, paper products, plastics) produce carbon monoxide as a result of incomplete combustion. During burning of organic fuels, CO is initially formed and then subsequently oxidized to carbon dioxide (CO_2). In underventilated fires or in fires where the initial products of combustion mix with colder gases (such as in smoldering fires), conversion of CO to CO_2 can be halted, and CO can become a major product of combustion. In well-ventilated fires, the level of CO produced may be as little as a few hundred parts per million (i.e., 0.02 percent). However, in underventilated, smoldering, or postflashover fires, CO concentrations of 1 percent to 10 percent (10,000 ppm to 100,000 ppm) can be produced. Elevated CO concentrations can also develop during fire suppression.

23.5.1.1 Carbon monoxide is an anesthetic and an asphyxiant. When inhaled, CO binds with hemoglobin in the blood, creating carboxyhemoglobin (COHb), which is approximately 200 times more stable than oxyhemoglobin. Therefore, the blood can accumulate dangerous levels of COHb from even low CO concentrations in the air. Thus, COHb reduces the oxygen-carrying capacity of the blood, leading to asphyxiation. In addition, CO delivered to the cells can interfere with cell respiration, causing incapacitation or death. The effects of carbon monoxide inhalation usually can be reversed by breathing fresh air or oxygen. However, carbon monoxide can remain in the blood for many hours after exposure. Consequently, repeated or long-term exposures to low levels of CO can result in the accumulation of a lethal level of COHb in the blood.

23.5.1.2 Because carboxyhemoglobin is so stable, it can be readily measured in the blood of fire victims, even long after death. The average fatal level of blood CO is widely accepted as 50 percent COHb. However, research has shown that fire victims have died from CO exposure with a blood COHb level as low as 20 percent. Also, COHb levels as high as 90 percent have been measured in fire victims. Thus, a victim's COHb level is an important indicator of his or her fate in a fire. Victims with less that 20 percent COHb most likely died from other causes, such as a lack of oxygen, or burns. In contrast, victims with COHb concentrations of 40 percent or higher are likely to have died from carbon monoxide alone or in combination with other factors (such as age, alcohol, or a heart condition) or may simply have been incapacitated sufficiently by carbon monoxide poisoning to be unable to flee the fire.

23.5.1.3 In assessing the significance of a victim's COHb level, it should be noted that smokers typically have a 4 percent to 10 percent COHb level as a result of smoking alone. Also, victims who were administered oxygen prior to blood being drawn may show a low COHb due to the introduced oxygen. Therefore, knowledge of the time elapsed between removal from the fire and death and the dosage of any oxygen administered to the victim prior to blood sampling is important in assessing the significance of the victim's COHb level *(see Section H23.8H)*.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.5.1.4 Studies have shown that most fire victims (75 percent to 80 percent) die from carbon monoxide poisoning, and that most of these people die remote from the room of fire origin. This type of death occurs because most fires do not produce lethal levels of CO until postflashover (the exception is smoldering fires). Thus, victims of carbon monoxide inhalation are typically outside the initial fire room unless the fire resulted from smoldering ignition. However, during flashover, thermal injury and lack of oxygen can cause death before substantial concentrations of COHb are developed. The same can occur if the victim is involved in a flash fire involving fuel gases or vapors.

23.5.2 Thermal Effects. Death or injury can result from the hot thermal environment of a fire. The two main thermal causes are hyperthermia and inhalation of hot gases.

23.5.2.1 Hyperthermia. Victims exposed to the hot environment of a fire, including high moisture content, are subject to incapacitation or death due to hyperthermia, especially if the person is active. The time duration and type of exposure can lead to either simple hyperthermia or acute hyperthermia.

23.5.2.1.1 Simple hyperthermia results from prolonged exposures (typically more than 15 minutes) to hot environments where the ambient temperature is too low to cause burns. Such conditions range from 80°C to 120°C (176°F to 248°F), depending on the relative humidity, and usually result in a gradual increase in the body core temperature. High humidity makes it harder for the body to dispel excess heat by evaporation and thereby accelerates the heating process. Core body temperatures above approximately 43°C (109°F) are generally fatal within minutes unless treated.

23.5.2.1.2 Acute hyperthermia involves exposure to high temperatures for short periods of time (less than 15 minutes). This type of hyperthermia is accompanied by burns. However, when death occurs shortly after exposure to severe heat, the cause of death is generally considered to be from a rise in blood temperatures rather than from burns.

23.5.2.2 Inhalation of Hot Gases. Inhalation of hot fire gases can result in death or injury. However, it is difficult to distinguish the effects of thermal inhalation burns from edema and inflammation caused by chemical irritants in smoke. A distinguishing characteristic of thermal inhalation burns is that they are always accompanied by external facial burns, as the temperatures are sufficient to burn skin and facial hair.

23.5.3 Other Toxic Gases. There are many toxic gases found in fire environments that can cause irritation and swelling (edema) sufficient to interfere with breathing. Hydrogen cyanide (HCN) can be produced during the combustion of wool, hair, or polyurethane foams. Hydrogen chloride (HCl) can be produced during the combustion of polyvinyl chloride (PVC) plastics. Acrolein is produced during the combustion of wood and other cellulosic products.

23.5.4 Soot and Smoke. Soot and smoke can contribute to fire deaths and injuries through several mechanisms. Hot soot particles can be inhaled and can cause thermal injuries leading to edema in the respiratory system. Soot particulate can also contain toxic chemicals and can provide inhalation and ingestion pathways for these toxins. Excessive soot can also physically block the airways, causing asphyxiation. Liquid aerosols (mists) of pyrolysis are often acidic, causing chemical edema, and are often very toxic, causing systemic failures upon inhalation.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.5.5 Hypoxia. Hypoxia is a condition caused by breathing a reduced oxygen atmosphere. A reduced oxygen environment occurs in an enclosure fire as a natural consequence of the combustion process. There is little effect of reduced environmental oxygen down to 15 percent oxygen in air. However, as the oxygen concentration in inhaled air decreases from 15 percent to 10 percent, a gradual increase in respiration occurs, followed by disorientation and loss of judgment. As the oxygen concentration in the ambient environment decreases below 10 percent, unconsciousness occurs, followed rapidly by cessation of breathing and death. This situation is aggravated by a high level of carbon dioxide in the air, which causes a substantial increase in the rate and depth of respiration. It should be noted that neither carbon dioxide nor oxygen levels can be measured in the blood postmortem because their levels begin to change immediately upon cessation of breathing.

23.6 Postmortem Tests and Documentation.
The following is a list of procedures found to provide valuable information in the postmortem examination of victims of fires, to help establish identity, cause, and manner of death. The fire investigator should encourage the tests listed in 23.6.1 through 23.6.7 to be conducted and the results provided to the appropriate authority. Information concerning emergency medical treatment provided to the victim prior to a declaration of death should be provided to the appropriate authority.

23.6.1 Blood. Blood (from major blood vessel or chamber of the heart, not from a body cavity) should be tested for the following:
(1) COHb percent saturation in blood
(2) HCN concentration
(3) Blood alcohol level or concentration
(4) Drugs (prescription, nonprescription, or illegal) presence and concentration
(5) Poisons (when indicated)

23.6.2 Internal Tissue. When indicated, internal tissue (brain, kidney, liver, and lung) should be tested for the following:
(1) Drugs
(2) Poisons
(3) Volatile hydrocarbons

23.6.3 External Tissue (Skin Near Burns). When indicated, skin excised should be tested for vital chemical or cellular response to burns (antemortem versus postmortem burns).

23.6.4 Stomach Contents. Activities prior to death, and possible time of death, may be established through assaying of stomach contents, which should be examined when indicated. Presence or absence of soot in the esophagus and stomach contents should be noted.

23.6.5 Airways. Full longitudinal transection of airways from mouth to lungs may reveal the presence and distribution of edema, scorching or dehydration, and soot and should be conducted where indicated.

23.6.6 Internal Body Temperature. Internal body temperature may be used to aid in establishing the time and mechanism of death and should be determined where indicated. The temperature may be elevated due to hyperthermia, antemortem condition, or postmortem exposure to radiant heat.

23.6.7 X-rays. In order to establish identity, x-rays may need to be taken of the entire body, plus details of teeth. X-ray examination, including the clothing and associated debris found near the body, may also reveal unusual items such as bullets or shrapnel.

Source - NFPA 921, Chapter 23, 2004.

Extract

23.6.8 Clothing and Personal Effects. Clothing and personal effects should be examined to document the type, material, brand, and burn patterns present. All clothing associated with the body should be collected, packaged, and preserved after appropriate x-rays and evaluation. These items should be collected in accordance with Chapter 16. If the presence of an ignitible liquid is suspected, the material should be collected in accordance with Section 16.5.

23.6.9 Photographs. At the time of the postmortem examination, any burns or other injuries should be photographed, including close-ups with a suitable scale in the field of view. Overall photographs of the victim before and after clothing is removed should also be taken.

23.6.10 Diagrams of Burns and Injuries. The location, distribution, and degree of burns or other injuries should be shown on a body diagram such as shown in Figure 23.6.10. Such documentation of the burn patterns may assist the investigator in determining the victims' activities and location during the fire. *[See 23.7.2.3 and Figure A.15.3.2(b).]*

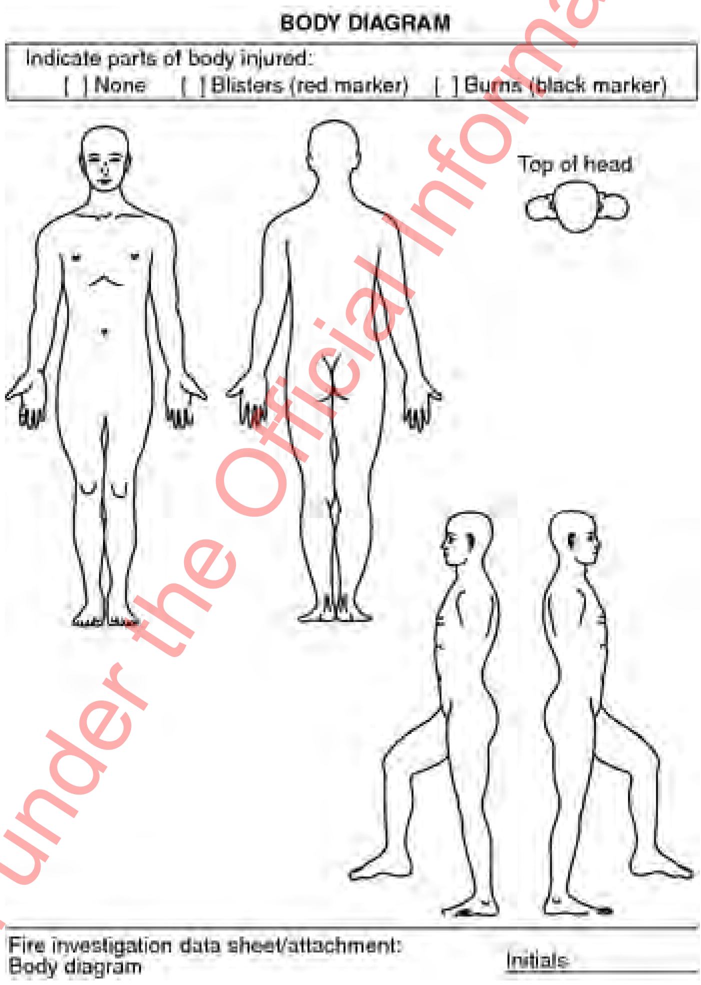


FIGURE 23.6.10 Example of a Chart that Can Be Used to Diagram Injuries.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.6.11 Documentation of Major Physical Trauma and Wounds. Major physical trauma and wounds to the body, such as gunshot, fractures, blunt trauma, and knife wounds, should be examined and thoroughly documented.

23.6.12 Sexual Assault Evidence. Physical evidence of possible sexual assault should be collected in accordance with applicable regulations and procedures.

23.6.13 Collection of Other Physical Evidence. When possible, the investigator should be present when the postmortem examination (autopsy) is conducted, not only to ensure that appropriate observations are made, but also to be on hand to answer any questions that arise during the examination. Pathologists and medical examiners may have limited knowledge of fire chemistry, fire dynamics, or blast effects. In such instances, the investigator can advise as to fire conditions in the vicinity of the body. The investigator should ensure that physical evidence such as bullets, casings, explosive residue, knives, and other weapons found with the body, as well as body fluids, recorded fingerprints, and dental records, are appropriately collected, preserved, and analyzed.

23.7 Fire and Explosion Injuries.
Because fire and explosion injuries can lead to death hours, days, or even weeks after the event, every fire and explosion that involves serious injuries should be investigated in the same way as a fire and explosion that has immediate fatalities. The clothing and injuries of people injured in a fire or explosion may constitute important physical evidence to the investigator, and the scene deserves the same careful examination whether death or injuries resulted.

23.7.1 Physical Evidence. Physical evidence from fires or explosions may extend beyond the body itself. Such evidence may be obvious (e.g., blood stains) or may be microscopic (e.g., hairs or fibers). This evidence may be found on such things as clothing or furnishings.

23.7.1.1 Clothing. Clothing of people injured in fires or explosions is likely to be removed by emergency personnel or by emergency room staff and then discarded. The clothing, including outer clothing, undergarments, shoes, and socks, should be collected and preserved. If there is a suspicion that ignitible liquids or explosives were involved, there may be residues present. In any case, the clothing should be collected and preserved in accordance with Section H16.5H and H21.13.3H for later analysis. The clothing items may indicate the activity of the wearer at the time of the fire or explosion. What the clothing is made of and how it is made may play a role in its ignitibility by flaming or smoldering sources (loose long sleeves, fine fabrics, etc.). It may be important for the investigator to determine the ignitibility, burning properties (char, melt, or both), or heat release rate of the clothing involved.

23.7.1.2 Furnishings. At the scene, the furnishings that appear to have been involved in the fire should be assessed for the same fire properties as clothing. The position and condition of the furnishings involved may indicate the activity of the victim at the time of the fire or explosion. The ignitibility by smoldering ignition versus flaming sources should be evaluated. Furnishings may have shielded victims from the blast and may include explosive residue and shrapnel.

23.7.1.3 Ignition Sources. A search of the scene should be carried out to establish what ignition sources are found. Careful examination of these sources may reveal whether they were involved. Melted or charred residues of the clothing or furnishing involved may be found adhering to the ignition source.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.7.1.4 Notification Laws. Many jurisdictions have reporting laws that require emergency or medical personnel to notify police or fire authorities when a person suffering from significant burns is treated. These laws are patterned after gunshot wound notification laws and have been found to be successful in identifying both victims of assault and abuse, as well as perpetrators of arson who are burned in the execution of their crime.

23.7.2 Medical Evidence (Burns). Evidence of burn injuries is often recorded in medical reports using terms with which the investigator should be familiar.

23.7.2.1 Degree of Burn.

23.7.2.1.1 Degrees of burn describe the depth and seriousness of injury as follows:
(1) First degree: reddened skin only (like simple sunburn)
(2) Second degree: blistering
(3) Third degree: full-thickness damage to skin
(4) Fourth degree: damage to underlying tissue, charring

23.7.2.1.2 Alternate descriptions of degrees of burn to skin are *superficial*, *partial*, and *full-thickness* burns.

23.7.2.2 Body Area (Distribution). Burn damage to the body is often estimated by the medical community by the "rule of nines," where the major areas are represented by increments of 9 percent as follows:

(1) Front of torso, 18 percent
(2) Right arm, 9 percent
(3) Front of right leg, 9 percent
(4) Rear of right leg, 9 percent
(5) Head, 9 percent
(6) Rear of torso, 18 percent
(7) Left arm, 9 percent
(8) Front of left leg, 9 percent
(9) Rear of left leg, 9 percent
(10) Genitals, 1 percent

Source - NFPA 921, Chapter 23, 2008.

Extract

23.7.2.2.1 A more precise distribution of skin surface to body area, which reflects the true proportions of the body, and which is sometimes used, is provided in Table 23.7.2.2.1.

Table 23.7.2.2.1 Percentage of Body Surface Area

Body Part	Infant	Child	Adult
Front of head	9.5	8.5	3.5
Rear of head	9.5	8.5	3.5
Front of neck	1.0	1.0	1.0
Rear of neck	1.0	1.0	1.0
Chest and abdomen	13.0	13.0	13.0
Genitalia	1.0	1.0	1.0
Back and buttocks	17.0	17.0	17.0
Front of arm and hand	4.25	4.25	4.75
Rear of arm and hand	4.25	4.25	4.75
Front of leg and foot	6.25	6.75	10.0
Rear of leg and foot	6.25	6.75	10.0
Infant: Up to age 4. Child: Age 5 to 10. Adult: Age 11 and Above.			

23.7.2.2.2 The total burned area of the body is sometimes used as a predictor of survivability, as indicated in the Figure 23.7.2.2.2. Whether the victim survives or not may dictate further investigation. This figure can be used for assessing the likelihood of survivability.

Body Area Burned (%)	Age (year)																
	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80+
93+	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
88–92	0.9	0.9	0.9	0.9	1	1	1	1	1	1	1	1	1	1	1	1	1
83–87	0.9	0.9	0.9	0.9	0.9	0.9	1	1	1	1	1	1	1	1	1	1	1
78–82	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1	1	1	1	1	1	1	1	1
73–77	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	1	1	1	1	1	1	1	1
68–72	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1	1	1	1	1	1
63–67	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1	1	1	1	1	1
58–62	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1	1	1	1	1
53–57	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	1	1	1	1	1
48–52	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.5	0.6	0.6	0.7	0.8	0.9	1	1	1	1
43–47	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.7	0.8	1	1	1	1
38–42	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.8	0.9	1	1	1
33–37	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.7	0.8	0.9	1	1
28–32	0	0	0	0	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.9	1	1
23–27	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.9	1
18–22	0	0	0	0	0	0	0	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.6	0.8	0.9
13–17	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.3	0.5	0.6	0.7
8–12	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.3	0.5	0.5
3–7	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.2	0.3	0.4
0–2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.2	0.2

1 = 100% mortality; 0.1 = 10% mortality (from Bull, 1979).

FIGURE 23.7.2.2.2 Mortality by Percentage of Body Burned and Age.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.7.2.3 Documentation. Documentation should include line art diagrams of distribution of burn injuries and color photographs. *(See 23.6.10.)* Photos should be taken as soon as possible after the injury (preferably, before significant treatment is under way). Medical treatment and healing will affect appearance; therefore, photos taken later in the healing process may be difficult to interpret. Removal of eschar (scar tissue formed over healing burn wounds), skin grafts, and incisions made to relieve pressure and allow flexibility can make burn areas look different (better or worse) than the original burns.

23.7.2.4 Mechanism of Burn Injury. Burns induced by chemicals or contact with hot liquids (scalds) may not be distinguishable from those induced by hot gases or flames. When radiant heating raises the temperature of the skin, the higher the radiant flux, the faster damage will occur. For instance, a heat flux of 2 kW/m^2 will cause pain after a 30-second exposure, while a heat flux of 10 kW/m^2 will cause pain after just 5 seconds. A flux of 2 kW/m^2 will not cause blisters, while 10 kW/m^2 will blister in 12 seconds. *(See Figure 23.7.2.4 and the following references for burn injury data: Stoll and Greene, 1959; SFPE, March 2000; Stoll and Chianta, 1969; Derkson, Monohan, and deLhery, 1963.)* A radiant heat flux of 20 kW/m^2, typically associated with flashover, is sufficient to cause severe burns or death by thermal exposure and to ignite clothing. Radiant heat, sufficient to cause burns, can be reflected from some surfaces. Heat can be transferred through clothing, causing burns to the underlying skin, without any readily identifiable damage to the clothing.

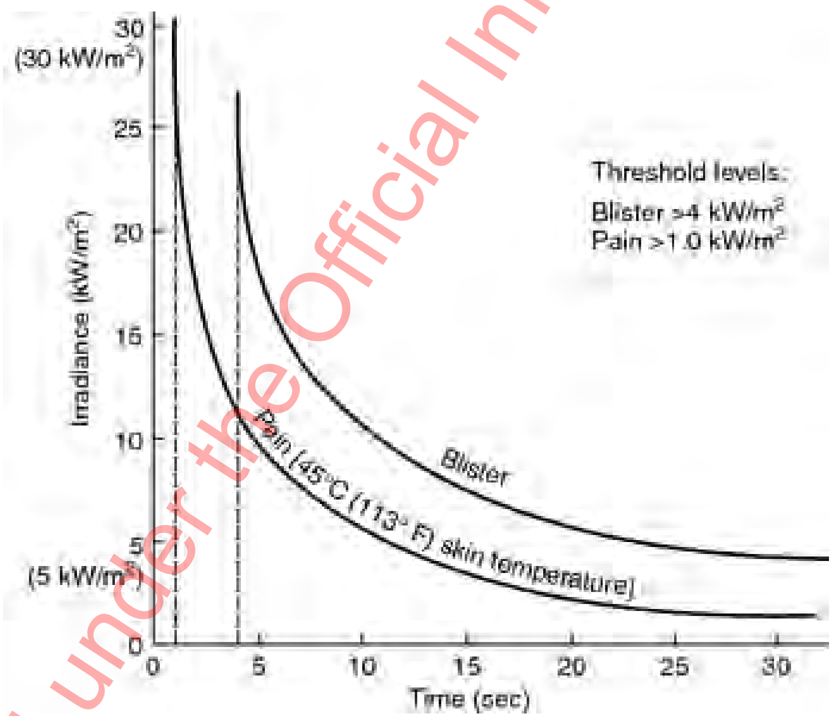


FIGURE 23.7.2.4 Diagram Showing Incident Radiant Heat Flux Effect on Bare Skin (Based on Stoll and Greene, 1959).

23.7.2.4.1 Conducted heat can be more dangerous than radiant or convected heat because the heat source is brought into more intimate contact with the skin than typically occurs with either radiant or convected heat transfer. Skin can be damaged when it reaches a temperature of 54°C (130°F). This exposure can result from immersion in water for 30 seconds at 54°C (130°F) or by immersion for only 1 second at 65°C (150°F). Clothing, especially heavier cellulosic fabrics like denim or canvas, can transmit enough heat by conduction to cause skin burns even though the fabric does not exhibit any burning or charring.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.7.2.4.2 The mass movement of hot gases involved in convective heating can produce similar increases in skin temperature.

23.7.3 Medical Evidence (Inhalation). Like medical evidence concerning skin burns, medical evidence concerning inhalation exposure to toxic gases and heat can provide important information to the investigator to understand both the actions of the injured individual and the fire environment to which the individual was exposed.

23.7.3.1 Sublethal Inhalation Exposure Effects on the Individual. Much of the information provided in Section 23.5 is also relevant to injuries, and the reader is referred to that section for additional information. The discussion here is limited to effects specific to sublethal effects of narcotic gases [carbon monoxide, hydrogen cyanide, oxygen-depleted air (hypoxia)], irritant gases (hydrogen chloride, acrolein, etc.), and smoke.

23.7.3.1.1 Narcotic Gases. Carbon monoxide, hydrogen cyanide, oxygen-depleted air (causing hypoxia) are all narcotic gases. Narcotic gases cause loss of alertness (intoxication), mental function, and psychomotor ability (the ability to carry out simple coordinated movements as are required in exiting a building). Carbon monoxide acts without the subject being aware of the extent of exposure and impairment. Hypoxia as a result of reduced oxygen concentration has a similar effect. Conversely, while hydrogen cyanide will ultimately result in mental depression and unconsciousness just as other narcotic gases, the effects of HCN exposure are more rapid and dramatic. At sublethal conditions, all these gases will reduce the ability of an individual to make decisions and carry out intended actions.

23.7.3.1.2 Irritant Gases. Irritant gases can alert people to the presence of a fire, even at low concentrations. Because of the unpleasant aspects of irritation of the eyes and respiratory tract, individuals may become aware of a fire earlier than would otherwise be the case, and may be motivated to escape. As the irritant effects become more pronounced, irritancy can have a direct impact on the ability of individuals to see and in this way may interfere with exiting behaviors. Post-fire effects of these irritants can be lung edema and inflammation.

23.7.3.1.3 Smoke. Visible products of combustion will impair the ability of individuals to see, and this in turn will reduce the speed of movement of escaping individuals. Sufficiently reduced visibility will cause individuals to not use an exit path. The extent of reduced visibility required to prevent the use of an exit path is dependent upon many factors, including the individual's familiarity with the building.

23.7.3.2 Hospital Tests and Documentation. Normally, upon hospital entry of a patient with fire-related injuries, a blood sample should be taken and analyzed for percent saturation of carboxyhemoglobin (percent of COHb), HCN concentration, blood alcohol, drugs, and blood pH to aid in the diagnosis and treatment of the individual. These measurements may be valuable in assessing the conditions of the individual at the fire scene and the fire environment to which the individual was exposed. In particular, the percent of COHb is a valuable indicator. However, since the percent of COHb begins to be reduced as soon as the individual is removed from the fire environment, it is important that the blood sample be taken as soon as possible.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.7.3.2.1 The rate at which CO is eliminated from the body is dependent on the oxygen concentration of the inhaled air. The concentration of CO in the blood will be decreased by one half (COHb half-life) in approximately 5 hours at normal air oxygen concentrations (21 percent by volume). COHb half-life is approximately 1 hour when a near 100 percent oxygen concentration is administered during emergency medical treatment. Because treatment and time can significantly reduce the measured percentage of COHb, the time from fire exposure to sampling of the blood for analysis and the treatment of the individual with oxygen by ambulance and hospital caregivers prior to sampling are important information, which the investigator should determine.

23.7.3.2.2 Other information of importance to the fire investigator is the condition of the airways. The presence of soot or thermal damage in the upper airways provides information about the fire environment to which the individual was exposed. Lung edema and inflammation can be indications of exposure to irritant gases.

23.7.4 Access to Medical Evidence. The fire investigator should be aware of the applicable legal protections regarding the confidentiality of medical records, and the appropriate methods for obtaining and safeguarding this confidential information.

23.8 Mechanism of Inhalation Injuries.

23.8.1 Elimination of CO by O_2/Air. The carboxyhemoglobin level of a fire survivor begins to decrease as soon as the person is removed from the fire environment. The rate at which CO is eliminated from the body is dependent on the oxygen concentration of the air being breathed. The concentration of CO in the blood (COHb saturation) will be decreased by one-half (COHb half-life), for example, reducing COHb from 45 percent to 22 percent in 250 minutes to 320 minutes at ambient O_2 levels in air (21 percent). COHb half-life is approximately 60 minutes to 90 minutes when a near 100 percent oxygen concentration is administered during emergency medical treatment. Hyperbaric oxygen treatment can reduce COHb half-life to approximately 30 minutes.

23.8.2 Explosion-Related Injuries. The location and distribution of explosion injuries to a victim can be useful in the reconstruction of the incident. These findings may indicate the location and activity of the victim at the time of the explosion, and they may help establish the location, orientation, energy, and function of the exploding mechanism or device. Explosion injuries can be divided into four categories based largely upon the explosion effect that caused them: blast pressure, shrapnel, thermal, and seismic.

23.8.2.1 Blast Pressure Injuries. The concussive effect upon a victim can cause internal injuries to various organs and body systems such as the gastrointestinal tract, lungs, eardrums, and blood vessels.

23.8.2.1.1 Frequently, the blast pressure front is strong enough to violently move or even propel the victim into solid objects, or conversely, both low- and high-order damage *(see Section 21.3)* can violently move or propel large solid objects (walls, doors, etc.) into victims. These actions can cause blunt trauma injuries, fractures, lacerations, amputations, contusions, and abrasions.

23.8.2.1.2 Dirt, sand, and other fine particles can be blasted into unprotected skin, causing a type of injury commonly called *tattooing*.

23.8.2.1.3 With detonations, there may be violent amputations or dismemberment of the body caused by the blast pressure wave. Parts of the body or its clothing may be propelled great distances and should be searched for and documented.

Source - NFPA 921, Chapter 23, 2008.

Extract

23.8.2.2 Shrapnel Injuries. Shrapnel (solid fragments) traveling at high speeds from the epicenter of an explosion can cause amputations, dismemberment, lacerations or perforations resembling stab wounds, localized blunt trauma such as broken and crushed bones, and soft tissue damage.

23.8.2.3 Thermal Injuries. Thermal injuries associated with explosion flame fronts (and not the following fires, which often accompany low-order explosions) are usually of the first- and second-degree types because of their very short duration. Third-degree burns can also be encountered in these situations, but with much less frequency. These burns can be fatal. Brief exposure to the high-temperature expanding flame front causes burn damage to the exposed skin surfaces. Often even a thin layer of clothing can protect the underlying skin from injury. Frequently, the burn injuries can be localized to the side of the body that is facing the expanding flame front. This finding can be used by the investigator as a heat and flame or explosion dynamics vector. Synthetic-fabric clothing may be melted by exposure to flash flames from deflagrations, where cotton fabrics may only be scorched.

23.8.2.4 Seismic Effect Injuries. The seismic effects of explosions are most dangerously manifested in the collapse of buildings and their structural elements. Injuries and deaths resulting from such occurrences are similar to what might be encountered by building damage from blast pressure waves. Collapse of buildings can cause blunt trauma injuries, lacerations, fractures, amputations, contusions, and abrasions. When examining victims of explosions, the investigator should take extreme care to scrutinize the body parts, clothing, and associated debris to find, document, and preserve items of evidence, such as clothing and any foreign objects found.

Source - NFPA 921, Chapter 23, 2008.

Analytical Tools

Section Contents

1. Methodologies of Fire Investigation

NFPA 921, Chapter 4 – Basic Methodology

Extract

4.1 Nature of Fire Investigations.

A fire or explosion investigation is a complex endeavor involving skill, technology, knowledge, and science. The compilation of factual data, as well as an analysis of those facts, should be accomplished objectively and truthfully. The basic methodology of the fire investigation should rely on the use of a systematic approach and attention to all relevant details. The use of a systematic approach often will uncover new factual data for analysis, which may require previous conclusions to be reevaluated. With few exceptions, the proper methodology for a fire or explosion investigation is to first determine and establish the origin(s), then investigate the cause: circumstances, conditions, or agencies that brought the ignition source, fuel, and oxidant together.

4.2 Systematic Approach.

The systematic approach recommended is that of the scientific method, which is used in the physical sciences. This method provides for the organizational and analytical process desirable and necessary in a successful fire investigation.

4.3 Relating Fire Investigation to the Scientific Method.

The scientific method *(see Figure 4.3)* is a principle of inquiry that forms a basis for legitimate scientific and engineering processes, including fire incident investigation. It is applied using the following steps.

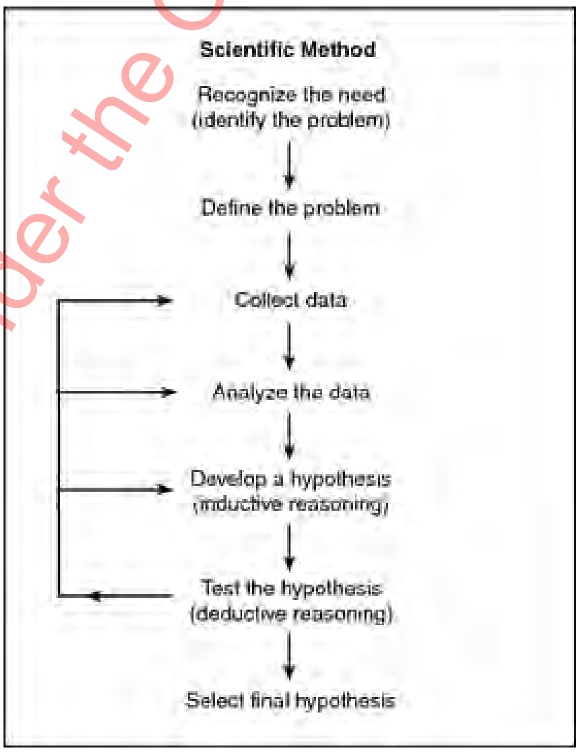


FIGURE 4.3 Use of the Scientific Method.

Source – NFPA 921, Chapter 4, 2008.

Extract

4.3.1 Recognize the Need. First, one should determine that a problem exists. In this case, a fire or explosion has occurred and the cause should be determined and listed so that future, similar incidents can be prevented.

4.3.2 Define the Problem. Having determined that a problem exists, the investigator or analyst should define in what manner the problem can be solved. In this case, a proper origin and cause investigation should be conducted. This is done by an examination of the scene and by a combination of other data collection methods, such as the review of previously conducted investigations of the incident, the interviewing of witnesses or other knowledgeable persons, and the results of scientific testing.

4.3.3 Collect Data. Facts about the fire incident are now collected by observation, experiment, or other direct data-gathering means. The data collected is called empirical data because it is based on observation or experience and is capable of being verified.

4.3.4 Analyze the Data. The scientific method requires that all data collected be analyzed. This is an essential step that must take place before the formation of the final hypothesis. The identification, gathering, and cataloging of data does not equate to data analysis. Analysis of the data is based on the knowledge, training, experience, and expertise of the individual doing the analysis. If the investigator lacks expertise to properly attribute meaning to a piece of data, then assistance should be sought. Understanding the meaning of the data will enable the investigator to form hypotheses based on the evidence, rather than on speculation.

4.3.5 Develop a Hypothesis (Inductive Reasoning). Based on the data analysis, the investigator produces a hypothesis, or hypotheses, to explain the phenomena, whether it be the nature of fire patterns, fire spread, identification of the origin, the ignition sequence, the fire cause, or the causes of damage or responsibility for the fire or explosion incident. This process is referred to as inductive reasoning. These hypotheses should be based solely on the empirical data that the investigator has collected through observation and then developed into explanations for the event, which are based upon the investigator's knowledge, training, experience, and expertise.

4.3.6 Test the Hypothesis (Deductive Reasoning). The investigator does not have a provable hypothesis unless it can stand the test of careful and serious challenge. Testing of the hypothesis is done by the principle of deductive reasoning, in which the investigator compares his or her hypothesis to all the known facts as well as the body of scientific knowledge associated with the phenomenon relevant to the specific incident. A hypothesis can be tested either physically by conducting experiments or analytically by applying scientific principles in "thought experiments." When relying on experiments or research of others, the investigator must ensure that the conditions and circumstances are sufficiently similar. When the investigator relies on previously conducted research, references to the research relied upon should be noted. If the hypothesis cannot be supported, it should be discarded and alternate hypotheses should be developed and tested. This may include the collection of new data or the reanalysis of existing data. The testing process needs to be continued until all feasible hypotheses have been tested and one is determined to be uniquely consistent with the facts, and with the principles of science. If no hypothesis can withstand an examination by deductive reasoning, the issue should be considered undetermined.

4.3.7 Avoid Presumption. Until data have been collected, no specific hypothesis can be reasonably formed or tested. All investigations of fire and explosion incidents should be approached by the investigator without presumption as to origin, ignition sequence, cause, fire spread, or responsibility for incident until the use of scientific method has yielded a provable hypotheses.

Source - NFPA 921, Chapter 4, 2008.

Extract

4.3.8 Expectation Bias. Expectation bias is a well-established phenomenon that occurs in scientific analysis when investigator(s) reach a premature conclusion too early in the study and without having examined or considered all of the relevant data. Instead of collecting and examining all of the data in a logical and unbiased manner to reach a scientifically reliable conclusion, the investigator(s) use the premature determination to dictate their investigative processes, analyses, and, ultimately, their conclusions, in a way that is not scientifically valid. The introduction of expectation bias into the investigation results in the use of only that data that supports this previously formed conclusion and often results in the misinterpretation and/or the discarding of data that does not support the original opinion. Investigators are strongly cautioned to avoid expectation bias through proper use of the scientific method.

4.4 Basic Method of a Fire Investigation.

Using the scientific method in most fire or explosion incidents should involve the steps shown in 4.4.1 through 4.4.6.

4.4.1 Receiving the Assignment. The investigator should be notified of the incident, told what his or her role will be, and told what he or she is to accomplish. For example, the investigator should know if he or she is expected to determine the origin, cause, and responsibility; produce a written or oral report; prepare for criminal or civil litigation; make suggestions for code enforcement, code promulgation, or changes; make suggestions to manufacturers, industry associations, or government agency action; or determine some other results.

4.4.2 Preparing for the Investigation. The investigator should marshal his or her forces and resources and plan the conduct of the investigation. Preplanning at this stage can greatly increase the efficiency and therefore the chances for success of the overall investigation. Estimating what tools, equipment, and personnel (both laborers and experts) will be needed can make the initial scene investigation, as well as subsequent investigative examinations and analyses, go more smoothly and be more productive.

4.4.3 Conducting the Investigation.

4.4.3.1 It is during this stage of the investigation that an examination of the incident fire or explosion scene is conducted. The fundamental purpose of conducting an examination of any incident scene is to collect all of the available data and document the incident scene. The investigator should conduct an examination of the scene if it is available and collect data necessary to the analysis.

4.4.3.2 The actual investigation may include different steps and procedures, which will be determined by the purpose of the assignment. These steps and procedures are described in detail elsewhere in the document. A fire or explosion investigation may include all or some of the following tasks: a scene inspection or review of previous scene documentation done by others; scene documentation through photography and diagramming; evidence recognition, documentation, and preservation; witness interviews; review and analysis of the investigations of others; and identification and collection of data from other appropriate sources.

Source - NFPA 921, Chapter 4, 2008.

Extract

4.4.3.3 In any incident scene investigation, it is necessary for at least one individual/organization to conduct an examination of the incident scene for the purpose of data collection and documentation. While it is preferable that all subsequent investigators have the opportunity to conduct an independent examination of the incident scene, in practice, not every scene is available at the time of the assignment. The use of previously collected data from a properly documented scene can be used successfully in an analysis of the incident to reach valid conclusions through the appropriate use of the scientific method. Thus, the reliance on previously collected data and scene documentation should not be inherently considered a limitation in the ability to successfully investigate the incident.

4.4.3.4 The goal of all investigators is to arrive at accurate determinations related to the origin, cause, fire spread, and responsibility for the incident. Improper scene documentation can impair the opportunity of other interested parties to obtain the same evidentiary value from the data. This potential impairment underscores the importance of performing comprehensive scene documentation and data collection.

4.4.4 Collecting and Preserving Evidence. Valuable physical evidence should be recognized, documented, properly collected, and preserved for further testing and evaluation or courtroom presentation.

4.4.5 Analyzing the Incident. All collected and available data should be analyzed using the principles of the scientific method. Depending on the nature and scope of one's assignment, hypotheses should be developed and tested explaining the origin, ignition sequence, fire spread, fire cause or causes of damage or casualties, or responsibility for the incident.

4.4.6 Conclusions. Conclusions, which are final hypotheses, are drawn as a result of testing the hypotheses. Conclusions should be drawn according to the principles expressed in this guide and reported appropriately.

4.5 Reporting Procedure.

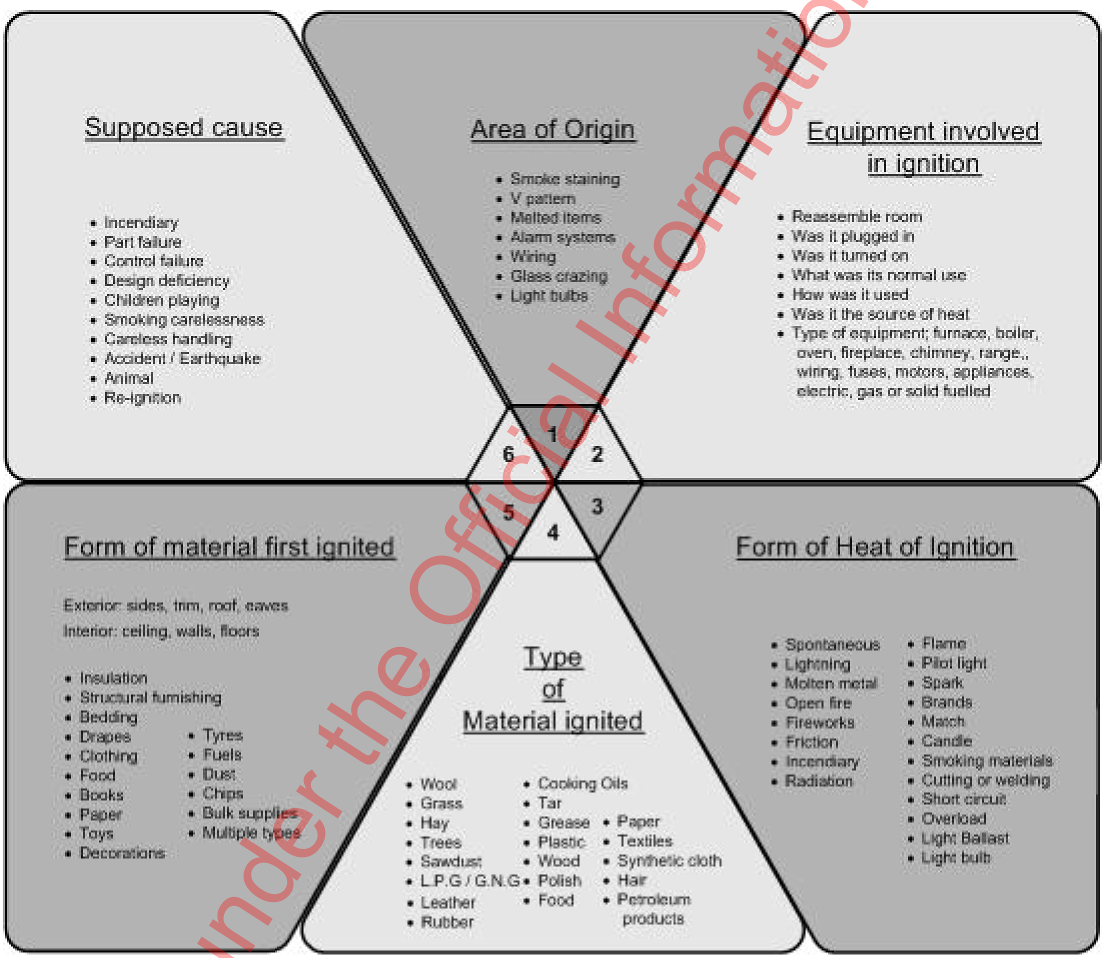
The reporting procedure may take many written or oral forms, depending on the specific responsibility of the investigator. Pertinent information should be reported in a proper form and forum to help prevent recurrence.

Source - NFPA 921, Chapter 4, 2008.

Hexagonal elimination process

During a Fire Scene Examination it is helpful to apply a scientific method and a systematic approach to the investigation. By following the hexagonal elimination process and by gathering information, facts and evidence from the wider scene narrowing into the supposed cause, we can hopefully start to get a clearer picture on the area of origin and cause of the fire.

Extract



This reprinted material is not the complete and official position of the National Fire Protection Association on the referenced subject, which is represented only by the standard in its entirety.

Source – NFPA 901, Fire Investigation Data Coding Guide 1976.

2. Timelines

NFPA 921, Chapter 20 – Failure Analysis and Analytical Tools

Extract

20.1 Introduction.
This chapter identifies methods available to assist the investigator in the analysis of a fire/explosion incident. Additional tools requiring special expertise are also discussed. These methods can be used to analyze fires of any size or complexity. In many cases, the methods are used to organize information collected during the documentation of the incident into a rational and logical format. They can also be used to identify aspects of the investigation needing additional information and where future efforts should be directed.

20.2 Time Lines.

20.2.1 General. A time line is a graphic or narrative representation of events related to the fire incident, arranged in chronological order.

20.2.1.1 The events included in the time line may occur before, during, or after the fire incident. This investigative tool can show relationships between events, identify gaps or inconsistencies in information and sources, assist in witness interviews, and otherwise assist in the analysis and investigation of the incident. A graphic time line is useful as a demonstrative document. The value of a time line is dependent upon the accuracy of the information used to develop the time line.

20.2.1.2 Estimates of fire size or fire conditions are frequently valuable in developing time lines. Using the tools of fire dynamics analysis *(see 20.4.8)*, fire conditions can be related to specific events. If there are sufficient events it may be possible to develop an estimate of the heat release history for at least the early stages of a fire.

20.2.1.2.1 For example, the observed height of flames, relative to the height of known objects, can be used to estimate the rate of heat release of the fire. Given the response characteristics of detectors and sprinklers, the size of a fire at the time of operation of such devices can be estimated. If the time of operation is recorded at an alarm panel or remote location such as a central alarm service, the estimated size of the fire in the area of the building where the alarm occurred can become part of the time line. Where the detection or suppression systems have multiple zones, the time of operation in each zone can be used to track the spread of the fire through a building and the events can be added to the time line. If the heat release can be estimated for several points in time, a possible heat release history may be postulated and used as one means to assist in testing various hypotheses for the cause and growth scenarios in a given fire.

Source – NFPA 921, Chapter 20, 2008.

Extract

20.2.1.2.2 Fire dynamics analysis can also be used to provide estimated times for relevant events to occur where limited eyewitness observations or hard times are available. Such events include ignition of additional fuels, detector activation, flashover, window breakage, fire spread to adjacent compartments, and occupant incapacitation and death. These analysis tools have acknowledged limitations, and the associated input data are subject to uncertainties. Therefore, estimates of fire conditions and related events in the time line may require to be described as a time interval (e.g., flashover between 10:46 and 10:48) as opposed to a single and specific time (e.g., 10:46).

20.2.1.3 In order to construct a time line, it is necessary to relate events or activities to the time of their occurrence. In assigning time to events or activities, it is important to identify the confidence the investigator has in the assigned time. One means of doing this is to identify the quality of the data as hard time (actual) or soft time (estimated or relative).

20.2.2 Hard Time (Actual).

20.2.2.1 Hard time identifies a specific point in time that is directly or indirectly linked to a reliable clock or timing device of known accuracy. It is possible to have a time line with no hard times. Hard times can be obtained from sources such as the following:

(1) Fire department dispatch telephone or radio logs
(2) Police department dispatch and radio logs
(3) Emergency Medical Service reports
(4) Alarm system records (on-site, central station, fire dispatch, etc.)
(5) Building inspection report(s)
(6) Health inspection report(s)
(7) Fire inspection report(s)
(8) Utility company records (maintenance/emergency/repair records)
(9) Private videos/photos (check with local film developers)
(10) Media coverage (newspaper photographer, radio, television, magazines)
(11) Timers (clocks, time clocks, security timers, water softeners, lawn sprinkler systems)
(12) Weather reports (NOAA, airports, lightning tracking services)
(13) Current and/or prior owner/tenant records (re: maintenance)
(14) Interviews
(15) Computer-based fire department alarms, communications audio tapes, and transcripts
(16) Building or systems installation permits

20.2.2.2 All clocks and timing devices are usually not synchronized. Discrepancies between different clocks should be recorded and adjustments made where necessary.

20.2.3 Soft Time (Estimated).

20.2.3.1 Soft time can be either estimated or relative time. *Relative time* is the chronological order of events or activities that can be identified in relation to other events or activities. *Estimated time* is an approximation based on information or calculations that may or may not be relative to other events or activities. Often, relative or estimated times can be determined within a known degree of accuracy. For example, they may be bound by two known events or within a time range. It may be desirable to report them as a time range rather than as discrete time.

Source - NFPA 921, Chapter 20, 2008

Extract

20.2.3.2 Relative time can be very subjective in nature. The concept of elapsed time varies with the individual and the stress caused by the incident. It is important for witnesses to be as specific as possible by having them refer to their actions and observations in relation to each other and to other events. All relative time is based on an estimate. It is also possible to have events for which the estimated time cannot be related to a hard time but that are valuable to the analysis. These are referred to as *estimated times*. Relative or estimated times are generally provided by witnesses.

20.2.3.3 Potential sources of soft times include those sources for hard times listed in 20.2.2.1, along with estimation of times for an activity to be performed or an event to occur.

20.2.4 Benchmark Events. Some events are particularly valuable as a foundation for the time line or may have significant relation to the cause, spread, detection, or extinguishment of a fire. These are referred to as *benchmark events*. An example of a benchmark event could be the dispatch and arrival times of the fire fighters as recorded on the fire department incident report. Other examples may include events such as a roof collapsing, a window breaking out, or an explosion.

20.2.5 Multiple Time Lines. It is quite possible that two or more time lines will be required to effectively evaluate and document the sequence of events precipitating the fire, the actual fire incident, and post-fire activity. These time lines can be called *macro* and *micro*.

20.2.5.1 A macro evaluation of events may incorporate activity that occurred months before the fire and that terminated on the demolition of the building. As an example, this activity might include renovations that altered the building's electrical system and that may be attributable as the ignition source.

20.2.5.2 A micro evaluation of events focuses on some discrete segment of the total time line for which the investigator has a particular interest. For example, it may consist of an evaluation of events during the time period immediately prior to ignition, during initial fire fighting, during fire growth, or from ignition to extinguishment.

20.2.5.3 Parallel time lines can be presented to demonstrate two or more series of events. The purpose of such a presentation may be to show whether or not they are related in some manner.

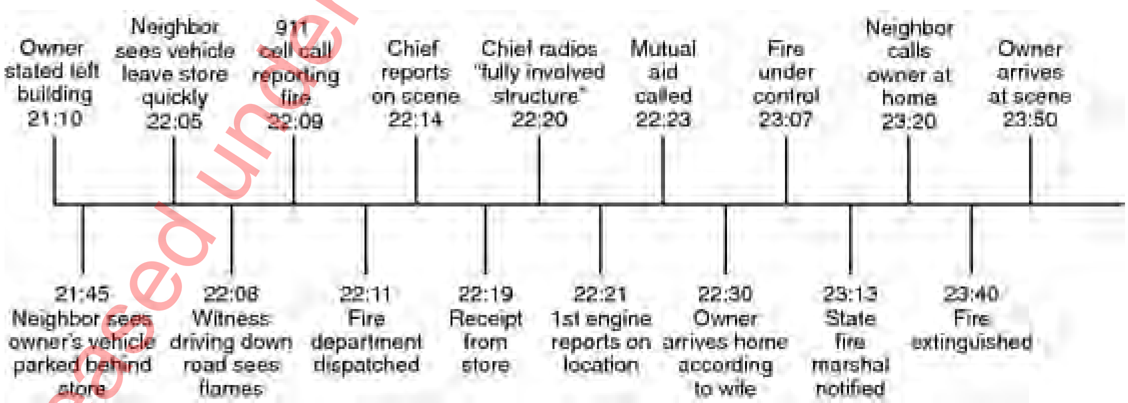


FIGURE 20.2.5.4 Illustration of a Simple Chronology Time Line.

Source - NFPA 921, Chapter 20, 2008

Extract

20.2.5.5 Scaled Time Line. A scaled time line displays a list of events that appear on the time line in both chronological and elapsed time relationship to each other. Individual events that are closer together to each other in time are drawn physically closer together on the time line, while events that are further apart in time are further apart on the time line and there is a definite scale or ratio of time to distance along the length of the line. See Figure 20.2.5.5. In addition, Figure 20.2.5.5 identifies hard and soft times by listing hard times above the time line and soft or estimated times below. Hard times in Figure 20.2.5.5 include when John Doe punched the time clock at work and the reported alarm and arrival times of the fire department, all of which can be correlated to known clocks. Soft times listed in Figure 20.2.5.5 include estimated times for ignition, smoke alarm activation, and flashover derived from computer modeling, and the estimated time that the eyewitness first became aware of the fire.

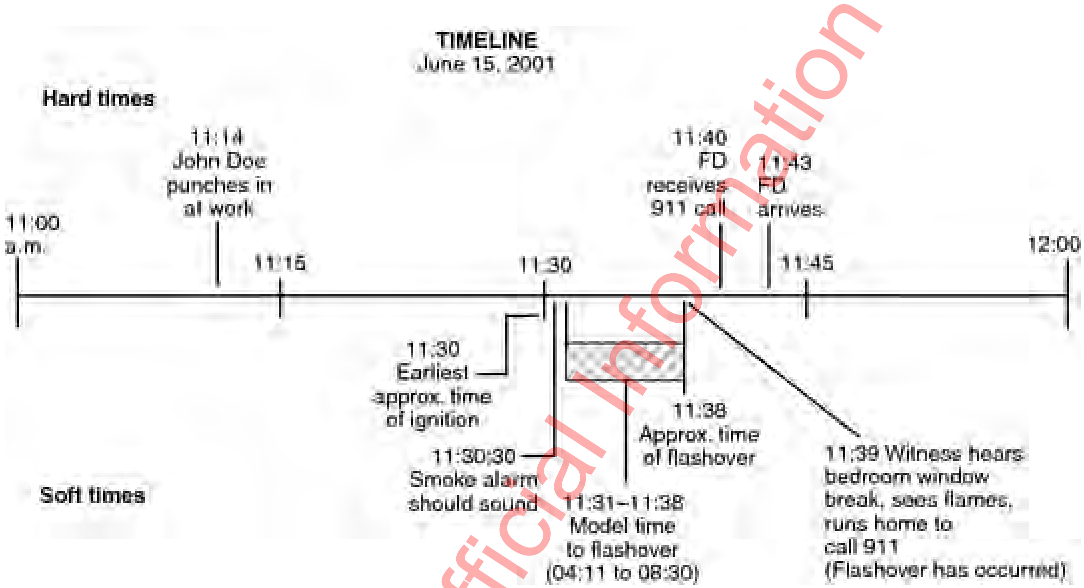


FIGURE 20.2.5.5 Example of a Scaled Time Line (displaying hard times above the line and soft, or estimated, times below).

20.3 Systems Analysis.

Systems analysis techniques are important tools in identifying when and how engineering analysis and modeling may be useful. These techniques, developed for use in system safety analyses, include failure modes and effects analysis, fault tree analysis, HAZOP analysis, and what-if analysis. These tools provide a systematic method for analyzing systems to determine hazards or faults. The tools can utilize either qualitative or quantitative formats. Hazard probabilities or failure rates can be factored in when using quantitative formats. Some of the more common techniques — fault tree analysis and failure mode and effects analysis — are described in 20.3.1 through 20.3.2. Several other systems analyses are available, each with its inherent advantages and limitations.

20.3.1 Fault Trees. A fault tree is a logic diagram that can be used to analyze a fire or explosion. A fault tree is developed using deductive reasoning. The diagram places, in logical sequence and position, the conditions and chains of events that are necessary for a given fire or explosion to occur.

Source - NFPA 921, Chapter 20, 2008

Extract

20.3.1.1 Fault trees can be used to test the possibility of a proposed fire cause or spread scenario and to identify or evaluate possible alternative scenarios. Fault trees are developed by breaking down an undesired event into its causal elements or component parts. The components are then placed in logical sequences of events or conditions necessary to produce the fire or explosion, or into categories of specific aspect of associated damage, death, or injury. If the conditions are not present or if the events did not occur in the necessary sequence, then the proposed scenario is not possible. For example, if the proposed scenario required a live electrical circuit and there was no electrical service, the scenario would be incorrect unless an alternative source for the electricity could be shown. The logic for evaluating the events and conditions that control undesired events is represented by “and” decisions and “or” decisions. In a graphic representation of a fault tree, these decision points are called *gates*. In most cases, fault trees involve combinations of “and” gates and “or” gates, as shown in Figure 20.3.1.1.

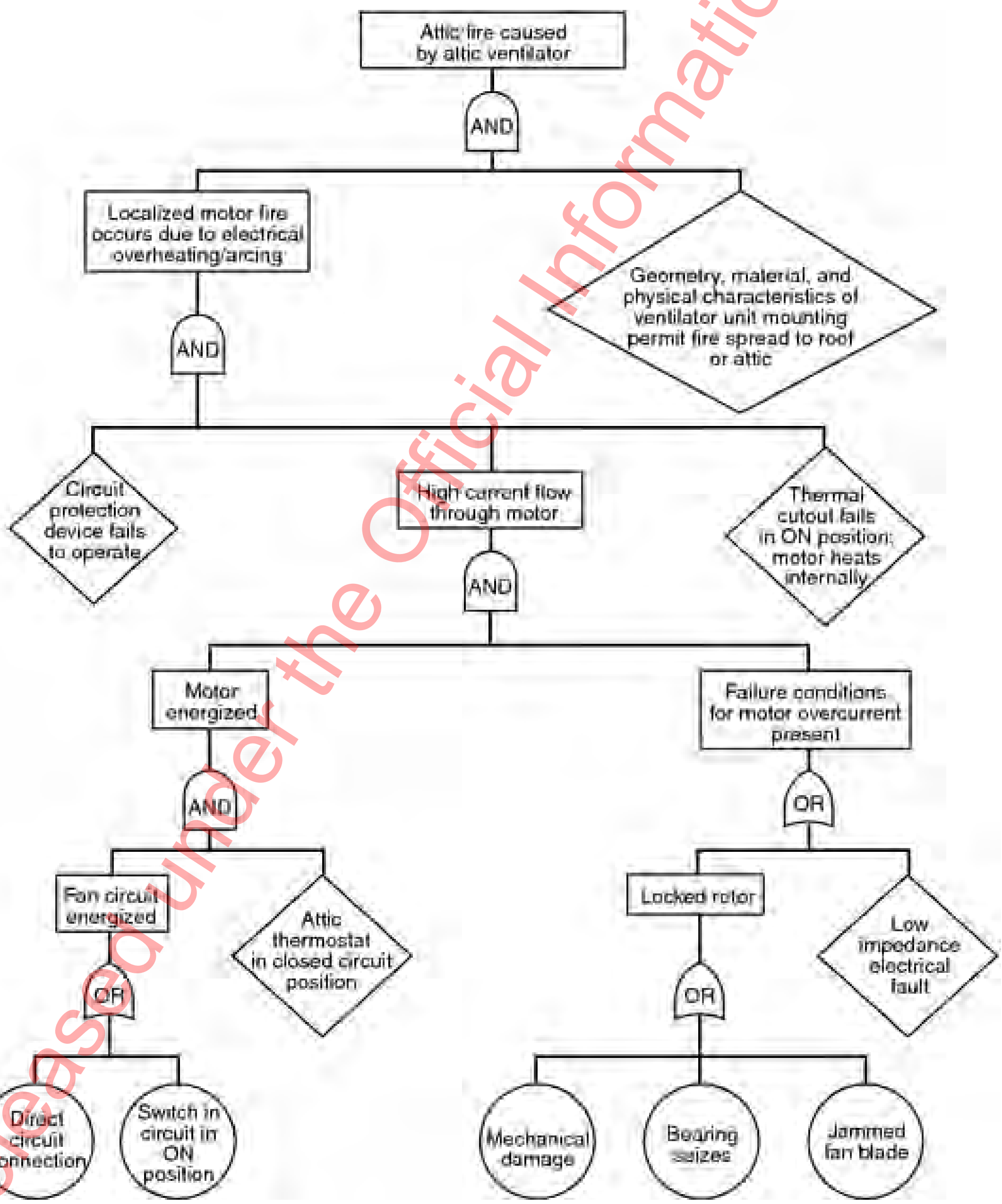


FIGURE 20.3.1.1 Fault Tree Showing Combination of “And” and “Or” Gates.

Source - NFPA 921, Chapter 20, 2008

Extract

20.3.1.2 For an “and” controlled event to occur, all the elements and conditions must be present. An example using an “and” gate is the set of conditions that must be present for a flashlight to work and produce light. There must be good batteries, the bulb must be good, and the switch must work to produce light. A fault tree for this process is shown in Figure 20.3.1.2.

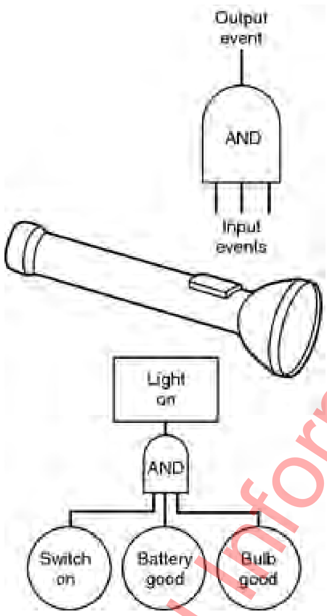


FIGURE 20.3.1.2 Example of Fault Tree Showing “And” Gate.

20.3.1.3 For an “or” controlled event, any one of several series of elements and conditions may result in the subject event. An example using an “or” gate would be a flashlight that does not work when the switch is operated. The failure might be due to a switch failure, a blown bulb, or battery problems. Figure 20.3.1.3 shows the fault tree for this example.

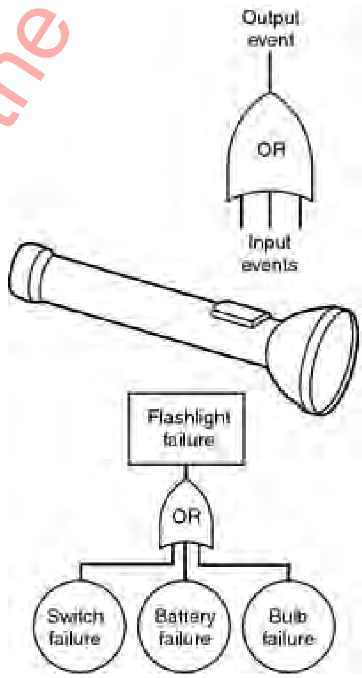


FIGURE 20.3.1.3 Example of Fault Tree Showing “Or” Gate.

Source - NFPA 921, Chapter 20, 2008

Extract

20.3.1.4 Fault tree analysis may be used to estimate the probability of an undesired event by assigning probabilities to the conditions and events. Assigning reliable probabilities to events or conditions is often difficult and may not be possible.

20.3.1.5 All system components, their relationships, and the validity of data used need to be identified. In order to construct a fault tree properly, it may be necessary to consult people with special expertise regarding the equipment, materials, or processes involved.

20.3.1.6 The fault tree method of analysis may produce multiple feasible scenarios for a given undesirable event. As a result of insufficient data, it may not be possible to establish which scenario is most likely.

20.3.1.7 Suggested sources for data to be used in fault tree analysis include the following:

(1) Operations and maintenance manuals
(2) Maintenance records
(3) Parts replacement and repair records
(4) Design documents
(5) Services of expert with knowledge of system
(6) Examination and testing of exemplar equipment or materials
(7) Component reliability databases
(8) Building plans and specifications
(9) Fire department reports
(10) Incident scene documentation
(11) Witness statements
(12) Medical records of victims
(13) Human behavior information

20.3.1.8 Fault trees are constructed using a standard format familiar to the technical community. Software is available for assisting the user in developing and analyzing fault trees.

Source - NFPA 921, Chapter 20, 2008

Extract

20.3.2 Failure Mode and Effects Analysis (FMEA). FMEA is a technique used to identify basic sources of failure within a system, and to follow the consequences of these failures in a systematic fashion. In fire/explosion investigations, FMEA is a systematic evaluation of all equipment and/or actions that could have contributed to the cause of an incident. FMEA is prepared by filling in a table with column headings such as are shown in Figure 20.3.2. The column headings and format of the table are flexible, but at least the following three items are common:

(1) Item (or action) being analyzed
(2) Basic fault (failure) or error that created the hazard
(3) Consequence of the failure

Component	Failure mode	Direct effect	Effect on system	Hazard category	Recommended change

Component	Operating mode	Failure mode	Hazardous aspect	Failure frequency	Hazard category	Corrective action

Item	Failure mechanism	Failure rate	Possible hazard	Hazard duration	Source of data	Remarks

FIGURE 20.3.2 Simplified Examples of Failure Mode and Effects Analysis Forms.

20.3.2.1 FMEA can help identify potential causes of a fire or explosion and can indicate where further analysis could be beneficial. FMEA is particularly useful in a large or complex incident. It can be effective in identifying factors, both physical and human, that could have contributed to the cause of the fire/explosion. Similarly, it can be helpful in eliminating potential causes of a fire/explosion.

20.3.2.2 Additional columns are added by the investigator as appropriate, to address the needs of the particular investigation. An assessment of the likelihood of each individual failure mode is frequently included. It is helpful to assess the consequence of a given failure relative to the fire/explosion. FMEA tables can be cataloged by item and can serve as reference material for further investigations. FMEA tables can be developed using computer spreadsheets or specialized software.

20.3.2.3 When filling out the table, the investigator should consider the range of environmental conditions and the process status (i.e., normal operation, shutdown, and startup) for each item or action. Probabilities or degrees of likelihood can be assigned to each occurrence. When a sequence of failures is required for the incident to occur, the probabilities or degrees of likelihood can be combined to assess the likelihood that any given sequence of events led to the incident.

Source - NFPA 921, Chapter 20, 2008

Extract

20.3.2.3 When filling out the table, the investigator should consider the range of environmental conditions and the process status (i.e., normal operation, shutdown, and startup) for each item or action. Probabilities or degrees of likelihood can be assigned to each occurrence. When a sequence of failures is required for the incident to occur, the probabilities or degrees of likelihood can be combined to assess the likelihood that any given sequence of events led to the incident.

20.3.2.4 All known system components and human actions that may have contributed to the incident need to be identified. The accuracy of the determination of the sequence of the events is dependent on the accuracy assigned to each of the individual failure modes.

20.3.2.5 The data required for an FMEA depend on the extent of the analysis desired. Minimum information typically includes a list of all system components and human actions that may have led to the incident, possible failure modes for each component and action, and the immediate consequences of each failure. It is important to recognize that many system components will have more than one failure mode, so each possible failure mode and its particular consequences should be listed for each component or action.

20.3.2.6 Data for systems and components can be obtained from many sources, including the following:

(1) Operations and maintenance manuals
(2) Maintenance records
(3) Parts replacement and repair records
(4) Design documents
(5) Services of expert with knowledge of system
(6) Examination and testing of exemplar equipment or materials
(7) Component reliability databases
(8) Building plans and specifications
(9) Fire department reports
(10) Incident scene documentation
(11) Witness statements
(12) Medical records of victims
(13) Human behavior information

Source - NFPA 921, Chapter 20, 2008

Extract

20.3.2.7 Table 20.3.2.7 shows a hypothetical example of an FMEA applied to a particular fire scenario, in the determination of a cause of that fire.

Table 20.3.2.7 Sample Failure Mode and Effects Analysis for Lunchroom Fire

Component Item	Failure Mode	Cause of Failure	Effects of Failure	Hazard Created	Necessary Conditions	Indication of Failure
Coffee maker	Heater current flows without shutoff	Switch left on and controls fail	"Boils" out any water in reservoir; thermal runaway of heating element; local temperature increases above 600°C	Ignition of plastic housing	Power on; switch on or fails closed; thermostat fails in ON position; both thermal fuses fail to open	Melting of aluminum housing around heating element; condensed aluminum at base of maker; thermostat closed circuit; both fuses closed circuit
Range (electric)	Autoignition of cooking oil	Unattended cooking Control failure	Oil temperature raised above autoignition temperature	Burning oil fire and large amount of smoke	Unit on; switch on or fails in closed position; no temperature regulation	Burner control in ON position; melted aluminum pan; oil consumed or spilled on unit; contacts fused or welded

Note: The data and conclusions presented in this table are hypothetical and used for example purposes only.

Source - NFPA 921, Chapter 20, 2008

Extract

20.4 Mathematical Modeling.

20.4.1 General. Mathematical modeling techniques provide the investigator with tools for testing hypotheses regarding the origin and cause of the fire/explosion and the cause of the resulting damage to property or injury to people. Even when the origin and cause are not issues, it is often possible and important to establish the cause of the resulting damage to property or injury to people.

20.4.1.1 The scope of this discussion emphasizes models and analyses that can be exercised using hand or computer-aided calculations. Usage of these analytical tools depends on the scope of the investigator's assignment, the particular incident, and the practical purpose of the investigation. A special expert may be needed to complete the analysis.

20.4.1.2 Mathematical models are intended to simulate or predict real-world phenomena using scientific principles and empirical data. There are numerous fields and specialty disciplines that use models. Some that have proven useful in fire and explosion investigations are discussed in 20.4.2 through 20.4.8.

20.4.1.3 Limitations of Mathematical Modeling. Mathematical modeling, whether simplified hand calculations or computer fire models, has inherent limitations and assumptions that should be considered. Models generally rely upon empirical data and are validated via comparison with other empirical data. Care must be taken to assure that the model is being used with due regard for limitations, assumptions, and validation. While computational models can be used to test hypotheses, models should not be utilized as the sole basis of a fire origin and cause determination.

20.4.1.4 In the selection of a mathematical model for use in hypothesis testing, the scope, applicability, basis, and validation and verification of the model should be considered. Models selected should be known to be capable of addressing the technical issues posed in the hypothesis testing. Use of proprietary software may create issues that will need to be addressed, with respect to the ability of other parties to examine the results and use the software.

20.4.1.5 Inputs to mathematical models are subject to uncertainties that should be considered in the evaluation of model results. The effect of input uncertainties on model results should be assessed through the use of sensitivity analysis. Uncertainties in model inputs may be significantly increased if standardized methods for input determination have not been developed in conjunction with the selected model. Other sources of uncertainty in inputs can result from the use of generic data from the fire science literature or use of exemplar materials for experimental determination of model inputs.

20.4.1.6 Results of mathematical models are subject to uncertainties resulting from approximations made within the model. The uncertainties introduced by modeling approximations should be considered in hypothesis testing. Information on modeling uncertainties is typically included in validation and verification (V & V) documents. Additional comparisons of model results with relevant existing experimental results may be useful to further establish the V & V basis of the model for use in the investigation.

Source - NFPA 921, Chapter 20, 2008

Extract

20.4.2 Heat Transfer Analysis.

20.4.2.1 Heat transfer models allow quantitative analysis of conduction, convection, and radiation in fire scenarios. These models are then used to test hypotheses regarding fire causation, fire spread, and resultant damage to property and injury to people. Heat transfer models are often incorporated into other models, including structural and fire dynamics analysis. Various general texts on heat transfer analysis are available.

20.4.2.2 Heat transfer models and analyses can be used to evaluate various hypotheses, including those relating to the following:

(1) Competency of ignition source *(See Section 18.3.)*
(2) Damage or ignition to adjacent building(s)
(3) Ignition of secondary fuel items
(4) Thermal transmission through building elements

20.4.3 Flammable Gas Concentrations. Models can be used to calculate gas concentrations as a function of time and elevation in the space and can assist in identifying ignition sources. Flammable gas concentration modeling, combined with an evaluation of explosion or fire damage and the location of possible ignition sources, can be used (a) to establish whether or not a suspected or alleged leak could have been the cause of an explosion or fire, and (b) to determine what source(s) of gas or fuel vapor were consistent with the explosion or fire scenario, damage, and possible ignition sources.

20.4.4 Hydraulic Analysis.

20.4.4.1 Analysis of automatic sprinkler and water supply systems is often required in the evaluation of the cause of loss. The same mathematical models and computer codes used to design these systems can be used in loss analysis. However, the methods of application are different for design than they are for forensic analysis.

20.4.4.2 A common application of hydraulic analysis is to determine why a sprinkler system did not control a fire. Modeling can also be used to investigate the loss associated with a single sprinkler head opening, to investigate the effect of fouling in the piping, and to determine the effect of valve position on system performance at the time of loss. There are also models and methods available to analyze flow through systems other than water-based systems, such as carbon dioxide, gaseous suppression agents, dry chemicals, and fuels.

20.4.5 Thermodynamic Chemical Equilibrium Analysis. Fires and explosions believed to be caused by reactions of known or suspected chemical mixtures can be investigated by a thermodynamics analysis of the probable chemical mixtures and potential contaminants.

20.4.5.1 Thermodynamic chemical equilibrium analysis can be used to evaluate various hypotheses, including those relating to the following:

(1) Reaction(s) that could have caused the fire/explosion
(2) Improper mixture of chemicals
(3) Role of contamination
(4) Role of ambient conditions
(5) Potential of a chemical or chemical mixture to overheat
(6) Potential for a chemical or chemical mixture to produce flammable vapors or gases
(7) Role of human action on process failures

Source - NFPA 921, Chapter 20, 2008

Extract

20.4.5.2 Thermodynamic reaction equilibrium analysis traditionally required tedious hand calculations. Currently available computer programs make this analysis much easier to perform. The computer programs typically require several material properties as inputs, including chemical formula, mass, density, entropy, and heat of formation.

20.4.5.3 Chemical reactions that are shown not to be favored by thermodynamics can be eliminated from consideration as the cause of a fire. Thermodynamically favored reactions must be further analyzed to determine whether the kinetic rate of the considered reactions is fast enough to have caused ignition, given the particular circumstances of the fire.

20.4.6 Structural Analysis. Structural analysis techniques can be utilized to determine reasons for structural failure or change during a fire or explosion. Numerous references can be found in engineering libraries, addressing matters such as strength of materials, formulas for simple structural elements, and structural analysis of assemblies.

20.4.7 Egress Analysis. The failure of occupants to escape may be one of the critical issues that an investigator needs to address. Egress models can be utilized to analyze movement of occupants under fire conditions. Integrating egress models with a fire dynamics model is often necessary to evaluate the effect of the fire environment on the occupants. See Section 10.3 on human factors.

20.4.8 Fire Dynamics Analysis. Fire dynamics analyses consist of mathematical equations derived from fundamental scientific principles or from empirical data. They range from simple algebraic equations to computer models incorporating many individual fire dynamics equations. Fire dynamics analysis can be used to predict fire phenomena and characteristics of the environment such as the following:

(1) Time to flashover
(2) Gas temperatures
(3) Gas concentrations (oxygen, carbon monoxide, carbon dioxide, and others)
(4) Smoke concentrations
(5) Flow rates of smoke, gases, and unburned fuel
(6) Temperatures of the walls, ceiling, and floor
(7) Time of activation of smoke detectors, heat detectors, and sprinklers
(8) Effects of opening or closing doors, breakage of windows, or other physical events

20.4.8.1 Fire dynamics analyses can be used to evaluate hypotheses regarding fire origin and fire development. The analyses use building data and fire dynamics principles and data to predict the environment created by the fire under a proposed hypothesis. The results can be compared to physical and eyewitness evidence to support or refute the hypothesis.

20.4.8.2 Building, contents, and fire dynamics data are subject to uncertainties. The effects of these uncertainties should be assessed through a sensitivity analysis and should be incorporated in hypothesis testing. Uncertainties may include the condition of openings (open or closed), the fire load characteristics, HVAC flow rates, and the heat release rate of the fuel packages. See Section 20.6 for recommended data-collection procedures.

20.4.8.3 Fire dynamics analyses can generally be classified into three categories: specialized fire dynamic analyses, zone models, and field models. They are listed in order of increasing complexity and required computational power.

Source - NFPA 921, Chapter 20, 2008

Extract

20.4.8.3.1 Specialized Fire Dynamics Routines. Specialized fire dynamics routines are simplified procedures designed to solve a single, narrowly focused question. In many cases, these routines can answer questions related to a fire reconstruction without the use of a fire model. Much less data is typically required for these routines than is required to run a fire model. Examples of available routines can be found in the FIREFORM section of the FPETOOL program.

20.4.8.3.2 Zone Models. Most of the fire growth models that can be run on personal computers are zone models. Zone models usually divide each room into two spaces or zones, an upper zone that contains the hot gases produced by the fire, and a lower zone that is the source of the air for combustion. Zone sizes change during the course of the fire. The upper zone can expand to occupy virtually all the space in the room.

20.4.8.3.3 Field, Computational Fluid Dynamics (CFD) Models. CFD models usually require large-capacity computer work stations or mainframe computers. By dividing the space into many small cells (frequently tens of thousands), CFD models can examine gas flows in much greater detail than zone models. Where such detail is needed, it is often necessary to use the sophistication of a field model. In general, however, field models are much more expensive to use, require more time to set up and run, and often require a high level of expertise to make the decisions required in setting up the problem and interpreting the output produced by the model. The use of CFD models in fire investigation and related litigation, however, is increasing. CFD models are particularly well suited to situations where the space or fuel configuration is irregular, where turbulence is a critical element, or where very fine detail is sought.

20.5 Fire Testing.

20.5.1 Role of Fire Testing. Fire testing is a tool that can provide data that complement data collected at the fire scene *(see 4.3.3)*, or can be used to test hypotheses *(see 4.3.6)*. Such fire testing can range in scope from bench scale testing to full-scale recreations of the entire event. These tests may relate to the origin and cause of the fire, or to fire spread and development. The components and subsystems to be tested may include building contents, building systems, and architectural and structural elements of the building itself.

20.5.1.1 Used as a part of data collection, fire testing can provide insights into the characteristics of fuels or items consumed in the fire, into the characteristics of materials or assemblies affected by the fire, or into fire processes that may have played a role in the fire. This information is valuable in the analysis of data and the formation of hypotheses. *(See also Section 16.10.)*

20.5.1.2 Used as a part of hypothesis testing, fire testing can assist in evaluating whether a hypothesis is consistent with the case facts and the laws of fire science. In this manner, fire testing is used in much the same way as fire modeling. In addition, fire testing may support modeling by providing input data for models or by providing benchmark data that can be used to assess the accuracy and applicability of a model.

Source - NFPA 921, Chapter 20, 2008

Extract

20.5.2 Fire Test Methods. To the extent possible, fire test methods, procedures, and instrumentation should follow or be modeled after standard tests or test methods that have been reported in the fire science literature. Tests consistent with standard test methods or the fire science literature will contribute to the scientific credibility of the results. Testing not performed to a recognized standard should be consistent with the relevant facts of the case. Credible testing includes the use of materials and assemblies that are suitable exemplars of actual materials and assemblies, as well as conducting experiments that reflect the relevant conditions of the scene at the time of the fire. Valuable data may be obtained from testing that addresses limited aspects of a fire incident.

20.5.3 Limitations of Fire Testing. While fire testing can provide useful information, it is not possible to perfectly recreate all of the conditions of a specific fire that may affect the results of a full-scale test fire. Weather conditions are an example of a parameter that may not be reproduced readily and that may affect the results of a test fire. These conditions should be considered in reaching conclusions that are based on the test results.

20.6 Data Required for Modeling and Testing.
Scene data required for modeling and testing, typically obtained by the fire investigator, are used to quantify or characterize the physical scene. Relevant scene data include structural dimensions; type of building materials; size, location, and type of contents; and size, location, and type of sources of ventilation.

20.6.1 Materials and Contents.

20.6.1.1 A meaningful analysis of a fire requires understanding of the heat release rate, fire growth rate, and total heat released. The determination of these parameters requires identification of the types, quantities, location, and configuration of fuel actually involved in the fire. For example, a vertical configuration will burn faster than a horizontal configuration of the same fuel.

20.6.1.2 The composition, thickness, condition, and layers of the materials comprising the walls, floors, windows, doors, and ceiling should be documented. The ceiling, wall, and decorative finishes, as well as the type, configuration, and condition of contents, should be documented.

20.6.2 Ventilation. Understanding ventilation conditions is important to the validity of a fire test or model. The position and condition of doors, windows, skylights, and other sources of ventilation, such as thermostatically controlled exhaust fans, should be determined. Determining when ventilation sources were opened or closed is important. Ventilation effects may include wind, fire department ventilation, and HVAC operation and should be considered.

Source - NFPA 921, Chapter 20, 2008

3. Computer Modelling

Introduction

Fire modelling programmes are important tools that assist in fire reconstructions. They were initially created to simulate smoke handling systems and conduct heat detector activation studies.

Many computer-based fire-modelling programs are in use today. For a specific building design, use these models in a fire engineering analysis to predict smoke movement and temperature gradients within a particular space. Generally 'zone' or 'computational fluid dynamics' (CFD) models are used depending on the complexity of the design.

On-going development of these models is providing more accurate and user-friendly information. Organisations such as the National Institute of Standards & Technology (NIST) in the United States are continually working to improve on these models.

Remember, use fire-modelling programmes to complement and not replace physical evidence.

Note: If you are considering using fire modelling, discussion with fire engineers at an early stage is vital. It will be necessary for the fire engineer to visit the scene in order for them to do first-hand data collection.

How fire modelling can be used

Using numerical equations, it is possible to estimate the fire's:
- behaviour
- expected growth
- development
- eventual decay.

Many of these modelling programmes require input of specific information to enable the programme to run accurately. This information needs to be collected at fires and recorded in detail at the time of the fire to obtain the most benefit from fire modelling programmes.

Note: Computer models are just that – models. Many are based on ventilation conditions and are only capable of modelling the fire in steady ventilation conditions. Thus, the ability to model post-flashover conditions is limited.

Because of the complex nature of computer modelling programmes and their particular data requirements and error factors, members of EIRSA should be consulted for assistance.

Zone and field modelling

Model Type	Description
Zone	In a zone model, the fire is represented as a series of simple models, such as fire zone, plume zone, etc. Because they are simple to set up and easy to match to experimental results, zone models are common. However, they are based on semi-empirical models and the features of the flow are determined by the choice of model or zoning and so should not be used outside the range of their validity or where the mechanisms of the fire are not known or not fully understood.
Field	Field Modelling, which is often referred to as computational fluid dynamics (CFD), is a more flexible approach. It seeks to resolve mathematical equations that govern fluid flow over a domain by splitting it into many cells. A simple CFD analysis solves a set of equations for the velocity and pressures in the fluid. Where required, consider equations for other variables, such as temperature, turbulence, radiation and combustion. The CFD model makes no assumptions about a flow, or how it will develop, so the only requirement is that enough information is provided and the appropriate model is used to find a solution. For example, natural convection will only be correctly modelled if suitable relationships between temperature and density are included in the set of equations to be solved.

Advanced modelling software

Advanced modelling software is designed to predict:

- heat release rate
- flame height
- flame propagation
- smoke generation and propagation.

Dealing with Evidence

Section Contents

1. Identifying and Managing Evidence

Introduction

Evidence has a far broader meaning than most people suppose.

The law of evidence is a set of rules and principles affecting judicial investigation into questions of fact. In other words, the law determines:

- What facts may and may not be proved in particular cases
- What sort of evidence must be given in order to prove a fact
- By whom and in what manner the evidence must be produced to prove a fact.

The value of items to be used as physical evidence hinges directly on several factors such as:

- identification
- collection
- non-contamination
- documentation
- packaging.

The purpose of evidence

In terms of fire investigation the purpose of evidence is to:

1. establish an accidental cause of a fire, or
2. establish an incendiary cause of a fire.

Definition of evidence

Real evidence

Evidence is categorised into various classes, one of which is called "real evidence". It is a type of "Primary Evidence" and the one most Fire Service personnel think of most often.

Real evidence is material objects presented for the inspection of the Court. It can include such objects as:

- tools used in a crime (e.g. a jemmy)
- cast taken of a footprint
- recovered property
- fingerprints.

What evidence is

In general, evidence is not an "item" or "thing". It is not a category into which the investigator can insert some items and omit others. Evidence is not measured by what it is, but rather by what it does. It must do something within the framework of a case, or it is not evidence.

Evidence can be anything that establishes facts surrounding the fire. For example:

- It may be the account of an eyewitness who saw something, or someone
- It might have been thick black smoke at the start of the fire
- The odour of an accelerant recognised by a firefighter can be evidence
- It might be items that show that the fire was not deliberately set
- Both the records of a business involved in the fire or any fingerprints found on the scene can be evidence.

Evidence can establish guilt or innocence. Through evidence:

- The identity of a criminal can be established. The eyewitness sees someone fleeing the scene prior to the fire, or someone watches the suspect carry fuel cans into the structure. These cans can then be traced to the offender, or a service station attendant remembers filling them for the suspect.
- It can be a statement that places the suspect kilometres away from the scene when the fire started.

Rules about evidence

The rules of evidence are:

1. Record everything about the scene using photographs, sketches and notes
2. Properly collect and preserve samples.

Protection and preservation

Two things should be kept clearly in mind by the firefighter regarding protection and preservation of the evidence of fire causes:

1. Keeping the evidence *in situ*, untouched and undisturbed if at all possible
2. Properly identifying, removing and safeguarding such evidence that cannot be left at the scene of a fire as it was discovered.

No changes of any kind should be permitted in the evidence other than what is absolutely necessary to suppression the fire. Photographs are excellent supporting evidence if taken immediately and should be taken before any close examination of the scene occurs.

Verbal evidence

Verbal indicators

The term ‘Verbal Indicators” is used to describe the information the investigator may receive from individuals who have witnessed the incident. This information may be particularly important in assessing fire movement as well as the pre-fire actions of individuals and the conditions within the building.

Verbal Indicators may take the form of sworn statements or anecdotal evidence received from building owners and occupants. They may also include evidence from witnesses, responding fire fighters or passing motorists. In some cases, such as total destruction fires verbal indicators may provide the only clues to establish cause and origin.

Recording information

As with any evidence it is important that verbal information is recorded accurately and timely. In general, persons providing information about the fire should be contacted as soon as possible and asked to record as much as they can remember. After 24 hours of a significant event, short-term memory may not provide high levels of accuracy and consistency.

The most suitable method of recording information is still by written notes. Other methods such as tape recording and video recording while useful in speed and efficiency may be subject to other influences, which can ultimately affect their usability, such as, wind and noise across the microphone.

The value of this type of information should be recognised by recording it accurately and in as much detail as possible. Often this may mean repeating questions or asking the individual to supply a full written statement.

Interviewing witnesses

The interview process should be focused towards answering the five (5) “W’s” and “H”. That is, Where, What, Who, When, Why and How. With these questions in mind, every phase of the fire and its human interaction can be documented in a logical process, which results in support of the physical evidence recovered from the scene. Where possible the investigator should attempt to record the details in a chronological order and must refrain from guiding the replies received.

In large events where many witnesses are involved the process may need to be repeated a number of times. In these cases, it is appropriate to develop a pre-interview checklist of the sorts of questions to be asked of each witness. The investigator may also wish to add their own notes relating to the demeanour and behaviour of the individual, however, this should be recorded on a separate piece of paper and retained for the file.

Before conducting any interview the investigator should inform the individual of the reason why the questions are being asked. In general terms, the New Zealand Fire Service obtains information from witnesses in an attempt to determine the origin and cause to enable the New Zealand Fire Service to target pro-active strategies to prevent reoccurrence.

Archiving and filing

Where additional notes, hard copy material and photographs have been obtained in relation to an incident these should be retained by the organisation for a period of up to seven (7) years. It is important to ensure that some cross-reference is made either by date or incident number to ensure that they may be readily accessed.

Actions to consider

It is always better to make a preliminary investigation when possible before mopping up or overhauling the fire, especially at the point of origin since walking on or moving any of the burned debris will alter the picture in some way and may destroy clues as to the cause of the fire. The Fire Service taught in years past that to reduce fire loss and create good "public image", firefighters should thoroughly clean out the premises and leave everything ship-shape.

When you consider the end result of this type of action, it is more than probable that it increased fire losses and most certainly valuable evidence of fire causes (both incendiary and accidental) were shovelled out of windows and doors.

The following actions should be considered during a fire scene investigation:

Action	Description
Exercise caution	• Everyone at the fire scene should avoid tramping over possible arson evidence and obliterating it so badly that it is useless, or introducing contamination into the area • Excessive amounts of water for firefighting operations destroy the fire scene • Once a fire scene is considered to be of an unlawful incendiary origin, or if a fatality is discovered, the attendance of the Police is to be requested (refer NCI 56).
Protect physical evidence	• Evidence remaining at the scene of a fire can be protected in various ways, if and when discovered • Areas containing evidence can be cordoned off with barrier tape or rope • Post guards (and change, if necessary) to prevent tampering or needless handling of evidence • Leave adequate room around evidence to protect it where it was found, this may include covers over it for protection • Preserve burned or partially burned paper found in furnaces, stoves or fireplaces by eliminating or reducing drafts by closing dampers or openings.

Action	Description
Preserve tyre and footprints	• Protect sections of discovered tyre tracks, and if the vehicle turned, allow the print of all 4 wheels to show, including the place at which the vehicle turned • Protect human footprints for several metres to allow for measurement of the prints, comparisons of prints, estimates of length of stride, position of feet, and any peculiarities of the gait (walk or run) of a suspect • It may also be possible to secure identifying marks on soles and heels on the shoes worn • Boxes placed over prints will prevent water, dust of other footprints from damaging an otherwise clear print.
Protect Fingerprints	• Bottles and containers, which have been used to carry flammable liquids, can sometimes be used to develop latent fingerprints. It is important to protect all such containers from indiscriminate handling so that if such prints do exist, they will not be obliterated and can be identified.
Avoid disturbing or destroying evidence	• Use of spray with minimum water where possible • Avoid use of jets on areas where evidence is located • Do not clean up until the cause of the fire has been established • Use due care in salvage and overhaul.
Secure the fire scene	• Once the investigating officer has established that the fire is of an incendiary nature, they should immediately take steps to secure the property on which the fire occurred either by having guards posted at all possible points of entry, or by locking the premises • Use of a single point of entry where no unauthorised persons are permitted to enter is one method. Even Fire Service personnel should not enter unless for a specific purpose, e.g. flare up of the fire. An Incident Log should be initiated (see Section, page 15) • Inform the Police of the incendiary nature identified and the supporting information.

Searching for evidence

When a fire is obviously an unlawful incendiary fire, the involved structure is searched for evidence of the crime and the criminal. The search centres on the point or areas of origin. The searchers seek such items as incendiary devices, containers and residues that may be related to flammable liquids, remnants of a missing heat source, signs of robbery or vandalism, and burn patterns that may be hidden under debris.

Small but important items of evidence might easily be missed in an unplanned or hurried search. The search area should be gone over systematically and thoroughly. The searcher or searchers should work through the area slowly, observing what they see.

In this type of case, the police should be notified. The staff from a forensic science laboratory attached to Environmental and Scientific Research (ESR) may assist with the scene examination.

It must be mentioned here that irrespective of the circumstances of the fire, a complete, organised and thorough search should still be made to establish the cause.

Search patterns

In most cases, the scene search will be divided into two sections:

- the exterior of the scene, e.g., the areas surrounding a building or the area surrounding a vehicle
- the interior of the building.

Section	What to do . . .
Exterior Search	• Examine structure from all sides -- this will give an idea of damage including areas of severe damage • Examine for forcible entry • Examine for external fire sources which could have spread to the interior of the structure, e.g., trailers, rubbish fires, grass or scrub fires, etc • Examine area for obvious evidence such as tools, containers, matches, trailers, etc • Examine for footprints or tyre prints that cannot be explained by the presence of firefighters or other emergency personnel.

Section	What to do . . .
Interior Search	• Start the examination from the area(s) of least fire damage, looking for evidence of items, such as matches, containers, trailers, etc. • Work through structure until the area(s) of most severe damage is located • When the most severe area(s) is located, examine it extensively. If in a room, start from the door -- clearing an area approximately 1 metre square and examine the debris for evidence of the ignition source(s). Work away from the door along one wall, clearing small areas at a time and placing debris onto the previously searched area • Continue this examination up and down the room until the whole room is covered and the seat and cause of the fire are established.
Large Rooms and Areas	• Large rooms and areas should be divided into smaller areas and grids using items such as light rope or markers • Examine each of the areas as you would a small area or room, therefore, covering the whole area with an extensive search for evidence.

Fire scene examinations

As stated above, once the fire's point of origin is determined, a careful search will uncover evidence to discover the ignition source.

Electrical in origin

If the fire is electrical in origin:

- An examination of electrical wiring and appliances should produce evidence of electrical malfunction in the form of damaged electrical wiring or components
- This damage usually consists of solid droplets or globules on the wire, but, as before, care must be taken in interpreting this damage as the temperature reached in fires can also damage copper wiring
- As a general rule, rounded globules with inclusions of oxides are the result of exposure to fire temperatures (approximately 1100^{O}C) and sharp "stalactites" result from exposure to the higher temperatures (approximately 5000^{O}C) produced in electrical short circuits
- However, it should be remembered that even if it is established that the damage to wiring is the result of electrical heating, the question still remains as to whether the fire caused the short circuit or the short circuit caused the fire.

Deliberately lit with the assistance of flammable liquids

If the fire has been deliberately lit with the assistance of flammable liquids:

- There is may be a characteristic pattern of damage at the origin
- This can consist of sharply defined areas of charring in the floor coverings and deep charring between the floorboards
- This charring may finally become a hole if the fire is not extinguished early in its progress
- For this reason, holes in floors are particularly important and care must be taken to ascertain if they have been burnt from above by falling debris, such as beams and furniture or rather burnt from below which can be indicative of the use of an accelerant.

If the fire has been extinguished before it causes extensive damage, the class o accelerant can often be deduced from damage patterns. These are:

- A very even pattern of damage covering a wide area is indicative of a low flash-point fuel, e.g. petrol, paint thinners, etc.
- A more concentrated pattern of damage is usually the result of the burning of a relatively high flash-point fuel, e.g. kerosene, heating oil, etc.

Collecting the evidence

Only those trained and legally authorised to do so should undertake collection of evidence. Fire Service investigators may be requested to advise suitable locations from which physical samples are to be collected. The Police or ESR forensic scientists should collect samples.

Remember, it is better to collect too much rather than not enough. Excess samples can always be disposed of later. However, explanations for the disposal must be recorded.

Flammable liquids

To prove beyond doubt that a flammable liquid has been used to accelerate the ignition and spread of the fire, samples of floor covering, floorboards, soil, etc. must be taken and analysed at the laboratory.

Please note, this is expensive and care may be exercised when selecting samples. Control samples should also be taken to confirm that the findings are actually flammable liquids and not pyrolysis products produced by the materials burnt.

If a flammable liquid is involved in the starting of the fire, it is likely that the container is still in the debris. The recovery of this container is extremely important for the purpose of questioning both eyewitnesses and others who may recognise it.

Sifting debris

A search for small pieces of evidence requires that the debris be sifted through a mesh. Mesh sizes of 75mm, 25mm and 6mm will serve for most situations for locating such items as matches, melted metal from wires, pieces of light bulbs and bits of cloth.

The debris from a particular grid area should be sifted onto a sheet of newspaper or a piece of canvas, and then discarded outside the search area. This avoids confusion as to which debris was already examined and which wasn't.

This type of detailed search is not common, but used by Police in areas of explosions and where a criminal act is suspected to provide the physical evidence.

Case closed

From a scientific point of view, the case is completed once the fire origin and cause have been established. The opinions drawn from the scene inspection can often be subsequently supported by laboratory tests but at this point many fire cause investigations terminate for forensic laboratory staff.

2. Recording the Scene

Introduction

An important aspect of any investigation is recording information. By documenting the scene thoroughly the investigator to be able to prepare a report that will reflect well on their actions and support their decisions and findings.

SMS

The most common means of reporting on a fire will be via SMS. From SMS, click on the Incidents tab, then select an incident.

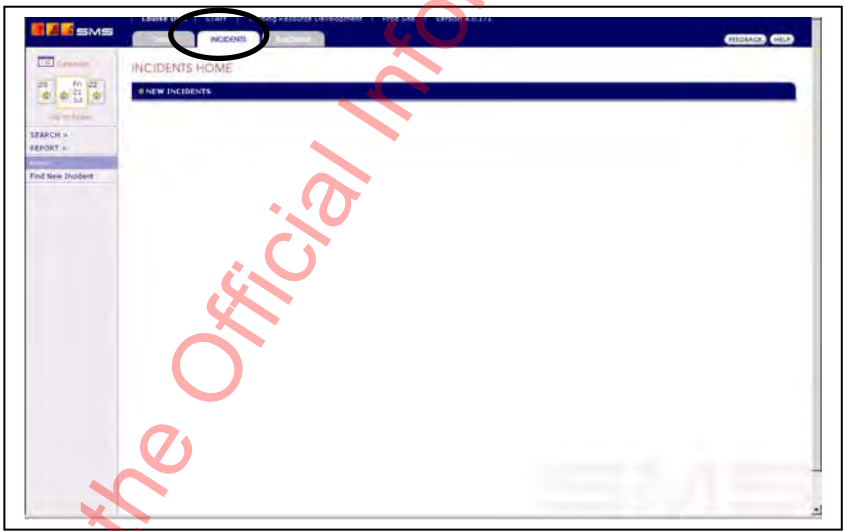


Figure 1 SMS Incident

SMS > Incidents > select an incident.
This system will be appropriate for most incidents.

Make a comment

It is strongly recommended that appropriate comments be included via the "Make a comment" facility. This facility has a capacity of about 1500 characters total, or about one and a third normal pages of text. The comments should be able to explain and back up the data in the SMS incident report. This will enable other people who read the incident data to understand what you have done.

Tip: Compose the comments in Word, then cut and paste them into "Make a comment". This allows for spell checking and formatting making the comments easier to read.

Other online tools

Word

The standard investigation report template can be found in Word.

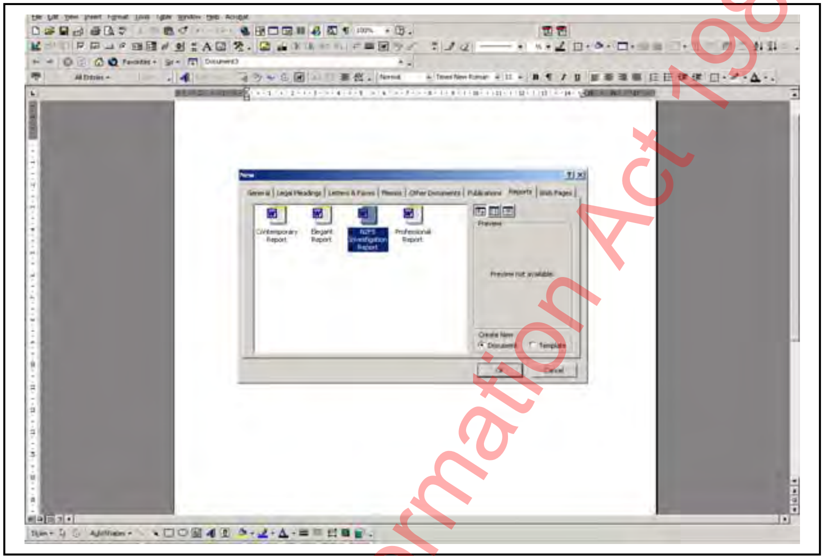


Figure 2 NZFS Investigation Report

Word > New > Report > NZFS Investigation Report

This template is for use for reporting incidents requiring a greater level of reporting and information, such as fatal fires. This template has some online instructions to assist with its use.

A formal peer review process needs to take place when this report is utilised.

Visio

Within the on-line environment access is available for users to make drawings in Visio, an application commonly found in Citrix.

NFPA 921 clause 15.4.4(C) makes comment about scale for drawing.

Building plans

Whenever plans of a building are required agencies such as the Building Owner, Territorial Authorities (Councils), Ministry of Education – property section, Housing New Zealand offices and similar sources are often helpful. However be aware that the plans may be out of date due to more recent building works having been undertaken that are not included on the plan. Utilising these sources of plans may save the investigators a lot of time by not having to draw the plans themselves.

NFPA 921, Chapter 15 – Documentation of the Investigation

Extract

15.1 Introduction.

15.1.1 The goal in documenting any fire or explosion investigation is to accurately record the investigation through media that will allow investigators to recall and communicate their observations at a later date. Common methods of accomplishing this goal include the use of photographs, videotapes, diagrams, maps, overlays, tape recordings, notes, and reports.

15.1.2 Thorough and accurate documentation of the investigation is critical because it is from this compilation of factual data that investigative opinions and conclusions can be supported and verified. There are a number of resources to assist the investigator in documenting the investigation.

15.2 Photography.

15.2.1 General. A visual documentation of the fire scene can be made using either film or video photography. Images can portray the scene better than words. They are the most efficient reminders of what the investigator saw while at the scene. Patterns and items may become evident that were overlooked at the time the photographs or videos were made. They can also substantiate reports and statements of the investigator.

15.2.1.1 For fire scene and investigation-related photography, color images are recommended.

15.2.1.2 Taking a basic photography or video course through a vocational school, camera club, or camera store would be most helpful in getting the photographer familiar with the equipment.

15.2.1.3 As many photographs should be taken as are necessary to document and record the fire scene adequately. It is recognized that time and expense considerations may impact the number of photographs taken, and the photographer should exercise discretion. It is far preferable to err on the side of taking too many photographs rather than too few.

15.2.1.4 The exclusive use of videotapes, motion pictures, or slides is not recommended. They are more effective when used in conjunction with still photographs. Also, additional equipment is obviously required to review and utilize videos, films, and slides.

15.2.2 Timing. Taking photographs during or as soon as possible after a fire is important when recording the fire scene, as the scene may become altered, disturbed, or even destroyed. Some reasons why time is important include the following:

(1) The building is in danger of imminent collapse or the structure must be demolished for safety reasons.

(2) The condition of the building contents creates an environmental hazard that needs immediate attention.

(3) Evidence should be documented when discovered as layers of debris are removed, as is done at an archaeological dig. Documenting the layers can also assist in understanding the course of the fire.

Source – NFPA 921, Chapter 15, 2008.

Extract

15.2.3.4 Digital Photography. With the advancements of computer-based technology and the improvement of digital cameras and technology, there are a number of issues that have been raised regarding the acceptance of the photograph during testimony. At this time, there is no established case law that bars the use of digital images in the courtroom. With digital photographs, as with all photographs, the tests of “a true and accurate representation” and “relevance to the testimony” must still be met.

15.2.3.4.1 Digital images can be manipulated and altered using readily available computer technology. Very often, legitimate alterations of the image can be used to further interpret or understand the image and examples of this type of alteration include digital enhancement, brightening, color adjustment, and contrast adjustment. Similar techniques have also been used when developing prints from negatives; however, the film negative remains as a permanent record. If an image has been enhanced, it is incumbent upon the investigator to preserve the original image and to clearly state the extent to which the image was enhanced so as to not mislead the trier of fact.

15.2.3.4.2 When the investigator chooses to utilize digital photography, steps should be taken to preserve the original image and establish a methodology to allow authentication. An agency procedure should be established for the storage of images such as placement on a storage medium (CD ROM) that will not allow them to be altered, or the utilization of a computer software program that does not allow the original image to be altered and saved using the original file name, or other programs that may be developed in the future.

15.2.3.5 Lenses. The camera lens is used to gather light and to focus the image on the surface of the film. Most of today’s lenses are compound, meaning that multiple lenses are located in the same housing. The fire investigator needs a basic understanding of the lens function to obtain quality photographs. The convex surface of the lens collects the light and sends it to the back of the camera, where the film lies. The aperture is an adjustable opening in the lens that controls the amount of light admitted. The adjustments of this opening are sectioned into measurements called f-stops. As the f-stop numbers get larger, the opening gets smaller, admitting less light. These f-stop numbers are listed on the movable ring of the adjustable lenses. Normally, the higher the f-stop that can be used, the better the quality of the photograph.

15.2.3.5.1 Focal lengths in lenses range from a normal lens (50 mm, which is most similar to the human eye) to the wide angle (28 mm or less) lenses, to telephoto and zoom lenses (typically 100 mm or greater). The investigator needs to determine what focal lengths will be used regularly and become familiar with the abilities of each.

15.2.3.2.2 Manual operation is sometimes desired by the investigator so that specialty photographs can be obtained that the automatic camera, with its built-in options, cannot perform. For example, with a manual camera, bracketing (taking a series of photographs with sequentially adjusted exposures) can be performed to ensure at least one properly exposed photograph when the correct exposure is difficult to measure. There are some cameras that can be operated in a manual as well as an automatic mode, providing a choice from the same camera. Most investigators prefer an automatic camera.

15.2.3.2.3 A 35 mm single-lens reflex camera is preferred over other formats, but the investigator who has a non–35 mm camera should continue to take photographs as recommended. A backup camera that instantly develops prints can be advantageous, especially for an important photograph of a valuable piece of evidence.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.3.3 Film. There are many types of film and film speeds available in both slide and print film. There are numerous speeds of film (ASA ratings), especially in the 35 mm range. Because 35 mm (which designates the size of the film) is most recognized and utilized by fire investigators, film speeds will be discussed using this size only. The common speeds range from 25 to 1600 in color and to 6400 in black and white. The numbers are merely a rating system. As the numbers get larger, the film requires less light. While the higher ASA-rated (faster) film is better in low light conditions with no flash, a drawback is that it will produce poorer-quality enlargements, which will have a grainy appearance. The film with the lowest rating that the investigator is comfortable with should be used because of the potential need for enlargements. Most investigators use a film with an ASA rating between 100 and 400. Fire investigators should practice and become familiar with the type and speed of film they intend to use on a regular basis.

15.2.3.4 Digital Photography. With the advancements of computer-based technology and the improvement of digital cameras and technology, there are a number of issues that have been raised regarding the acceptance of the photograph during testimony. At this time, there is no established case law that bars the use of digital images in the courtroom. With digital photographs, as with all photographs, the tests of “a true and accurate representation” and “relevance to the testimony” must still be met.

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Source - NFPA 921, Chapter 15, 2008.

Extract

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15.2.3.5.2 The area of clear definition or depth of field is the distance between the farthest and nearest objects that will be in focus at any given time. The depth of field depends on the distance to the object being photographed, the lens opening, and the focal length of the lens being used. The depth of field will also determine the quality of detail in the investigator's photographs. For a given f-stop, the shorter the focal length of the lens, the greater the depth of field. For a given focal length lens, a larger f-stop (smaller opening) will provide a greater depth of field. The more the depth of field, the more minute are the details that will be seen. This is an important technique to master. These are the most common lens factors with which the fire investigator needs to be familiar. If a fixed-lens camera is used, the investigator need not be concerned with adjustments, because the manufacturer has preset the lens. A recommended lens is a medium range zoom, such as the 35 mm to 70 mm, providing a wide angle with a good depth of field and the ability to take high-magnification close-ups (macros).

15.2.3.6 Filters. The investigator should know that problems can occur with the use of colored filters. Unless the end results of colored filter use are known, it is recommended that they not be used. If colored filters are used, the investigator should take a photograph with a clear filter also. The clear filter can be used continually and is a good means of protecting the lens.

15.2.3.7 Lighting. The most usable light source known is the sun. No artificial light source can compare realistically in terms of color, definition, and clarity. At the beginning and end of the day, inside a structure or an enclosure, or on an overcast day, a substitute light source will most likely be needed. This light can be obtained from a floodlight or from a strobe or flash unit integrated with the camera.

15.2.3.7.1 Because a burned area has poor reflective properties, artificial lighting using floodlights is useful. Floodlights, however, will need a power source either from a portable generator or from a source within reach by extension cord.

15.2.3.7.2 Flash units are necessary for the fire investigator's work. The flash unit should be removable from the camera body so that it can be operated at an angle oblique to that of the lens view. This practice is valuable in reducing the amount of reflection, exposing more depth perception, and amplifying the texture of the heat- and flame-damaged surfaces. Another advantage to a detachable flash unit is that, if the desired composition is over a larger area, the angle and distance between the flash and the subject can be more balanced.

15.2.3.7.3 A technique that will cover a large scene is called photo painting. It can be accomplished by placing the camera in a fixed position with the shutter locked open. A flash unit can be fired from multiple angles, to illuminate multiple subjects or large areas from all angles. The same general effect can be obtained by the use of multiple flash units and remote operating devices called slaves.

15.2.3.7.4 For close-up work, a ring flash will reduce glare and give adequate lighting for the subject matter. Multiple flash units can also be used to give a similar effect to the ring flash by placing them to flash at oblique angles.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.3.7.5 The investigator should be sure that glare from a flash or floodlight does not distort the actual appearance of an object. For example, smoke stains could appear lighter or nonexistent. In addition, shadows created could be interpreted as burn patterns. Movie lights used with videotapes can cause the same problems as still camera flash units. Using bounce flash, light diffusers, or other techniques could alleviate this problem.

15.2.3.7.6 The investigator concerned with the potential outcome of a photograph can bracket the exposure. Bracketing is the process of taking the same subject matter at slightly different exposure settings to ensure at least one correct exposure.

15.2.3.8 Special Types of Photography. Today's technology has produced some specialty types of photography. Infrared, laser, and microscopic photography can be used under controlled circumstances. An example is the ability of laser photography to document a latent fingerprint found on a body.

15.2.4 Composition and Techniques.

15.2.4.1 Photographs may be the most persuasive factor in the acceptance of the fire investigator's theory of the fire's evolution.

15.2.4.1.1 In fire investigation, a series of photographs should be taken to portray the structure and contents that remain at the fire scene. The investigator generally takes a series of photographs, working from the outside toward the inside of a structure, as well as from the unburned toward the most heavily burned areas. The concluding photographs are usually of the area and point of origin, as well as any elements of the cause of the fire.

15.2.4.1.2 It can be useful for the photographer to record, and thereby document, the entire fire scene and not just the suspected point of origin, as it may be necessary to show the degree of smoke spread or evidence of undamaged areas.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.4.2 Sequential Photos. Sequential photographs, shown in Figure 15.2.4.2, are helpful in understanding the relationship of a small subject to its relative position in a known area. The small subject is first photographed from a distant position, where it is shown in context with its surroundings. Additional photographs are then taken increasingly closer until the subject is the focus of the entire frame.

FIGURE 15.2.4.2 Sequential Photographs of a Chair.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.4.3 Mosaics. A mosaic or collage of photographs can be useful at times when a sufficiently wide angle lens is not available and a panoramic view is desired. A mosaic is created by assembling a number of photographs in overlay form to give a more-than-peripheral view of an area, as shown in Figure 15.2.4.3. An investigator needs to identify items (e.g., benchmarks) in the edge of the view finder that will appear in the print and take the next photograph with that same reference point on the opposite side of the view finder. The two prints can then be combined to obtain a wider view than the camera is capable of taking in a single shot.

FIGURE 15.2.4.3 Mosaic of Warehouse Burn Scene from Aerial Truck.

15.2.4.4 Photo Diagram. A photo diagram can be useful to the investigator. When the finished product of a floor plan is complete, it can be copied, and directional arrows can be drawn to indicate the direction from which each of the photographs was taken. Numbers corresponding to the film frame and roll are then placed on the photographs. This diagram will assist in orienting a viewer who is unfamiliar with the fire scene. A diagram prepared to log a set of photographs might appear as shown in Figure 15.2.4.4.

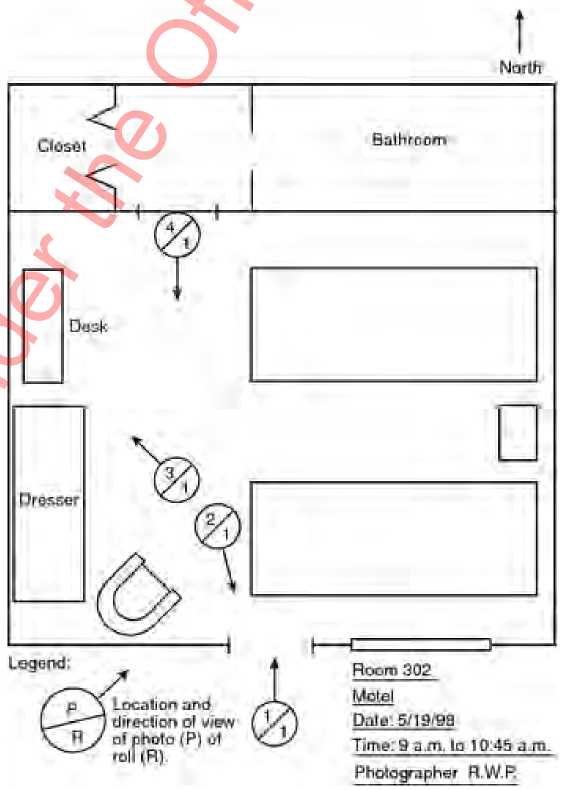


FIGURE 15.2.4.4 Diagram Showing Photo Locations.

Source - NFPA 921, Chapter 15, 2008

Extract

15.2.4.4.1 Recommended documentation includes identification of the photographer, identification of the fire scene (i.e., address or incident number), and the date that the photographs were taken. A title form can be used for the first image to record this photo documentation.

15.2.4.4.2 The exact time a photograph is taken does not always need to be recorded. There are instances, however, when the time period during which a photograph was taken will be important to an understanding of what the photograph depicts. In photographs of identical subject, natural lighting conditions that exist at noon may result in a significantly different photographic image than natural lighting conditions that exist at dusk. When lighting is a factor, the approximate time or period of day should be noted. Also, the specific time should be noted for any photograph taken prior to extinguishment of the fire, as these often help establish time lines in the fire's progress.

15.2.4.5 Assisting Photographer. If a person other than the fire investigator is taking the photographs, the angles and composition should be supervised by the fire investigator to ensure that shots needed to document the fire are obtained. Investigators should communicate their needs to the photographer, as they may not have a chance to return to the fire scene. The investigators should not assume that the photographer understands what essential photographs are needed without discussing the content of each photo.

15.2.4.6 Photography and the Courts. For the fire investigator to weave photographs and testimony together in the courtroom, one requirement in all jurisdictions is that the photograph should be relevant to the testimony. There are other requirements that may exist in other jurisdictions, including noninflammatory content, clarity of the photograph, or lack of distortion. In most courts, if the relevancy exists, the photograph will usually withstand objections. Since the first color photographs were introduced into evidence in a fire trial, most jurisdictions have not distinguished between color or black and white photographs, if the photographs met all other jurisdictional criteria.

15.2.5 Video. In recent years, advancements have made motion pictures more available to the nonprofessional through the use of video cameras. There are different formats available for video cameras, including VHS, Beta, and 8 mm. Video is a very useful tool to the fire investigator. A great advantage to video is the ability to orient the fire scene by progressive movement of the viewing angle. In some ways, it combines the use of the photo diagram, photo indexing, floor plan diagram, and still photos into a single operation.

15.2.5.1 When taking videos or movies, "zooming-in" or otherwise exaggerating an object should be avoided, as it can be considered to present a dramatic effect rather than the objective effect that is sometimes required for evidence in litigation work.

15.2.5.2 Another use of video is for interviews of witnesses, owners, occupants, or suspects when the documentation of their testimony is of prime importance. If demeanor is important to an investigator or to a jury, the video can be helpful in revealing that.

15.2.5.3 The exclusive use of videotape or movies is not recommended, because such types of photography are often considered less objective and less reliable than still photographs. Video should be used in conjunction with still photographs.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.5.4 Videotape recording of the fire scene can be a method of recording and documenting the fire scene. The investigator can narrate observations, similar to an audio (only) tape recorder, while videorecording the fire scene. The added benefit of video recording is that the investigator can better recall the fire scene, specifically fire patterns or artifact evidence, their location, and other important elements of the fire scene. Utilized in this method, the recording is not necessarily for the purpose of later presentation, but is simply another method by which the investigator can record and document the fire scene.

15.2.5.5 Video recording can also be effective to document the examination of evidence, especially destructive examination. By videotaping the examination, the condition and position of particular elements of evidence can be documented.

15.2.6 Suggested Activities to Be Documented. An investigation may be enhanced if as many aspects of the fire ground activities can be documented as possible or practical. Such documentation may include the suppression activities, overhaul, and the cause and origin investigation.

15.2.6.1 During the Fire. Photographs of the fire in progress should be taken if the opportunity exists. These help show the fire's progression as well as fire department operations. As the overhaul phase often involves moving the contents and sometimes structural elements, photographing the overhaul phase will assist in understanding the scene before the fire.

15.2.6.2 Crowd or People Photographs. Photographs of people in a crowd are often valuable for identifying individuals who may have additional knowledge that can be valuable to the overall investigation.

15.2.6.3 Fire Suppression Photographs. Fire suppression activities pertinent to the investigation include the operation of automatic systems as well as the activities of the responding fire services, whenever possible. All aspects pertinent to these, such as hydrant locations, engine company positions, hose lays, attack line locations, and so forth, play a role in the eventual outcome of the fire. Therefore, all components of those systems should be photographed.

15.2.6.4 Exterior Photographs. A series of exterior shots should be taken to establish the location of a fire scene. These shots could include street signs or access streets, numerical addresses, or landmarks that can be readily identified and are likely to remain for some time. Surrounding areas that would represent remote evidence, such as fire protection and exposure damage, should also be photographed. Exterior photographs should also be taken of all sides and corners of a structure to reveal all structural members and their relationships with each other. *(See Figure 15.2.6.4.)*

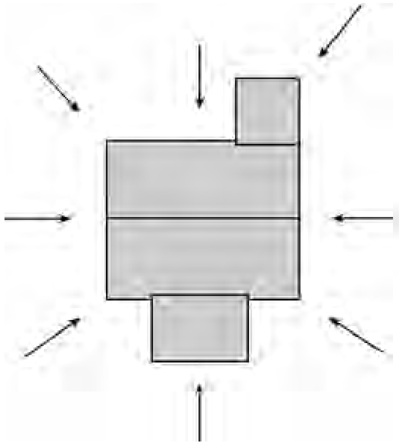


FIGURE 15.2.6.4 Photographing the Scene from All Angles and Corners.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.6.5 Structural Photographs. Structural photographs document the damage to the structure after heat and flame exposure. Structural photos can expose burn patterns that can track the evolution of the fire and can assist in understanding the fire's origin.

15.2.6.5.1 A recommended procedure is to include as much as possible all exterior angles and views of the structure. Oblique corner shots can give reference points for orientation. Photographs should show all angles necessary for a full explanation of a condition.

15.2.6.5.2 Photographs should be taken of structural failures such as windows, roofs, or walls, because such failures can change the route of fire travel and can play a significant role in the eventual outcome of the fire. Code violations or structural deficiencies should also be photographed because fire travel patterns may have resulted from those deficiencies.

15.2.6.6 Interior Photographs. Interior photographs are equally important. Lighting conditions will likely change from the exterior, calling for the need to adjust technique, but the concerns (tracking and documenting fire travel backward toward the fire origin) are the same. All significant ventilation points accessed or created by the fire should be photographed, as well as all significant smoke, heat, and burn patterns. Figure 15.2.6.6 provides a diagram of basic shots.

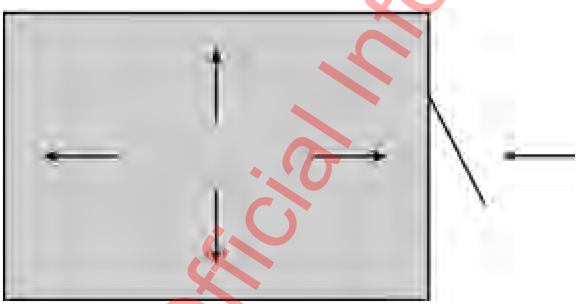


FIGURE 15.2.6.6 Photographing All Four Walls and Both Sides of Each Door.

15.2.6.6.1 Rooms within the immediate area of the fire origin should be photographed, even if there is no damage. If warranted, closets and cabinet interiors should also be documented. In small buildings, this documentation could involve all rooms; but in large buildings, it may not be necessary to photograph all rooms unless there is a need to document the presence, absence, or condition of contents.

15.2.6.6.2 All heat-producing appliances or equipment, such as furnaces, in the immediate area of the origin or connected to the area of origin should be photographed to document their role, if any, in the fire cause.

Source - NFPA 921, Chapter 15, 2004.

Extract

15.2.6.6.3 All furniture or other contents within the area of origin should be photographed as found and again after reconstruction. Protected areas left by any furnishings or other contents should also be photographed, as in the example shown in Figure 15.2.6.6.3.

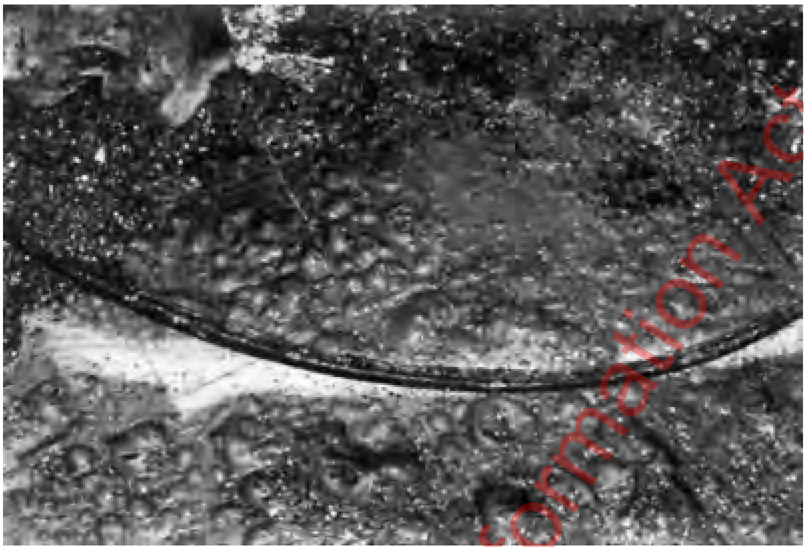


FIGURE 15.2.6.6.3 Floor Tile Protected from Radiant Heat by Wire.

15.2.6.6.4 The position of doors and windows during a fire is important, so photographs should be taken that would document those indications and resulting patterns.

15.2.6.6.5 Interior fire protection devices such as detectors, sprinklers, extinguishers used, door closers, or dampers should be photographed.

15.2.6.6.6 Clocks may indicate the time power was discontinued to them or the time in which fire or heat physically stopped their movement.

15.2.6.7 Utility and Appliance Photographs. The utility (gas, electric) entrances and controls both inside and outside a structure should be photographed. Photos should include gas and electric meters, gas regulators, and their location relative to the structure. The electric utility pole(s) near the structure that is equipped with the transformer serving the structure, and the electrical services coming into the structure, as well as the fuse or circuit breaker panels, should also be photographed. If there are gas appliances in the fire area of origin, the position of all controls on the gas appliances should be photographed. When photographing electrical circuit breaker panels, the position of all circuit breaker handles and the panel's schedule indicating what electrical equipment is supplied by each breaker, when available, should be photographed. Likewise, all electrical cords and convenience outlets pertinent to the fire's location should be photographed.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.6.8 Evidence Photographs. Items of evidentiary value should be photographed at the scene and can be rephotographed at the investigator's office or laboratory if a more detailed view is needed. During the excavation of the debris strata, articles in the debris may or may not be recognized as evidence. If photographs are taken in an archaeological manner, the location and position of evidence that can be of vital importance will be documented permanently. Photographs orient the articles of evidence in their original location as well as show their condition when found. Evidence is essential in any court case, and the photographs of evidence stand strong with proper identification. In an evidentiary photograph, a ruler can be used to identify relative size of the evidence. Other items can also be used to identify the size of evidence as long as the item is readily identifiable and of constant size (e.g., a penny). A photograph should be taken of the evidence without the ruler or marker prior to taking a photograph with the marker *(see 16.5.2.1)*.

15.2.6.9 Victim Photographs. The locations of occupants should be documented, and any evidence of actions taken or performed by those occupants should be photographed. This documentation should include marks on walls, beds victims were occupying, or protected areas where a body was located. *(See Figure 15.2.6.9.)* If there is a death involved, the body should be photographed. Surviving victims' injuries and their clothing worn should also be photographed.

FIGURE 15.2.6.9 Protected Area Where Body Was Located.

15.2.6.10 Witness Viewpoint Photographs. During an investigation, if witnesses surface and give testimony as to what they observed from a certain vantage point, a photograph should be taken from the most identical view available. This photograph will orient all persons involved with the investigation, as well as a jury, to the direction of the witnesses' observations and could support or refute the possibility of their seeing what they said they saw.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.6.11 Aerial Photographs. Views from a high vantage point, which can be an aerial fire apparatus, adjacent building, or hill, or from an airplane or helicopter can often reveal fire spread patterns. Aerial photography can be expensive, and a number of special problems exist that can affect the quality of the results. It is suggested that the investigator seek the advice or assistance of an experienced aerial photographer when such photographs are desired.

15.2.7 Photography Tips. Investigators may help themselves by applying some or all of the photography tips in 15.2.7.1 through 15.2.7.9.

15.2.7.1 Upon arrival at a fire scene and after shooting an 18 percent gray card, a written "title sheet" that shows identifying information (i.e., location, date, or situational information) should be photographed.

15.2.7.2 The film canister should be labeled after each use to prevent confusion or loss.

15.2.7.3 If the investigator's budget will allow, bulk film can be purchased and loaded into individual canisters that can allow for specific needs in multiple roll sizes and can be less expensive in certain situations.

15.2.7.4 A tripod that will allow for a more consistent mosaic pattern, alleviate movement and blurred photographs, and assist in keeping the camera free of fire debris should be available. A quick-release shoe on the tripod will save time.

15.2.7.5 Multiple fire incidents should not be combined on one roll of film. The last roll should be removed from the camera before leaving the scene. This will eliminate potential confusion and problems later on.

15.2.7.6 Extra batteries should be carried, especially in cold weather when they can be drained quickly. Larger and longer-life battery packs and battery styles are available.

15.2.7.7 Batteries should not be left in the photography equipment for an extended period of time. Leaking batteries can cause a multitude of problems to electrical and mechanical parts.

15.2.7.8 Obstruction of the flash or lens by hands, camera strap, or parts of the fire scene should be avoided. Additionally, when the camera is focused and ready to shoot, both eyes of the photographer should be opened to determine whether the flash went off.

15.2.7.9 In the event that prints from a single roll of film may have become out of sequence, examination of the numbering on the film negatives provides a permanent record of the sequence in which photographs were taken on that particular roll.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.2.8 Presentation of Photograph. There is a variety of methodologies available to the investigator for the presentation of reports, diagrams, and photographs. A key to the decision-making process is, "What method of presentation shows or presents the item with the greatest clarity?" A secondary consideration to assist in the preparation of the presentation is to follow guidelines or practices that are used for instructional presentations, specifically in the area of instructional aids. The investigator should determine what methods of presentation and types of photographs currently are acceptable to the court. Additionally, the investigator should identify and obtain equipment that may be needed to support the presentation, oversee the setup, and test the equipment prior to use. Preparation is one of the most important aspects of presenting demonstrative evidence.

15.2.8.1 Prints versus Slides.

15.2.8.1.1 There are advantages and disadvantages to both prints and slides. A benefit of slides over prints is that large size images may be displayed at no additional cost. When showing slides in court, the investigator can keep every juror's attention on what the investigator is testifying about. If prints are utilized, the investigator's testimony may be recalled only vaguely, if the jury member is busy looking at photographs that are passed among the jurors as testimony continues. The use of poster-sized enlargements can help.

15.2.8.1.2 Conversely, during testimony of a long duration or during detailed explanations of the scene, slides are a burden to refer to without the use of a projector. In this case, photographs are easier to handle and analyze. When slides are used, problems can occur, such as the slides jamming or a lamp burning out in the projector; thus, there may be no alternate way to display the scene to the jurors without delay. Prints require no mechanical devices to display them, and notations for purposes of identification, documentation, or description are easily affixed on or adjacent to a still photograph.

15.2.8.2 Video Presentation.

15.2.8.2.1 The use of video to present important information in testimony is an excellent methodology. Key to proper use of video presentation is to ensure that the size of the screen is sufficient to allow all interested parties to see the material adequately. The use of additional monitors may assist in overcoming this problem.

15.2.8.2.2 The investigator should be aware of quality issues when preparing the video presentation, as those that will be viewing the presentation are accustomed to broadcast-quality video.

15.2.8.3 Computer-Based Presentations. The advancement and increased use of computer-based presentations provides the investigator with an excellent tool for presentation. As with other presentation formats, there are inherent advantages and disadvantages to those programs.

15.2.8.3.1 Computer-based presentations provide the user with the ability to put drawings and photographs on the same slide, as well as to provide other highlighting or information that may enhance the observer's ability to understand relationships or information being presented.

15.2.8.3.2 The investigator should have backup resources available, such as the original photographs and drawings, in the event that hardware incompatibility or software problems prevent the presentation from being viewed or reduce the effectiveness of the presentation.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.3 Note Taking.
Note taking is a method of documentation in addition to drawings and photographs. Items that may need to be documented in notes may include the following:

(1) Names and addresses
(2) Model/serial numbers
(3) Statements and interviews
(4) Photo log
(5) Identification of items
(6) Types of materials (e.g., wood paneling, foam plastic, carpet)
(7) Data that was needed to produce an accurate computer model (see 20.6)
(8) Investigator observations (e.g., burn patterns, building conditions, position of switches and controls)

15.3.1 Forms of Incident Field Notes. The collection of data concerning an investigation is important in the analysis of any incident. The use of forms is not required in data collection; however, some forms have been developed to assist the investigator in the collection of data. These example forms and the information documented are not designed to constitute the report but, rather, they provide a means to gather data that may be helpful in reaching conclusions so that a report can be prepared.

15.3.2 Forms for Collecting Data. Some forms have been developed to assist the investigator in the collection of data. These forms and the information documented on them are not designed to constitute the incident report. They provide a means to gather data that may be helpful in reaching conclusions so that the incident report or the investigation report can be prepared. See Table 15.3.2.

Table 15.3.2 Field Notes and Forms

Form	Purpose
Fire Incident Field Notes	Any fire investigation to collect general incident data
Casualty Field Notes	Collection of general data on any victim killed or injured
Wildfire Field Notes	Data collection specifically for wildfire
Evidence Form	Documentation of evidence collection and chain of custody
Vehicle Inspection Form	Data collection of incidents specifically involving motor vehicles
Photograph Log	Documentation of photographs taken during the investigation
Electrical Panel Documentation	Collection of data specifically relating to electrical panels
Structure Fire Notes	Collection of data concerning structure fires
Compartment Fire Modeling	Collection of data necessary for compartment fire modeling

15.3.3 Dictation of Field Notes. Many investigators dictate their notes using portable tape recorders. Investigators should be careful not to rely solely on tape recorders or any single piece of equipment when documenting critical information or evidence.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.3.4 The retention of original notes, diagrams, photographs, and measurements such as detailed in Section 15.3 is the best practice. Unless otherwise required by a written policy or regulation, such data should be retained. These data constitute a body of factual information that should be retained until all reasonably perceived litigation processes are resolved. Information collected during the investigation may become significant long after it is collected and after the initial report is written. For example, notes or a diagram of a circuit breaker panel showing the status of the breakers may not be pertinent for a fire where the origin is in upholstered furniture, but may be of value regarding the status of the circuit powering a smoke detector. The retention of notes is not necessarily intended to apply to the fire fighter completing the required data fields in a fire incident reporting system.

15.4 Diagrams and Drawings.

Clear and concise sketches and diagrams can assist the investigator in documenting evidence of fire growth, scene conditions, and other details of the fire scene. Diagrams are also useful in providing support and understanding of the investigator's photographs. Diagrams may also be useful in conducting witness interviews. However, no matter how professional a diagram may appear, it is only as useful as the accuracy of the data used in its creation. Various types of drawings, including sketches, diagrams, and plans can be made or obtained to assist the investigator in documenting and analyzing the fire scene.

15.4.1 Types of Drawings. Fire investigations that can be reasonably expected to be involved in criminal or civil litigation should be sketched and diagrammed.

15.4.1.1 Sketches. Sketches are generally freehand diagrams or diagrams drawn with minimal tools that are completed at the scene and can be either three-dimensional or two-dimensional representations of features found at the fire scene.

15.4.1.2 Diagrams. Diagrams are generally more formal drawings that are completed after the scene investigation is completed. Diagrams are completed using the scene sketches and can be drawn using traditional methodologies or computer-based drawing programs. It should be noted that the completion of formal scene diagrams may not be required in some instances. The decision to complete a more formal scene diagram will be determined by the investigator, agency policies, and scope of the investigation.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.4.2 Selection of Drawings. It is recommended that original sketches and finalized diagrams be retained throughout the life of the investigation and any resulting litigation. See examples of various types of drawings in Figure 15.4.2(a) through Figure 15.4.2(f).

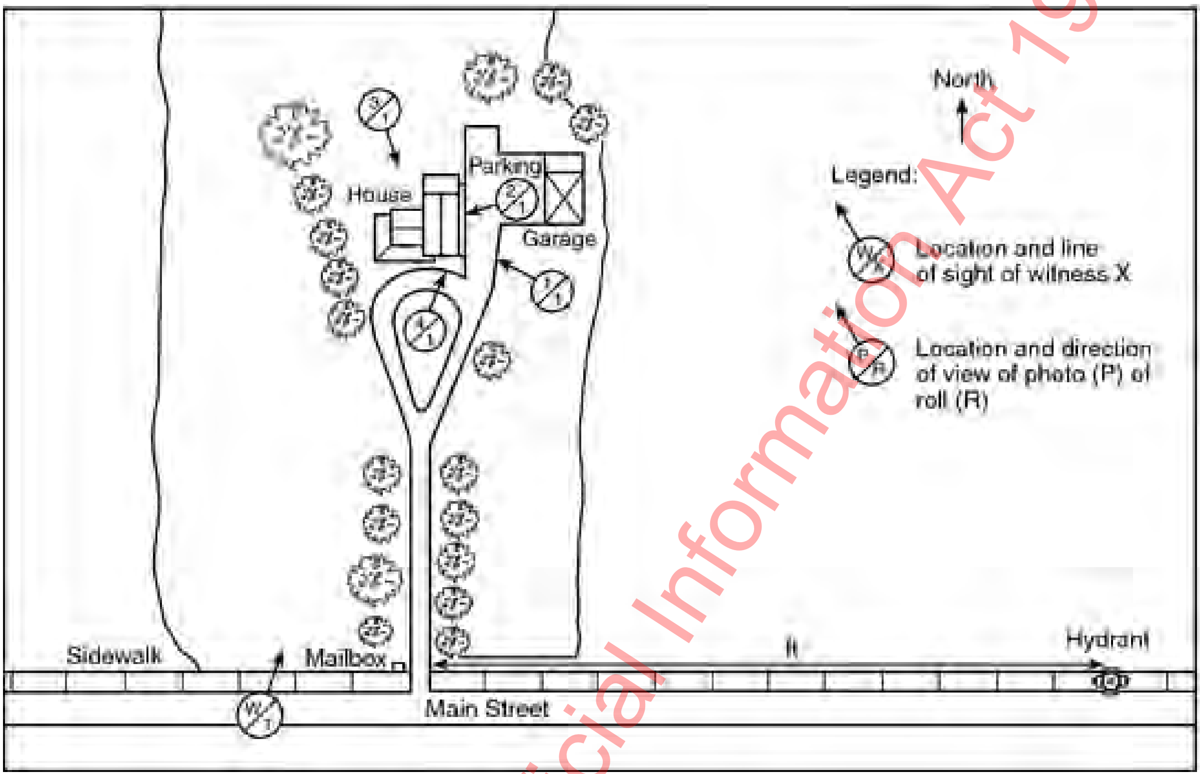


FIGURE 15.4.2(a) Site Plan Showing Photo and Witness Locations.

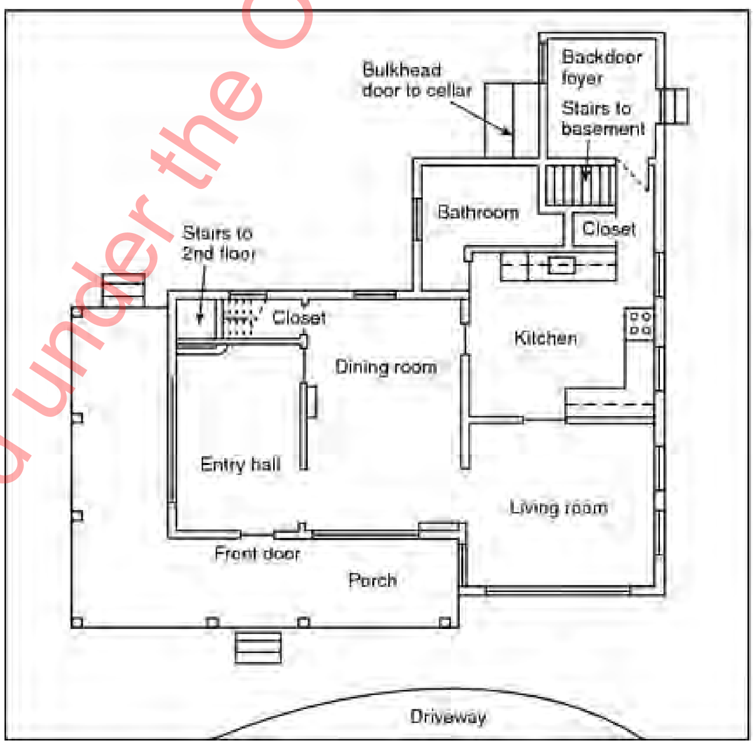
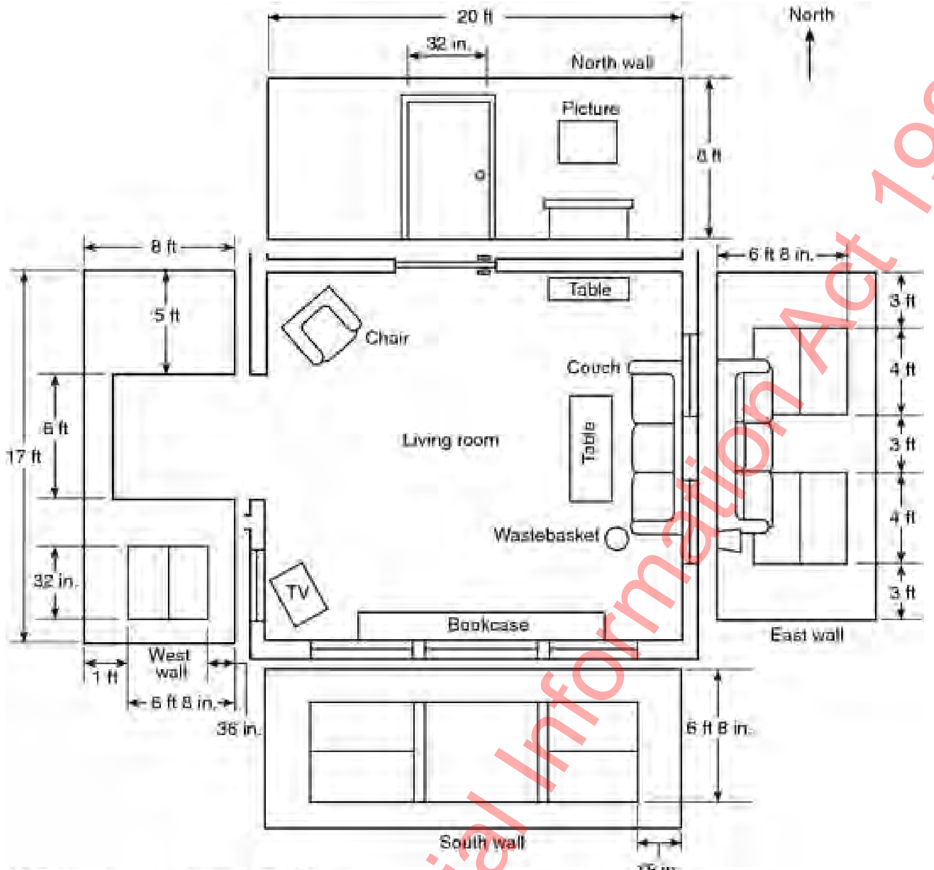


FIGURE 15.4.2(b) Detailed Floor Plan.

Source - NFPA 921, Chapter 15, 2008.

Extract



For SI units, 1 in. = 25 mm; 1 ft = 0.3 m.

FIGURE 15.4.2(c) Diagram of Room and Contents Showing Dimensions.

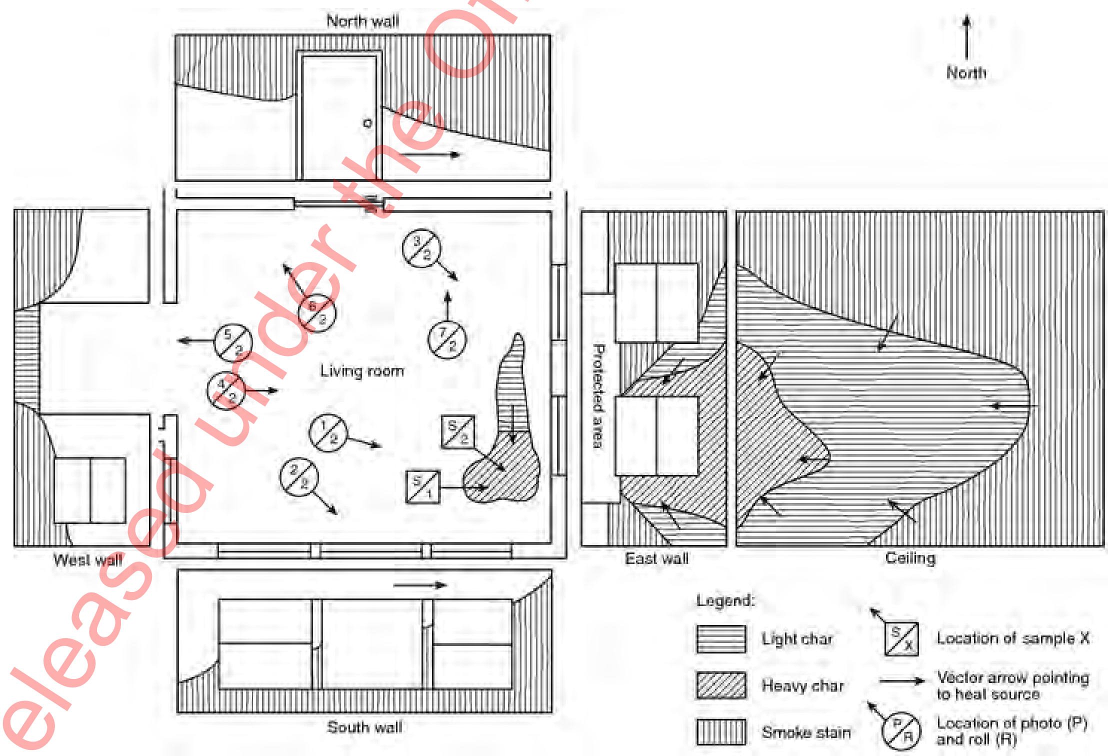


FIGURE 15.4.2(d) Exploded Room Diagram Showing Damage Patterns, Sample Locations, and Photo Locations.

Source - NFPA 921, Chapter 15, 2008.

Extract

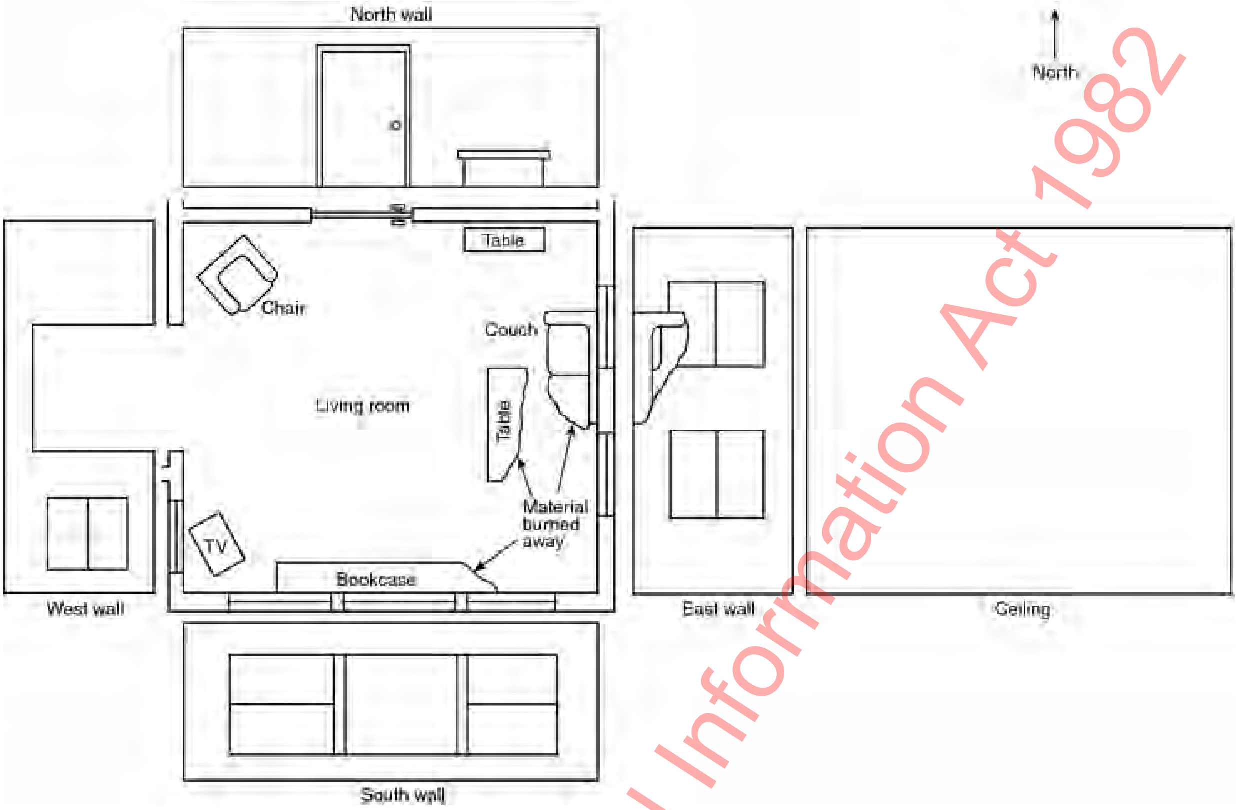


FIGURE 15.4.2(e) Contents Reconstruction Diagram Showing Damaged Furniture in Original Positions.

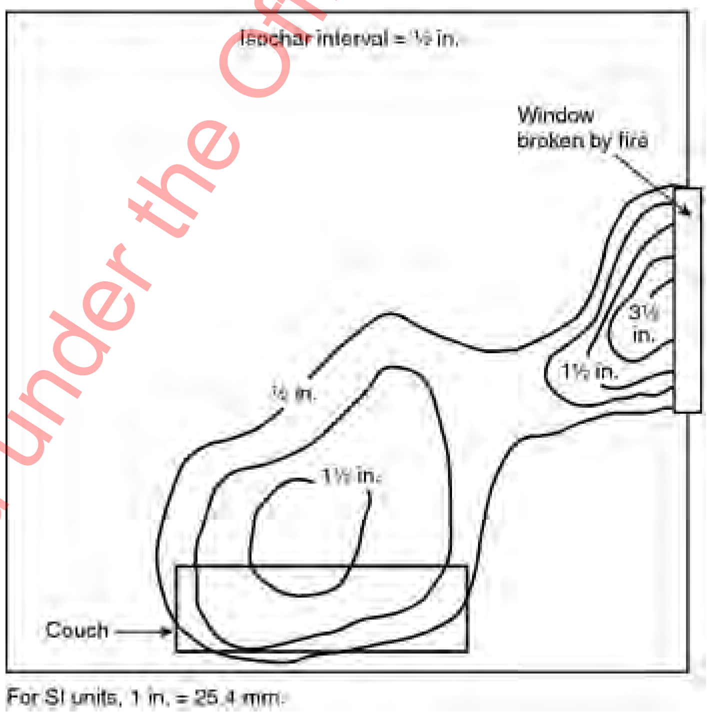


FIGURE 15.4.2(f) An Isochar Diagram Showing Lines of Equal Char Depth on Exposed Ceiling Joists.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.4.3 Drawing Tools and Equipment. Depending on the size or complexity of the fire, various techniques can be used to prepare the drawings. As with photographs, drawings are used to support memory, as the investigator may only get one chance to inspect the fire scene. As with the other methods of documenting the scene, the investigator will need to determine the type and detail of the diagrams developed and the type of drawings that may be requested from the building or equipment designer or manufacturer. During the course of the investigation, the investigator may have available a variety of drawings. These drawings may have been prepared by a building or equipment designer or manufacturer, may have been drawn by the investigator, or may have been developed by other investigators documenting conditions found at the time of their investigation.

15.4.3.1 Computer software is available that allows the investigator to prepare high-quality diagrams from scene-generated sketches. The fire investigator should look to several features in deciding on the best computer drawing tool to meet the intended goals. The fire investigator must first decide whether or not three-dimensional (3D) capability is required. In making that decision, the fire investigator must also decide whether or not the time invested in learning the package and additional complexity warrant the investment in such a tool. However, 3D drawings can yield great benefits in the investigation in determining and demonstrating such issues as the physical interrelationships of building components or the available view to witness. Regardless of the package selected, the most important criterion is the fire investigator's ability to create, modify, produce output, and manipulate a drawing within the selected package. Another consideration would be the compatibility of the Computer Aided Drawing (CAD) output to provide computer fire models input.

15.4.3.2 A good drawing package should also allow for the drawing on separate "layers" that can be turned on and off for different display purposes, such as pre-fire layout and post-fire debris. The package should also provide for automatic dimensioning and various dimensioning styles (i.e., decimal 1.5 ft, architectural 1 ft 6 in., and 457 mm). The package should also come with a wide variety of dimensioned "parts libraries." This component of the package provides the pre-drawn details, such as kitchen and bathroom fixtures, for placement by the investigator in the drawing.

15.4.4 Diagram Elements. The investigator, depending on the scope and complexity of the investigation, and on agency procedures, will decide on what elements to include on sketches and diagrams; however, there are a number of key elements that should be on all sketches and diagrams, as outlined in 15.4.4(A) through 15.4.4(D).

(A) General Information. Identification of the individual who prepared the diagram, diagram title, date of preparation, and other pertinent information should be included.

(B) Identification of Compass Orientation. Identification of compass orientation should be included on sketches and diagrams of fire scenes.

(C) Scale. The drawing should be drawn approximately to scale. The scale should be identified or indicated "Approximate Scale" or "Not to Exact Scale," and a graphic scale or approximate scale may be provided on the drawing.

(D) Symbols. Symbols are commonly utilized on sketches and drawings to denote certain features; for example, a door symbol is used to indicate that there is a door in the wall and is drawn in the direction of swing. To facilitate understanding, it is recommended that the investigator utilize standard drawing symbols commonly found in the architectural or engineering community. For fire protection symbols, the investigator may utilize the symbols contained in NFPA 170, *Standard for Fire Safety and Emergency Symbols.*

(E) Legend. If symbols are utilized that are not readily identifiable, the investigator should use a legend on the drawing to eliminate the potential for confusion as to what the symbol represents.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.4.5 Drawings. Generally, a simple sketch of the room of origin or immediate scene should be prepared and should include items such as furniture, windows and doors, and other useful data. A typical building sketch can show the relative locations of rooms, stairs, windows, doors, and associated fire damage. These drawings can be done freehand with approximate dimensions. This type of drawing should suffice on fire cases where the fire analysis and conclusions are simple. More complex scenes or litigation cases will often require developing or acquiring actual building plans and detailed documentation of construction, equipment, furnishings, witness location, and damage.

15.4.5.1 Site or Area Plans. Plot or area diagrams may be needed to show the placement of apparatus, the location of the fire scene to other buildings, water supplies, or similar information. Diagrams of this nature assist in documenting important factors outside of the structure. See Figure 15.4.2(a).

15.4.5.2 Floor Plans. Floor plans of a building identify the locations of rooms, stairs, windows, doors, and other features of the structure. See Figure 15.4.2(b).

15.4.5.3 Elevations. Elevation drawings are single plane diagrams that show a wall, either interior or exterior, and specific information about the wall. See elevation portion of Figure 15.4.5.3.

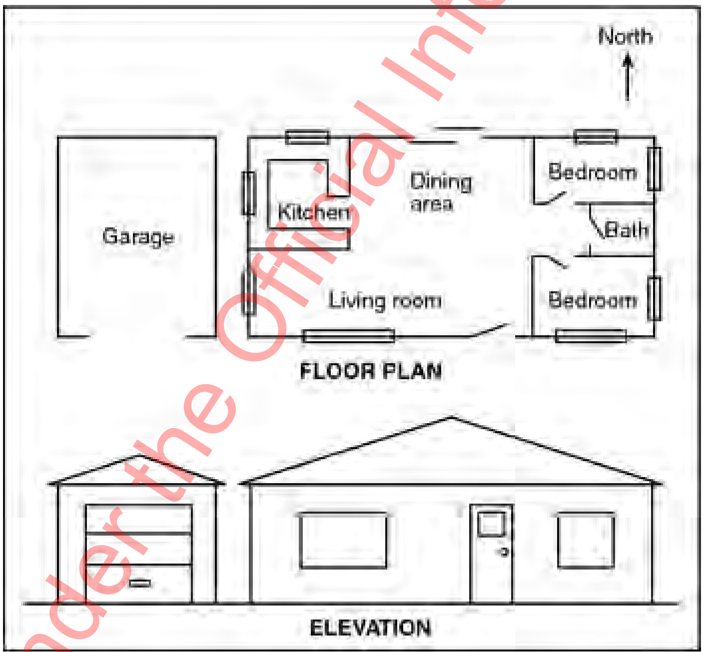


FIGURE 15.4.5.3 Minimum Drawing for Simple Fire Analysis.

15.4.5.4 Details and Sections. Details and sections are drawn to show specific features of an item. There is a wide variety of information that can be represented in a detail or section diagram, such as the position of switches or controls, damage to an item, location of an item, construction features, and many more.

15.4.5.5 Exploded View Diagrams. Exploded view diagrams are often used to show assembly of components or parts lists. The investigator may also utilize this format to show all surfaces inside of a room or compartment on the same diagram. See Figure 15.4.2(d).

Source - NFPA 921, Chapter 15, 2008.

Extract

15.4.5.6 Three-Dimensional Representations. In many cases, it will be desirable, if not necessary, for the investigator to obtain sufficient dimensional data to develop a three-dimensional representation of the fire scene.

15.4.5.6.1 Structural Dimensions. The investigator should measure and document dimensions that would be required to develop an accurate three-dimensional representation of the structure, as illustrated in Figure 15.4.2 (c). Consideration should be given to the documentation of such often overlooked dimensions as the thickness of walls, air gaps in doors, and the slope of floors, walls, and ceilings. Such representative geometry may be required if subsequent fire modeling and/or experimental tests are to be conducted as part of the incident investigation.

15.4.5.6.2 Availability of Dimensional Data. While dimensional data may be found in building plans, layouts, or as-built drawings, it may not be known at the time of the scene investigation if such sources of information exist, especially in the case of older structures. Thus, it is prudent for the investigator to collect the physical dimensions independent of the existence of plans, layouts, or drawings.

15.4.5.7 Specialized Fire Investigation Diagrams.

15.4.5.7.1 In addition to a basic floor plan diagram, it is recommended that the fire investigator utilize specialized sketches and diagrams to assist in documenting specifics of the fire investigation. The decision to utilize these or other specialized sketches and diagrams is dependent on the decision of the investigator and the need to represent a complex fact or issue. These types of specialized investigation diagrams will include electrical, mechanical, process system, and fuel gas piping schematics, fire pattern, depth of char survey, depth or calcination survey, witness line of sight, heat and flame vector analysis, and others, as required.

15.4.5.7.2 The use of a computer-drawing program facilitates the development of many different specialized drawings from the initial floor plan. The use of layers or overlays can assist in the understanding of specific features and prevent the drawing from becoming overly complicated.

15.4.6 Prepared Design and Construction Drawings.

15.4.6.1 General. Prepared design and construction diagrams are those diagrams that were developed for the design and construction of buildings, equipment, appliances, and similar items by the design professional. These diagrams are often useful to the investigator to assist in determining components, design features, specifications, and other items.

15.4.6.1.1 The availability and complexity of prepared design and construction drawings will vary, depending on the type and size of the occupancy for structures or the ability to identify a specific manufactured item.

15.4.6.1.2 During or after building construction or as a result of occupancy changes, modifications may occur. These modifications may not be reflected on any existing drawings. When using prepared building diagrams, the investigator will need to compare the drawing to the actual building layout.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.4.6.2 Architectural and Engineering Drawings. Within the design and construction process, there are several types of drawings with which the investigator should be familiar. The most common drawings along with the discipline that generally prepares them are shown in Table 15.4.6.2.

Table 15.4.6.2 Design and Construction Drawings That May Be Available

Type	Information	Discipline
Topographical	Varying grade of the land	Surveyor
Site plan	Structure on the property with sewer, water, electrical distributions to the structure	Civil engineer
Floor plan	Walls and rooms of structure as if you were looking down on it	Architect
Plumbing	Layout and size of piping for fresh water and wastewater	Mechanical engineer
Electrical	Size and arrangement of service entrance, switches and outlets, fixed electrical appliances	Electrical engineer
Mechanical	HVAC system	Mechanical engineer
Sprinkler/ fire alarm	Self-explanatory	Fire protection engineer
Structural	Frame of building	Structural engineer
Elevations	Shows interior/exterior walls	Architect
Cross-section	Shows what the inside of components look like if cut through	Architect
Details	Show close-ups of complex areas	All disciplines

15.4.6.3 Architectural and Engineering Schedules. On larger projects, it may be necessary to detail the types of equipment in lists that are called *schedules*. Where many components are specified in great detail, a schedule will usually exist. Typical schedules are as follows:

(1) Door and window schedule
(2) Interior finish schedule
(3) Electrical schedule
(4) HVAC schedule
(5) Plumbing schedule
(6) Lighting schedule

15.4.6.4 Specifications. Architects and engineers prepare specifications to accompany their drawings. While the drawings show the geometry of the project, the specifications detail the quality of the materials, responsibilities of various contractors, and the general administration of the project. Specifications are usually divided into sections for the various components of the building. For the fire investigator, the properties of materials can be identified through a specification review and may assist in the analysis of the fire scene.

Source - NFPA 921, Chapter 15, 2008.

Extract

15.4.6.5 Appliances and Building Equipment. Parts diagrams and shop drawings may be available for appliances and equipment that may have been involved in a fire scenario. These diagrams may assist the investigator in determining or obtaining specific information about components or other features.

15.5 Reports.

The purpose of a report is to effectively communicate the observations, analyses, and conclusions made during an investigation. The specific format of a report is not prescribed. For guidance on court-mandated reports, see Chapter 11.

15.5.1 Descriptive Information. Generally, reports should contain the following information, preferably in the introduction:

(1) Date, time, and location of incident
(2) Date and location of examination
(3) Date the report was prepared
(4) Name of the person or entity requesting the report
(5) The scope of the investigation (tasks completed)
(6) Nature of the report (preliminary, interim, final, summary, supplementary)

15.5.2 Pertinent Facts. A description of the incident scene, items examined, and evidence collected should be provided. The report should contain observations and information relevant to the opinions. Photographs, diagrams, and laboratory reports may be referenced.

15.5.3 Opinions and Conclusions. The report should contain the opinions and conclusions rendered by the investigator. The report should also contain the foundation(s) on which the opinion and conclusions are based. The name, address, and affiliation of each person who has rendered an opinion contained in the report should be provided.

Source - NFPA 921, Chapter 15, 2008.

Victim Awareness

Section Contents

1. Impact of Fire on Victims

Fire impact and support systems

Introduction

The purpose of this chapter is to raise officer awareness on how the public is affected in emergency situations and to provide guidelines on what the New Zealand Fire Service can do to assist the public during and after the event.

Members of the public who are unfortunate enough to experience a fire, flood, road crash or other emergency, often rely on the New Zealand Fire Service to make things safe again. Our training and experience is used in all sorts of situations, and in every case, our work should be done with genuine care for the welfare and survival of those involved.

For emergency workers, there is great satisfaction in helping others and to take every effort to minimise the impact of the event. No scene is left until it is safe.

Usually, we arrive at an incident, perform our duties and go back to the station again. We do the job with enthusiasm and efficiency and may be unaware of the impact that this occasion has on the victims of the event. Occasionally, we might notice their reactions and behaviours, but we have a job to do and we generally focus on doing that job until we are told it's time to leave.

Officers In Charge and Fire Safety Officers assigned to carry out investigations may have more personal contact as they interview victims and gather information. This process may be brief or lengthy.

What's it like for the victim?

Apart from taking out insurance cover against possible loss, people who experience a fire or other emergencies are invariably unprepared for the impact it may have on their lives.

With empathy, we may be able to accelerate their recovery. If we have, to some degree, knowledge of what it is like to have been through a fire, flood, or other disaster, we are better prepared to act in ways that do not make their experience worse.

The majority of the public will never have seen a fire damaged property; reactions can range form total amazement at the extent of the damage, to distress from the sense of loss and tragedy.

Explaining how and why damage has occurred may help people understand and overcome their distress.

Reactions are unpredictable

One cannot predict with certainty how anyone will react to any particular incident, as the variables are too many. However, it may be safe to generalise, keeping in mind there will always be exceptions and that one should not assume that a person is feeling in any particular way.

For example,

- some people are so pleased that they are alive that nothing else matters
- others seem to be disproportional in their responses to what appears to us a very minor fire
- also, some people are able to cover their distress so successfully that we may believe that they are unaffected.

Symptoms

In general, people who find themselves in a critical emergency will experience symptoms associated with shock, stress, loss and grief. These symptoms can be physical, emotional, cognitive and behavioural. Sadness disbelief, anger and guilt are common.

We need to realise that no matter how they look or how they behave, people deserve our understanding and we must be professional and respect they are vulnerable and act accordingly.

Note:

Remember, any emergency that we attend is “just another job”, but for the public, it may be one of the most significant events of their lives. For us it becomes part of the history of all the other incidents we have attended, whereas for the victim, it is most likely to be the one thing that they never forget.

Loss

Most often the experience of the victim is one of loss – actual or perceived – and can include:

- Acquaintance, partner, child, relative, friend
- Business
- Dwelling
- Belongings
- Memorabilia
- Precious things
- Essentials
- Sense of safety
- Hope for the future
- Cars/toys
- Refuge/safe place for recuperation
- Neighbours if they have to move
- School time/work time
- Holidays
- Home in which personality was carefully displayed.

We may think that objects are only that – things which can usually be replaced. For the victim, however, these things may have great significance because of the assigned meanings they have given to them. It is not professional to put value on to another person's possessions.

Care and respect

Care

Show care at all time; showing evidence of empathy and understanding can help significantly with recovery.

In assisting recovery, we must ensure that we do not make the experience any worse than it already is. People may take notice of things said and done by us because of our key position as authority figures. At an incident, victims are vulnerable and have a heightened awareness of the things around them. You may be part of the most significant day of their life. You may not remember them but they will almost certainly remember you and your actions.

Respect

Respect must be given, and demonstrated by us. Our actions and words are all important because they can show respect or contempt. Firstly, consider our actions – the things we are seen to be doing. Secondly, consider the things we are heard to say. For almost all of us, this is second nature and is only stated here for clarity and completeness.

Consider	Guide
The things we are seen to do	As a guide: • Be careful to handle people's possessions with care no matter if they are intact or nearly destroyed • Respect their privacy • Take special care with items that are clearly significant such as letters, photographs and purses/handbags • Even if you are enjoying your work, keep the laughter and frivolous antics for back at the station. There is no need for gloom or solemnity—just appropriate, professional and tactful control.
The things we are heard to say	As a guide: • Keep comments professional • Suppress any temptation to make statements of judgement of the lifestyle or conditions in which the people live.

When talking with victims

What not to say

Though the following statements may be true, it's not helpful for us to say:

- "At least nobody was hurt"
- "You can replace furniture and things"
- "At least you were insured"
- "Look on the bright side . . . "

These statements are best coming from the victims themselves. They are not interested in hearing about other, or worse, fires that we have been to in comparison to theirs – even if they show polite signs of interest.

Avoid laying blame or guilt. Statements about things that they could have done to prevent the fire from happening are not helpful now. People will know if they have made a mistake, and they do not need us to help them feel guilty. Save the fire safety messages until later – perhaps when they ask for them.

In discussing issues with people, we should avoid any temptation to make comments that may be taken as reminding people how stupid or negligent they may have been. Avoid being patronising. Be mindful of how and what you say because in stressful situations the person may misinterpret it.

What we can do

Demonstrate the professional attitude and caring behaviour that we are famous for:

- Go the extra mile
- Show respect at all times
- Refer, if needed, to other appropriate organisations such as:
  - Victim Support
  - Age Concern
  - Salvation Army
  - St. Vincent de Paul
  - Housing New Zealand
  - Citizens Advice Bureau
  - Work and Income New Zealand
  - A chosen friend / relative / Whanau
  - Church
- If appropriate, suggest that someone, such as an advocate, speak for them
- Find an interpreter if language is a problem

- Have brochures available, such as:
  - "After a Fire or Other Emergency" – NZFS
  - "Working with Victims of Crime, Accident and Emergency" – Victim Support
  - "Crisis and Trauma: Helping you cope with crisis and trauma"
  - Victim Support.

Authority Figure

You are an authority figure and people take notice of what you say and do. At an incident, victims are vulnerable and have heightened awareness of what is around them. They will usually listen attentively to your every word. You are part of perhaps the most significant day of their lives. You may not remember them – but they will remember you or at least the character of the person wearing the uniform. To the public, it is possibly a once in a lifetime crisis – to you it's just "another day at the office".

2. Fire Awareness & Intervention Programme (FAIP)

Introduction

The aim of the programme is to reduce the number of deaths, injuries and millions of dollars of property damage caused by children and juvenile fire setting through an interventional programme delivered by trained firefighters.

The programme content and delivery varies according to the age and maturity of the child.

The child/juvenile is visited in the home by a trained firefighter (youth liaison officer) over several weeks. In partnership, the practitioner, child and parents develop an awareness of fire safety issues in the home and actively work towards a safer home environment.

All children and juveniles with fire lighting tendencies are catered for in this programme. The children develop a greater respect for fire and its consequences. Referrals are received by parents over the phone, firefighters in the field, following lectures, via children's mental health agencies, Police, Police Youth Aid, Justice Department, schools and other concerned agencies.

How does the programme work?

The programme comprises of three components:

- Trust building – involves establishing a rapport with the child, parents or caregivers and youth liaison officer
- The programme – a course on fire safety practices tailored to the individual with the aim of raising fire awareness and modifying fire lighting behaviours
- Positive Reinforcement/Reward – these comprise of tangible and verbal rewards provided by the family.

Course structure

The programme has various elements which range from:

- A questionnaire used to formulate an educational strategy
- Photographic and video evidence of structural fires and burns to assess the child's concept of fire
- A fire awareness workbook to provide better understanding of safe fire practices
- Design a fire escape plan for the family home
- Maintain smoke alarms and general fire safety around the home – junior fire safety officer
- Where appropriate a star chart is used for younger children where a star is rewarded if the child has not engaged in any adverse fire activity and has successfully carried out their duties as junior fire safety officer.

There are resources available to help reinforce the key messages from the programme and post intervention work can be undertaken if the child's behaviour deteriorates back into unsafe fire play.

3. Human Behaviour

NFPA 921, Chapter 10 – Fire-related Human Behaviour

Extract

10.1 Introduction.
The initiation, development, and consequences of many fires and explosions are either directly or indirectly related to the actions and omissions of people associated with the incident scene. As such, the analyses of fire-related human behavior will often be an integral part of the investigation.

10.1.1 This chapter discusses research findings associated with factors that contribute to fire-related human behavior: how people react to fire emergencies, both as individuals and in groups; factors related to fire initiation; factors related to fire spread and development; factors related to life safety; and factors related to fire safety.

10.1.2 The information discussed in this chapter is based on research conducted by specialists in the fire scene analysis and human behavior fields. The analysis of human behavior is not a substitute for a thorough and properly conducted investigation. While the analysis of human behavior will provide valuable investigative insights, such analysis must be integrated into the total investigation.

10.1.3 For more information on fire-related human behavior, see the *SFPE Engineering Guide to Human Behavior in Fire*, which provides a summary of research related to occupant characteristics, notification of occupants, decision making by occupants, and movement through egress paths.

10.2 History of Research.
Fire-related human behavior began to emerge as a distinct field for study in the early 1970s. In 1972, English researcher Peter G. Wood, a pioneer in the field, completed a study of occupants in 952 fire incidents, published as Fire Research Note #953. A few years later, John L. Bryan, a U.S. researcher and professor of fire protection engineering at the University of Maryland, published the results of his extensive studies on behavior in fires. Bryan has summarized both his work and much of the work of other researchers in this field. This summary is contained in *The SFPE Handbook of Fire Protection Engineering*, "Behavioral Response to Fire and Smoke."

10.3 General Considerations of Human Responses to Fires.
Current accepted research indicates that there are myriad factors that affect an individual's or group's human behavior preceding, during, and following a fire or explosion incident. These factors can be broadly classified and evaluated as characteristics of the individual, characteristics of population groups, characteristics of the physical setting, and characteristics of the fire or explosion itself. A careful analysis and evaluation of these factors and their interaction with one another will provide valuable insight into the role of fire-related human behavior for any particular incident. These factors have been extensively examined in the U.S. Fire Administration publication, "Fire Related Human Behavior," (1994). This information is summarized in 10.3.1 through 10.3.2.4.

Source – NFPA 921, Chapter 10, 2008.

Extract

10.3.1 Individual. Fire-related human behavior is affected by characteristics of the individual in a variety of ways. These characteristics are comprised of physiological factors, including physical limitations, cognitive comprehension limitations, and knowledge of the physical setting. Each of these characteristics affect either an individual's ability to recognize and accurately assess the hazards presented by a fire or explosion incident or an individual's ability to respond appropriately to those hazards.

10.3.1.1 Physical Limitations. Physical limitations that may affect an individual's ability to recognize and react appropriately to the hazards presented by a fire or explosion incident include age (as it relates to mobility), physical disabilities, intoxication, incapacitating or limiting injuries or medical conditions, and other circumstances that limit an individual's mobility. Such limitations should be considered when evaluating an individual's fire-related human behavior, because they tend to restrict or limit one's ability to take appropriate action in response to a fire or explosion. The very old and very young are most affected by physical limitations.

10.3.1.2 Cognitive Comprehension Limitations. Cognitive comprehension limitations, which may affect an individual's ability to recognize and react appropriately to the hazards presented by a fire or explosion incident, include age (as it relates to mental comprehension), level of rest, alcohol use, drug use (legal or illegal), developmental disabilities, mental illness, and inhalation of smoke and toxic gases. These cognitive limitations are more likely to affect an individual's ability to accurately assess the hazards presented by a fire or explosion. Often such limitations account for delayed or inappropriate responses to such hazards. Children may fail to recognize the hazard and choose an inappropriate response, such as hiding or seeking a parent.

10.3.1.3 Familiarity with Physical Setting. An individual's familiarity with the physical setting in which a fire or explosion incident occurs may affect an individual's behavior. For example, a person would be more able to accurately judge a fire's development and progression in his or her own home than in a hotel. It is important to note, however, that physical and cognitive limitations may minimize the advantages of being familiar with the physical setting. Consequently, it may appear that a person has gotten "lost" in his or her home.

10.3.2 Groups. An individual's fire-related behavior is affected by more than his or her characteristics. When interacting with others, an individual's behavior will likely change and be further affected by his or her interaction with that population group and its characteristics. These group characteristics are related to the group size, structure, permanence, and its roles and norms.

10.3.2.1 Group Size. Research and experimental data indicate that when individuals are members of a group, they are less likely to acknowledge or react appropriately to the sensory cues that a fire or explosion incident presents. This tendency increases as the size of the group increases. Research suggests that this fire-related human behavior occurs because individuals in groups will delay their responses to such sensory cues until others in the group also acknowledge these cues and react. The same research suggests that this occurs because the responsibility for taking appropriate action is actually diffused among the group.

10.3.2.2 Group Structure. The structure of a group may also affect the fire-related behavior of both the group and its individual members. Generally, when the group has a formalized structure with defined and recognized leaders or authority figures, the group tends to react to fire and explosion incidents more quickly and in a more orderly manner. However, the reaction is not always appropriate. Examples of such groups include school populations, hospital populations, nursing home populations, and religious facility populations. The behaviors in 10.3.2.2.1 and 10.3.2.2.2 have been observed.

Source - NFPA 921, Chapter 10, 2008.

Specific Fire Types

Section Contents

1. Mobile Property

Introduction

Each year, motor vehicle fires in New Zealand cost millions of dollars in property loss. It is essential to identify the cause of as many fires as possible. Statistics tend to show that accidental fires are in the minority where vehicles are concerned.

In the event of a fire, insurance companies are no longer willing to absorb without question the costs of high priced vehicles. Vehicle fires mean loss of jobs, income and services to many people and may also damage or destroy the contents of the vehicle and any surrounding property.

Two separate vehicle examinations may be necessary in order to conduct a property vehicle fire investigation:

1. Incident scene examination, and
2. Detailed vehicle examination.

At times, you will be unable to complete the detailed examination of a burned vehicle at the incident scene. When this occurs, a second examination of the vehicle may be necessary after the burned vehicle has been moved from the incident scene.

Incident scene investigation

Do not rush any part of the investigation. However, you must focus on accomplishing these five objectives:

1. **Identify the fire's point of origin.** This is the exact location where the fire started. It is usually the lowest point of the fire where the damage is greatest.
2. **Find the heat source.** This is the energy that ignited the fire. An open flame is an example of a heat source.
3. **Determine the fuel source**. This is the material that was ignited by an ignition source.
4. **Determine the event of the fire.** This is the method by which the heat source and combustion combined at the point of origin to create a spark.
5. **Determine the category of fire.** Fires are accidental, incendiary, natural or undetermined. You must accomplish the other objectives before you can determine a fire's category.

Examination of the scene

The fire scene examination will usually provide a first impression of the fire. For example:

- Is the owner/operator available and able to describe what has happened?
- Where was the location of the fire?

The purpose of the scene examination is to obtain as much information as possible about the fire to help determine the cause of the fire.

What to check	Reason for checking
Petrol caps	The petrol cap and filler pipe to the gas tank should be examined. Tests have shown that petrol tanks do not ordinarily explode as a result of fire. They may fracture from other damage, or crack from the heat of an adjacent fire, releasing the contents/vapours of the tank -- probably resulting in total destruction of the car. A missing petrol cap may indicate that the cap was deliberately removed. The neck of the filler pipe will show striations if an explosion blew off the cap. Newer vehicles' plastic caps have threads and screw in. This type of cap may melt from heat and leave residue in and around the filler opening.
Accelerant residue	Accelerant residue may be recovered from the soil under or near the vehicle. The floor of the vehicle contains seams and drain-plugs and if an accelerant is poured on the floor of a vehicle it will often leak out onto the ground. Spillage from the container may also occur as the arsonist pours or splashes the accelerant in or on the vehicle. Accelerant may be used as a trailer allowing the arsonist to start a fire some distance from the vehicle. Take soil samples from a depth of several centimetres from under the vehicle or by the doors and have these samples analysed. However, keep in mind that liquid on soil also may be from leaking fuel from the engine or transmission.
Accelerant containers	Accelerant containers are often recovered at the incident area. The arsonist may throw these containers into nearby ground cover. Check each side of the road for several hundred yards in each direction from the scene. An accelerant container may be thrown from the vehicle used to transport the arsonist after the fire was set.

Detailed vehicle examination

Prior to commencing the detailed vehicle examination, it is worth noting the following modern vehicle safety designs and the impact they may have on the fire.

Design	Impact
Vehicle electrical systems	Manufacturers' designs of vehicle electrical systems provide for basic fire safety. Electrical overload protection helps limit short circuit damage. Damage from short circuits is usually limited to the wiring between the short and the first-line fuse. Equipment and accessory short circuits usually cause only localised damage. Materials used as electrical insulation seldom add to the overall fire damage.
Vehicle fuel systems	Fuel systems do not usually pose explosion hazards because flammable vapours are released from the fuel storage tank. These vapours usually burn away at or near the tank filler neck. However, the rubber fuel lines positioned along the body for the transportation of the fuel liquid to various vehicle components may rupture causing pool fires and increasing the spread of fire to other vehicles. Consideration must also be given to modern vehicles having pressurised fuel systems, such as diesel and petrol injection. Fuel pumps may be either in the fuel tank or engine compartment and may spray high-pressure fuel out of ruptured fuel lines if the ignition system is live. LPG or CNG cylinders may rupture (BLEVE) due to direct fire impinging onto these cylinders.
Ignition Systems	Vehicle designs usually provide the maximum separation between fuel and ignition sources, however, there are overall moderate ignition possibilities as fire causes. The ignition system should always be examined.

Vehicle exterior examination

Once the fire scene examination is completed, move on to inspect the exterior of the vehicle. It is best to examine the vehicle at the fire scene, so evidence is not damaged or destroyed.

What to check	Reason for checking
Vehicle roof	At one time, a sagging vehicle roof was believed to indicate an incendiary fire. Earlier interior finishes did not produce a high enough temperature to weaken the roof. On newer vehicles, a sagging roof can be the result of the burning of certain types of seat padding. The sagging of the roof should be noted and documented, but in newer vehicles, it does not prove the fire was incendiary.
Underside of vehicle	An arsonist may spray or pour an accelerant on the underside of a vehicle. Usually this is indicated by soot on the vehicle's undercarriage. However, this soot may have been caused by liquid from a leaking fuel line or transmission.
Exterior fire damage	Liquid accelerants on the exterior of a vehicle may show evidence of running or dripping down the sides of the vehicle. Examine the burn patterns on the exterior paint for signs that an accelerant was used. A normal burn pattern is a wide 'V' shape starting at the fire's point of origin and moving up and out from there. The position of the windows and doors at the time of the fire will affect burn patterns. Also check for blistered or peeled paint, which may help identify the point of origin. For further information, refer back to section 6.3 - origin determination / fire patterns.
Tyres	Tyres are almost never totally consumed in a vehicle fire. The portion of the tyre that is resting on the ground will usually remain after the fire. Check tyres for odd treads or uneven wear, which may indicate a change of tyres prior to the fire.
Wheels (rims)	As with tyres, the wheel rims should be examined closely. These rims are made of steel or magnesium and may not suffer damage in a fire. Frequently, the vehicle will have new tyres replaced with old ones just prior to the fire, therefore, check for missing lugs or lug nuts, indicating haste in the fire preparations. Also check to see if all four rims are the same colour and if they match the rim of the spare tyre.

Vehicle interior examination

Fires in the cabin area are usually blamed on electrical shorts or foreign objects. The possibility of major damage caused by an electrical short is unlikely even if a fire does occur in today's newer vehicles. There is a better chance of a foreign object causing a fire, but unless exposed to an open flame, foreign objects usually will cause only minor damage. If neither of these appears to have caused the fire, you will have to look for other clues.

What to check	Reason for checking
Accelerant containers and residue	Frequently, accelerant containers are left inside the vehicle. The arsonist often believes the container will be consumed and in some instances, especially if a plastic milk container is used, this may be the case. Nevertheless, a relatively unburned spot on the floor may exist to show that something was there at the time of the fire. Glass containers are made of thick glass and will usually withstand the high temperatures of a fire. Therefore, when glass containers are used as accelerant containers, there may remain broken particles of glass, which can be used as a sample for testing purposes. The liquid accelerant may have been stored in metal containers. If the can was left in the car, it will still be present after the fire is suppressed. Residue of the ignitable liquid may still be available for comparison samples. Vehicle floors have low spots where accelerant residue may be recovered. Liquid accelerants may be recovered from floor carpets and padding, under floor mats, in metal floor indentations, insulation or around rubber grommets.
Windows	Position and/or condition of all the vehicle's windows may provide clues on the type of interior fire. Open windows during very cold weather are not normal, nor are closed windows in very hot weather unless the vehicle is air-conditioned. The fire may self-extinguish if windows are left closed, therefore, an arsonist may open vehicle windows to allow for oxygen to feed the fire. If glass is melted, check the window mechanical lift arms to determine the position of the windows at the time of the fire. If the arm is at the bottom of the door, the window was open and visa versa. Melted window glass indicates a hot fire but does not prove the fire was incendiary.

What to check	Reason for checking
Doors	The position of the vehicle doors may be an indicator of incendiarism. Vehicle doors are often left open when the vehicle is intentionally burned to allow oxygen to feed the fire. When interviewing firefighters, ask about the position of doors upon their arrival and determine whether or not they had to open the doors.
Ignition key	Examination of debris in the vehicle's interior should include looking for the ignition key. If the key was in the ignition at the time of the fire, it may fall to the floor when the ignition switch melts, and remain embedded in the white metal of the ignition assembly. Even if the key melts from the ignition, a portion of the key should still remain inside the assembly. Finding a single key usually is not normal, since most people carry more than one key. Quite often, keys are on a metal ring, which normally remains after a fire.
Removal of accessories	One of the more popular accessories in vehicles is the cellular phone. The brackets may be mounted on the floor area and wired directly to the battery to eliminate interference. Most vehicle accessories do not totally burn or melt and will leave melted metal in mount holes or brackets. Empty mounting brackets or holes should be considered suspicious.
Vehicle's boot	An empty car boot is usually considered suspicious. Most people always have something in their boot. Standard items found in the boot will include the spare tyre and jack tools.

Vehicle engine compartment examination

A thorough examination of the engine compartment must be conducted. As most accidental vehicle fires originate in this compartment, the investigator must eliminate all possible accidental causes. A clever arsonist will attempt to disguise an incendiary fire by making it appear as if there was an engine malfunction.

What to check	Reason for checking
Radiator	Solder in radiator joints does not usually melt out during an accidental fire. An exception to this is when a fuel line leaks and creates an unusually hot fire. If a fuel leak can be eliminated, the radiator damage may indicate the presence of an accelerant. Check the level of water or antifreeze inside the radiator and the radiator hose top and bottom to see if the connection is tight.

What to check	Reason for checking
Motor supports	Motor supports seldom receive extensive fire damage during accidental fires. If the supports show evidence of damage, it may indicate the presence of an accelerant. Broken motor supports may indicate a costly repair and show the reason for the intentional fire.
Belts	Fan, generator, or air conditioner belts are seldom destroyed in accidental vehicle fires. Damage to these belts may be localised in the area of an accidental fire, but if they are totally consumed it may indicate the use of an accelerant.
Missing accessories	Batteries, generators, alternators, starters, etc., are not completely destroyed in a fire. These accessories may receive heavy damage as a result of the fire, but some portion of them will remain. If these items are missing, it may indicate removal prior to the fire or extensive engine repairs that the owner/operator could not afford.
Catalytic converter	The catalytic converter is a device that uses a catalyst to convert three harmful compounds in car exhaust into harmless compounds. A catalytic converter is only used in vehicles running on unleaded fuel. The National Fire Protection Association (NFPA) 921, 2008 states:

Extract

25.5.2.4 Exhaust System. The exhaust system does more than carry the exhaust gases from the engine. It also serves as a part of the emission control system. The exhaust manifold is bolted directly to the engine. It is the collector for the exhaust gases coming from each cylinder. This manifold is generally located below the valve cover. A leak in the valve cover or gasket may allow engine oil to contact the manifold, which may result in ignition. *(See 25.4.3.)* In the inlet header pipe (the first section of pipe from the engine), there is usually an oxygen sensor. This sensor detects the oxygen content in the exhaust stream and sends a signal to the onboard computers to make fuel delivery and timing adjustments. The next device downstream, in the exhaust system is the catalytic converter. Surface temperatures range between 316°C to 538°C (600°F to 1000°F) under normal operations, depending on the engine design. However, temperatures may exceed 538°C (1000°F) due to high engine loads or during abnormal engine conditions (i.e., misfires), or rich fuel concentrations due to other sensor malfunctions.

25.5.2.5 A potential danger in a normally operating motor vehicle is contact with combustible items, such as tall grass or debris, with exhaust and catalytic converter surfaces. A malfunction in the engine can cause the catalytic converter to run hot enough to ignite undercoating and interior carpeting.

Source – NFPA 921, chapter 25, 2008.

Vehicle electrical system examination

What to check	Reason
Fuses and fusible links	Examine all fuses and fusible links. Modern vehicles are well protected from electrical short circuits and current overloads. Examine all wiring. Most electrical wiring in a vehicle is small-gauge, copper strand conductor and several circuits will run through a wiring harness. It may be difficult to trace the circuit to its origin, as circuits may sever and fall to the ground. Look for evidence of direct short circuits. Check for evidence of any tampering or attempt to bypass electrical circuits.
Battery	The battery may drain rapidly when a short circuit occurs. Batteries that remain fully charged probably were not involved in a short circuit malfunction. Always be cautious when working with or around the battery. Practical testing shows that damaged batteries can provide full voltage in excess of 20 minutes post-fire. Make sure the battery has been disconnected prior to any examination but not before consideration is given to onboard computers and safety features that require being energised. Battery acid is extremely corrosive and can burn skin or clothing.

Accidental vehicle fires

Vehicles may be destroyed by fires of various causes including:

- Chaffed or degraded wiring
- Leaking flammable liquids in contact with some ignition source
- Overheating or faulty mechanical equipment.

Accidental vehicle fires can cause vehicle destruction. However, most accidental vehicle fires cause limited or localised damage and most total-loss vehicle fires are thought to be of incendiary origin.

Motives and vehicle arson

Motives for incendiary vehicle fires are usually the same as those for incendiary structure fires.

Often, mechanical problems are a reason for an owner to burn their car. The following is a list of common excuses:	• Major repair work is required on the vehicle and the owner cannot afford it. • The vehicle is a 'lemon' and the owner can get no satisfaction from the dealer or manufacturer. • The vehicle is worn out and the insurance value is greater than the sale or trade value.

Gathering witness information

Finally, to assist you in determining origin and cause, information must be gathered from the owner / witness to ensure the investigator's findings are accurate. Therefore, the following information will be required from the owner / witness if available:

- When the car had last been used
- Where it had been parked
- Whether the vehicle was secure
- Whether the keys or any valuables had been left inside
- Whether there was any recent mechanical faults or repairs prior to the fire
- What damage was on the vehicle prior to the fire
- Insurance details
- License details
- Vehicle lease plan details.

External agencies

There are external agencies that will investigate aircraft fires, such as the Civil Aviation Authority. MSA authority may investigate boats and ships holding commercial passenger licences.

The New Zealand Defence Force will generally carry out an investigation on their mobile property.

Boats and caravan fires

Boats and caravan fires may have additional issues including:

- cooking fires (LPG plus cylinder)
- engine fires
- diesel / petrol.

Because of their light construction, a fire will spread throughout extremely fast.

Other motor types

Other motor types, such as methanol or hybrid (petrol electric) have their own specific issues. Expert advice should be sought when dealing with fires in these types of vehicles.

Later versions of following guides can be found at:

- Honda Civic Hybrid Emergency Response Guide

  http://villagehonda.com/docs/enHybridEmergency.pdf

- TOYOTA Prius Emergency Guide

  http://techinfo.toyota.com/public/main/2ndprius.pdf

Mobile Property Investigation Report

See also Section 4.2

To assist the fire investigator, the Mobile Property Fire Investigation Report should be completed (found on Firenet).

This report can be forwarded to the Police with the SMS report and photographs attached.

Case studies

Introduction

The following investigations were undertaken and are presented as an example to the process and procedures of detecting cause and origin in vehicle fires.

Both fires were straightforward accidental fires, but unusual in themselves. These examples may assist you with investigation of motor vehicle fire causes in the future.

Case study 1

This fire involved the interior of a passenger van, causing severe damage to the interior. The owner was alerted to the fire in the van and approached the vehicle to find the interior well alight. The fire brigade was alerted, attended and extinguished the fire.

The van had a battery hosing located within a well behind the driver's seat. A metal cover, which was secured with wing nuts to the body and tensioned under a metal handle, covered the battery-well. The 12-volt battery was negative to earth.

Initial cause determination	After a short inspection, it was determined that the fire had originated in the vicinity of the battery-well and at the rear of the driver's seat. The battery terminals were found to be towards the front of the vehicle, with the connections stretched over the battery.
Observations	The metal battery cover was heat damaged with carpet padding and rubber mat melted onto the top. Close inspection revealed a 'hot spot' showing on the battery cover, which coincided with the location of the positive terminal location within the well. Research was carried out through the manufacturer and it was found that the battery was located back to front within the well and that the incorrect battery was fitted to the vehicle (in terms of dimensions).

<table>
<tr><td>Observations cont.</td><td>
Figure 10.1 The hot spot and metal handle

1. The ‘hot spot’ on the battery cover
2. The metal handle where the cover was earthed onto the body.</td></tr>
<tr><td>Final cause determination</td><td>The final determination was that the wrong battery had been placed into the well incorrectly. When the cover was fitted and secured, the positive terminal of the battery touched the metal cover causing the electrical power to short circuit onto the metal cover.

At the point where the cover was tensioned onto the body, the cover earthed onto the body allowing a flow of electrical power. This flow caused heating of the metal cover that eventually caused ignition of the carpet padding, carpet and rubber floor mats, which spread to the seats and interior upholstery.</td></tr>
</table>

Case study 2

This fire involved a sedan within a carport. Severe damage was caused to the interior of the sedan and damage to the roof covering of the carport. The owner was alerted to a fire beneath the vehicle and on investigation, found a small fire near the exhaust pipe.

At the same time, smoke was observed inside the vehicle. When the doors were opened, the interior of the vehicle caught alight and by the time the Brigade was alerted and arrived, both the vehicle and carport were involved. Fire Safety was requested as the Station Officer could find no evidence of a fire beneath the vehicle and required a more detailed investigation of the cause.

Observation	• On closer inspection of the vehicle it was found that: • An area above the catalytic converter within the exhaust system was severely heat damaged. • The remainder of the underside of the vehicle was clean and clear of any fire damage. • PVC coated wiring, rubber seals and other combustible items within three hundred millimetres of the area were not affected by the heat. • Directly above the area within the passenger compartment, the carpet on the floor was completely destroyed with fire damage spreading outward from that point. • Very close to this point, a rubber boot had covered the base of the handbrake where a hole in the transmission tunnel allowed the brake cable to rise from below. The interior of the vehicle suffered severe fire damage to all fittings and contents.
Cause determination	After careful consider of the facts, it was determined that the catalytic converter developed sufficient heat to ignite the carpet in the area directly above the converter and the fire spread through the combustible contents of the vehicle. Possibly the vehicle was poorly tuned and fulfilled the criteria noted in NFPA 921 for heating of the exhaust component (see earlier discussion of catalytic converter).

2. Wildfire Investigation

Cause and origin of wildfires

Introduction

This is a guideline for officers and firefighters in determining the cause and origin of wildfires. It will assist front-line firefighters who are involved in investigation and research.

It's the responsibility of fire management agencies to reduce the incidence of deliberately and carelessly lit fires. To do this, we must investigate each fire incident with a view to:

- Identify the point of origin of a bushfire, considering a range of indicators
- Follow procedures for examining the fire scene
- Identify the factors that affect bushfire behaviour
- Use a variety of indicators to determine the direction of fire travel
- Identify the cause of a bushfire using available fire patterns and fire spread indicators
- Identify the prevention issue.

Examining the fire scene

When examining a fire scene to determine the origin of a fire, the search must be thorough and methodical.

1. Always follow the majority of indicators when determining the direction of fire travel.

   Some of the vegetation or other materials within the burnt area may display indicators that are inconsistent with others. This may be attributable to a range of factors including:

   - A reduction or increase in wind strength
   - A change in wind direction
   - The presence or absence of particular fuels
   - Barriers that slow the progress of the fire or change its direction.

   It is essential to look at as many indicators as possible and base your assessment on the weight of evidence available.

2. The process of determining the point of origin of a fire is one of constantly and systematically reducing the area of origin.

3. Confusing indicators may indicate early stages of the fire. The immediate area around the point of origin will exhibit conflicting burn indicators. This is because the fire is small at its point of origin, and the ambient wind may be less effective in initial fire spread.

   Likewise, burning temperatures will vary slightly as the initial fire is building up to its regular burning temperatures. Until the wind affects the burning base, the fire may burn erratically, leaving a conflicting trail of burn indicators.

Witness information

Canvas potential witnesses

It is essential that the Investigator canvas members of the First Attack Crew and any other potential witnesses as soon as possible after the event to obtain any information which may be connected to the cause of the fire.

Who do you canvas?

If relevant to the locality you should canvas:

- Firefighters at the scene
- Neighbours in the vicinity of the fire or on the access routes to the fire
- Rural Fire Officers, Conservation, forest and farm workers, road gangs, etc.
- Anglers, hunters, bushwalkers, picnickers, children, etc.

Your purpose in these brief interviews is to identify any witnesses who may have ‘first hand’ knowledge of events and circumstances that could help with an investigation.

Introduce yourself

When approaching people to canvass them about a fire, introduce yourself and your purpose.

E.g. I’m ………… from the New Zealand Fire Service, I’m here to talk to you about the fire at………… on …………

What you are looking for

You are looking for people with knowledge of:

- the time and / or place of ignition
- persons and / or vehicles present at or about the time of ignition
- fire behaviour – particularly during the initial stages.

What you need to note

When looking for information you need to note:

- unusual events or circumstances – these are likely to be noticed in rural and forest areas – check all possibilities
- what people did **NOT** see or hear – a lack of such observations may assist in eliminating suspects or circumstances that are critical to the investigation
- that some witnesses may be at the scene during the investigation at the fire, others may have to be sought at a later date.

Open questions

When asking questions try to use open questions rather than closed ones.

Open questions usually begin with words like:

- How
- Why
- Where
- What
- When
- Who

These require fuller answers without restricting answers to yes/no. They are useful for collecting detailed information, e.g. "What else did you notice?"

Closed questions

Closed questions are useful for clarifying detail that require 'yes' or 'no' answers, e.g. Do you have a permit to light this fire?

Statements

If required, statements from relevant witnesses can be obtained at some later stage by Police Officers or Specialist Fire Investigators (i.e. those best trained and equipped to obtain statements from witnesses).

- A statement must be recorded in a witness's own words

Your role requires you to canvass witnesses to gain information to assist with the investigations.

- The investigator must not influence them with their own view or opinion of what may have occurred
- The investigator must only ask questions that establish the chronology of events and clarify their observations.

Point of origin

When examining the scene, there are often confusing indicators that make the determination of the point of origin difficult.

Indicator	Description
Size	The nearer you are to the area of origin, the smaller the indicators. This is because the indicators are burned away.
Factors affecting the direction of fire spread	• The fire dying down in intensity • Intense radiant heat from slow burning heavy fuels • The fire being partially stopped at barriers, rocky outcrops, etc. • The fire being split around a barrier then rejoining • The fire running back over the burnt area as a result of changed weather patterns and/or erratic convection and fire winds.
Multiple points of origin	Areas within the fire scene that display indicators of increasing fire intensity may contain more than one point of origin, for example: • Bushfires in forest areas are prone to spotting, causing new fires which may ultimately be consumed by the main fire • A wildfire which has been deliberately lit or caused by a passing vehicle may have more than one ignition point • A wildfire which has not been completely extinguished may re-light.

<table>
<tr>
<td>Initial stages of a fire</td>
<td>Fires start small. On level ground in the absence of wind, a fire will spread away from the point of origin in all directions.

In this situation, the fire will be slow burning and, in the initial period, temperatures lower. As a result, there will be less complete combustion of the fuels available. Indicators as to direction of spread in this situation are not readily apparent. This is the ‘zone of confusion’, which is an indicator of the origin of the fire.

As a fire extends its perimeter, the rate, intensity and direction of its spread is influenced by:

• the composition and quantity of the fuels available
• the direction and strength of the wind
• the direction and slope of the terrain.

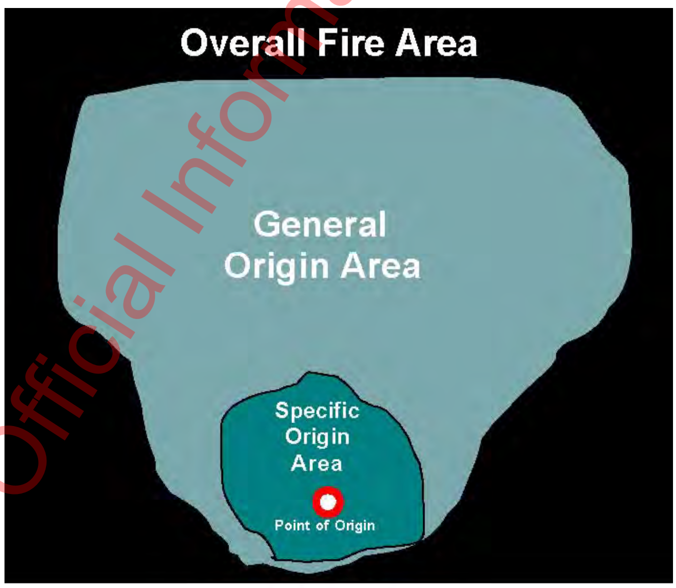


Figure 10.2 Overall Fire Area</td>
</tr>
</table>

Factors

<table>
<tr><th>Specific factors</th><th>Indicators</th></tr>
<tr><td>Weather</td><td>Wildfire behaviour is affected by four key weather factors:
• Air temperature
• Relative humidity
• Wind speed and direction
• Atmospheric stability.
•

Each of these factors must be taken into account when determining the direction of fire spread.

Air temperature
Air temperature will influence the temperature of the fuel elements in an area. The higher the temperature of fuel, the more easily it will be preheated by an existing fire to its ignition temperature. The higher the temperature of the fuel, the drier it will be.

Relative humidity
Relative humidity affects the dryness of dead fine fuels. At low humidity, fine fuels will ignite and burn more readily. As relative humidity changes, so fuel moisture will change, after a lag time of two hours or more.

Wind speed and direction
Wind will influence a wildfire's:
• direction of spread
• rate of spread
• intensity
• likelihood of spotting.
It does this by increasing oxygen supply to fire (increasing intensity) and bending flames towards new fuels (increasing pre-heating).

Figure 10.3 Influencing wind speed and direction</td></tr>
</table>

Fuel factors	The nature, quantity and arrangement of the vegetation will determine the intensity and rate of spread of a wild fire. Each vegetation type will respond to fire in a certain way and it is essential to consider each of the following when determining the direction of fire spread: *Fuel type* The species of plant determines the amount of fuel it produces, its ignitability, heat release and rate of burning. *Fuel load* The initial development of a wildfire depends largely upon the availability of 'fine fuel'. Fine fuel includes leaves, bark, grasses, shrubs and twigs (less than 6mm in diameter) and is measured in tonnes per hectare. Coarse fuel (heavy / solid fuel) such as branches and logs are not normally involved in the early stages of a fire but may become progressively involved as the fire develops in magnitude. *Fuel moisture* Fine fuel has a small cross-sectional area and responds quickly to hot drying weather, readily losing most of its moisture and therefore becoming combustible in the event of fire. Conversely, coarse fuel does not lose moisture and is therefore not as readily combustible. *Fuel continuity* Without available fuel products, wildfires may not reach their potential maximum intensity. Fuel reduced areas including creeks, rock ledges, and areas of bare or wet ground all contribute to a reduction in the intensity of a wildfire. *Fuel compaction* Where the fuel has become densely packed, it is more difficult to ignite and burns less rapidly. However, where the fuel is elevated and more aerated, it will ignite more rapidly and burn easily.
Topographic factors	*Slope* Slopes have an impact on the speed and intensity of a fire. The forward rate of spread of fire on level ground almost doubles for each 10° increase in upslope, up to 30°. For slopes steeper than 30°, the forward rate of spread increases exponentially. This is because more of the ground fuel is brought closer to the radiant heat from the flame front thereby decreasing the ignition time and increasing the intensity of the fire front. Burn patterns in the area should clearly indicate whether a fire travelled up or down the slope.

	Rough terrain The rougher the terrain and land surface, the more disturbed and erratic the wind will be when it blows across this surface. As wind passes over any sharp object such as a ridge or even the edge of a tall forest, it will tend to tumble or eddy – creating a zone of turbulence. Burn patterns on the vegetation in these areas are likely to be inconsistent. *Mountain, valleys and gullies* Wind will tend to be channelled and strengthened in mountain valleys. Burn patterns in these localities may indicate fire spread in an inconsistent pattern under the influence of turbulent winds.
The running edge of the fire	The running edge (front) of a fire is where it travels the fastest. In a running fire, the flames tend to lean towards the direction of fire travel and as a result the fuels ahead of the fire are preheated. This means there is more complete combustion. *Surfaces exposed to flames* Flames and radiant heat are blocked or deflected by any solid object. A blocking object intensifies the heat energy on the exposed surface and diverts the heat energy around the object. Surfaces exposed to flames are subjected to intense heat build-up with rapid cooling after the passage of fire. • In finer fuels, combustion will be more complete resulting in whiter ash. • On heavy fuels, the char will be deeper on the surface exposed to the oncoming flames. • On non-combustible objects, the extent and discolouration from the vaporised fuels and heated minute particles will be greater on the surface that is exposed to the oncoming fire. *Surfaces protected from exposure to flames* Surfaces protected from exposure to oncoming flames will receive lower more even temperatures for a longer period. • In fine fuels, burning may not be as complete and will leave a grey or black ash. • In heavy fuels, the depth of charring will be less than exposed fuels on the surface protected from the exposure of the flames. • On non-combustible objects, the extent of staining and discolouration from the vaporised fuels and heated minute particles will be less on the surface that is protected from exposure to the flames.

The backing edge of the fire	The backing edge (heel) of fire is where it travels the slowest. in a backing fire, the flames tend to stand more vertically or lean away from the direction of fire travel. As a result, there is less preheating of the fuel ahead of the fire and therefore less complete combustion. *Surfaces exposed to a backing fire* Surfaces exposed to a backing fire will receive lower, more even temperatures for a slightly longer period. • In fine fuels, burning may not be as complete and will therefore leave a grey or black ash. Some fuels, particularly living fuels and those with high moisture content, will remain intact with some charring or staining on most surfaces. • On heavy fuels, the depth of char will be less than in a running fire and may appear to be more evenly burnt on all surfaces. • On non-combustible objects, staining and discolouration from vaporised fuels and heated minute particles will tend to be evenly distributed on all surfaces. When compared to surfaces exposed to a running fire, the extent of staining will be distinctly less in a backing fire.

Indicators

There are various indicators that can help you determine the point of origin including: grass burn, scrub burn, tree burn, fences, posts and poles, rocks and other non-combustibles.

Pasture Grass

Running Fire	**Backing Fire**
There will be more complete combustion of pasture grass stems.	There will be less complete combustion and unburned grass stems and heads may fall towards the point of origin. • Many such stems must be identified before this indicator can be conclusive. • Most native grasses and grazed, curing, or green grasses are not reliable as an indicator • Fallen grass stems and heads will be disturbed in areas which have been subjected to strong winds or aggressive use of water by firefighters.

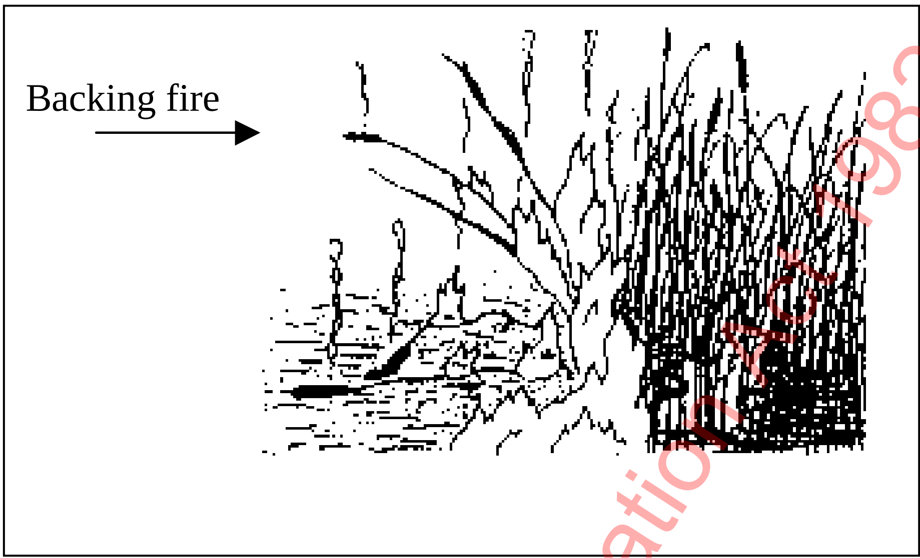
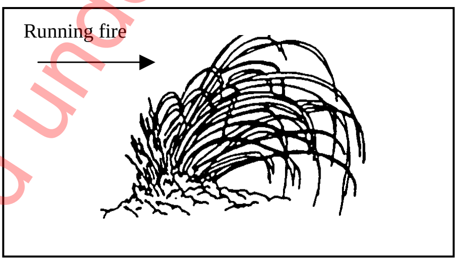
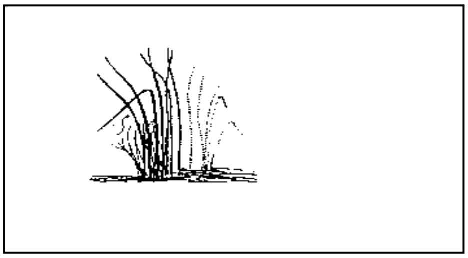


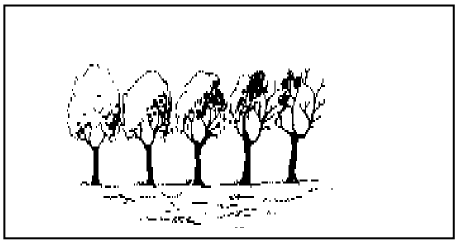
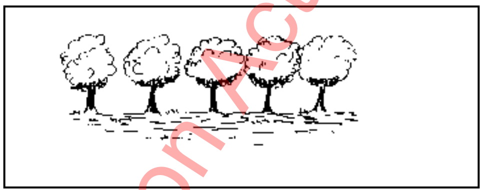
Figure 10.4 Pasture grass – backing

Grass Stems

Running Fire	Backing Fire
The butts or stubs of burnt grass stems will be uneven. On the side nearest the point of origin, the burnt butt or stub will be lower than on the side away from the point of origin, which is often evident on the clumps of many native tussock species. If this indicator is not readily visible, try rubbing the back of your hand against the butts. On the side towards the point of origin, the butt will have a smooth feeling. On the away side, it will feel rougher and more jagged.  Figure 10.5 Grass stems - running	There will be little or no distinction in the height of the ends of the burnt stems. A low burning fire with low heat will burn only that side of the vegetation facing the approaching fire. Often, fuels that are protected will not show any signs of being burned. A large area that burned slowly will look lighter due to ash deposits and more complete combustion when looking away from the point of origin, and darker when looking towards the origin.  Figure 10.6 Grass stems - backing

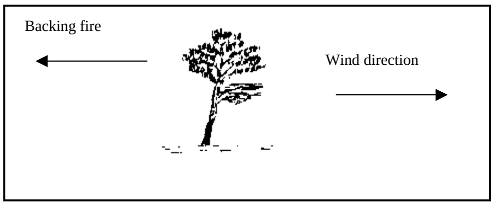
Scrub Scorch

At the origin, the fire is relatively cool and as a result, scrub crowns may be left intact.

Running Fire	Backing Fire
As the fire moves away from the origin, it becomes hotter, the flame becomes higher and as a result more crown is burnt.  **Figure 10.7 Scrub scorch - running** By stepping back from the scene, the upsweep of scorched and/or burnt scrub can become apparent.	The scorch on the foliage will be roughly parallel to the ground.  **Figure 10.8 Scrub scorch - backing**

Leaf Freeze

Leaves, needles and small stems tend to soften and wilt when they are heated.

Running Fire	Backing Fire
The preheating caused by the fire will rapidly extract the moisture from the leaves and stems – freezing them so that they point in the direction of fire spread.  **Figure 10.9 Leaf freeze - running**	There may be some freezing in the lower foliage – particularly if strong winds are present at the time of the fire.  **Figure 10.10 Leave freeze - backing**

White ash deposits

The burnt stub of branches on some scrub species may exhibit white ash deposits on the surface towards the origin.

Smooth bark trees

<table>
<tr><th>Running Fire</th><th>Backing Fire</th></tr>
<tr><td>The char line on the trunk of a smooth bark tree will be significantly lower on the surface towards the origin. In a running fire, the flames tend to lean towards the direction of fire travel. Lower air pressure on the downwind or uphill side of the trunk will cause the fire to curl around the trunk of the tree and burn upward.</td><td>Fires that have burnt down a slope or against the wind will leave a char line roughly parallel to the ground.

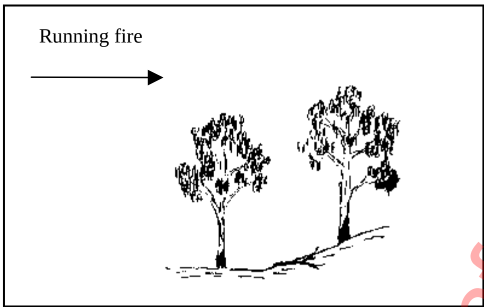
The flames of a fire travelling down a slope or against the wind will tend to be more vertical or be leaning away from the direction of travel.</td></tr>
<tr><td>

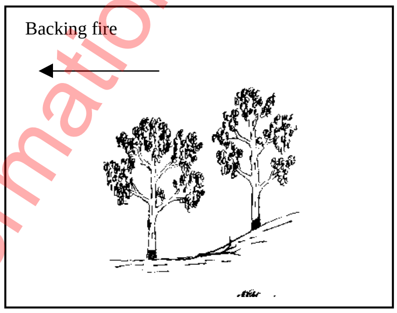
Figure 10.11 Smooth bark - running</td><td>

Figure 10.12 Smooth bark - backing</td></tr>
</table>

Staining

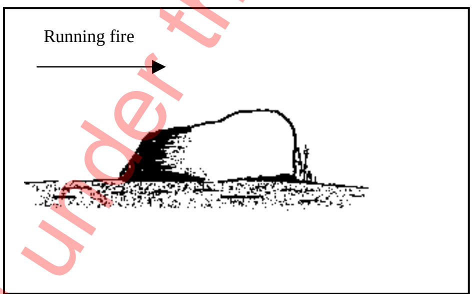
<table>
<tr><th>Running Fire</th><th>Backing Fire</th></tr>
<tr><td>There will be staining from vaporised fuels and minute particles on rocks, bottles, cans, cow pats and other non-combustible objects on the surface nearest the point of origin.


Figure 10.13 Staining</td><td>There will be less staining and little difference on any surface.</td></tr>
</table>

Protected Fuels

Fuel covered by, or adjacent to, rocks, fallen logs, cans, bottles, etc. will leave a distinct pattern.

Running Fire	Backing Fire
The fuel on the edge towards the point of origin will be burnt right up to the rock surface leaving a clean burnt line when the rock is removed. The edge away from the point of origin will be more ragged as a result of less complete consumption.	

Broom
"Cytisus scoparius"

Broom can assist the investigator in three ways:

- The lower branches, produced when the plant was young, are retained in much the same way as a pine tree. These branches will burn off almost completely on the side of the bush exposed to the most heat. On the protected side, they are retained at a much lower height and the finer branches remain.
- Sooting and charring are very evident on the smooth bark of broom, which does not burn as readily as gorse.
- Ash deposits are sometimes left on the side the fire approached.

Gorse
"Ulex europaeus"

The intensity with which gorse has burnt can be determined by close inspection of what is left behind. This allows the runs of the fire to be reconstructed if the fuels are all fairly similar. An intensity map sketched by the investigator using the following three categories is invaluable in this process:

Intensity	Description
Low intensity	• Flames less than 2 metres • Some spikes still evident on the trunks of the gorse plants and laterals still evident at the start of the crown of the plant • Laterals still exist at nodes along the upper branches • Many small spikes still evident on the branchlets in the crown
Medium intensity	• Flame height 2-4 metres • No spikes on the trunk of the plant • No laterals except in the very upper crown • Most branches burnt off
High intensity (running crown fire)	• Flame height 5 metres plus • Just stubs of branches left on trunk • Crown totally removed • What is left has a rounded appearance on the ends like a deer's antlers.

Char depth on tree trunks, fallen logs and branches

On fallen logs and branches, the depth of char will be deeper on the side towards the fire. The greater heat on the exposed surface and the resultant shrinkage of that surface causes this to happen.

The depth of char should be measured by using the blade of a knife or similar implement. In some instances, it may be appropriate to take sample sections from the tree or log to compare later in a laboratory or workshop.

Take care not to misinterpret charring resulting from previous fires. This indicator will also be apparent on fence posts or poles.

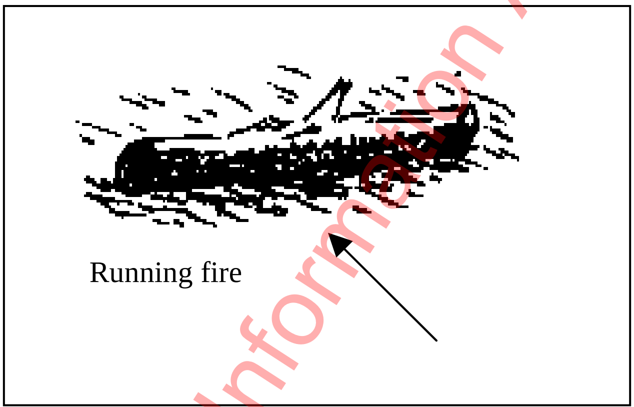
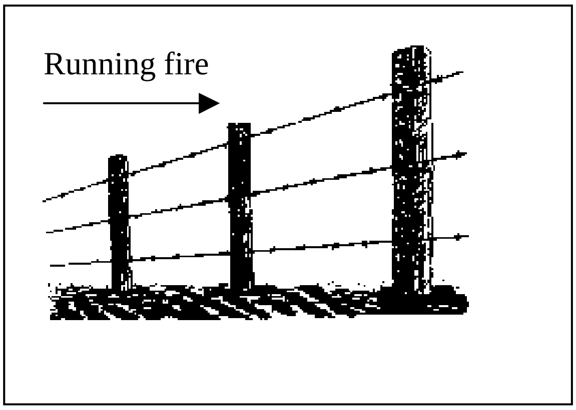
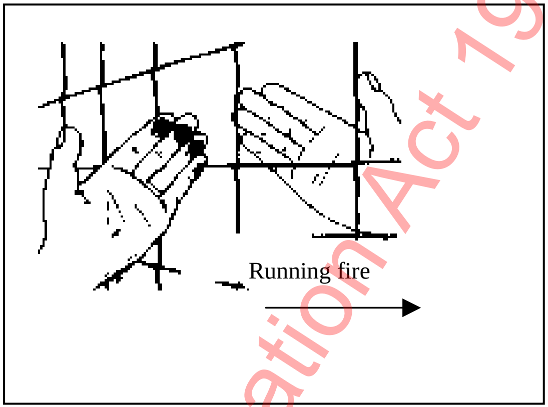


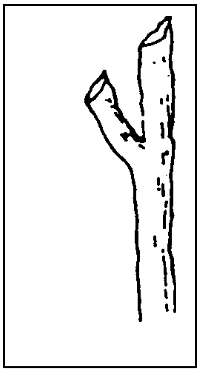
Figure 10.14 Depth of char

Fences

Part	Indicators
Char scales	Large shiny char scales indicate a hot fast fire. Small dust char scales indicate a cool slow fire.
Char depth	Deeper chars on posts and poles will be on the side towards the point of origin.  **Figure 10.15 Char depth**

Soot deposits	Soot will be deposited on the surface of the wire towards the point of origin. To check this indicator, run the wire between your forefinger and thumb. Soot staining will also occur on rocks and other non-combustibles.  **Figure 10.16 Soot deposit**
Previous charring	Take care not to misinterpret charring resulting from previous fires.

Twigs and stems

Part	Indicators
Cupping on twigs and stem	The burnt ends of twigs and stems on light fuels will leave similar features as those on grass stems.  **Figure 10.17 Cupping**

Cause determination

Origin and cause is very important in bushfire investigations. They will ensure that the community is aware of the signs that may precede a major destructive fire in areas that are prone to this type of incident and the ramifications of such a fire. It is up to you, the investigator, to locate the original ignition point, and also determine, if possible, the cause of the fire so that authorities can control and minimise this ignition source in the future.

Fire as a result of ...	Description
Exhaust fires from trains and/or vehicles	These fires are usually: • Downwind of road or railway track • Numerous • Within 6 metres of road or track • Started in an area where engine is idling or slowing down • Found with carbon fragments present at point(s) of origin.
Brake shoe fires	These fires are: • Usually on downhill grades or ahead of sharp turns • Often fires on both sides of road or track • Usually within 2 metres of edge or road.
Chainsaws and other non-stationary engines	• Evidence that equipment is still warm denoting recent usage • Evidence of faulty exhaust system or spark arrestor • Carbon fragments present at origin • Fresh sawdust is found in the vicinity.
Fuel spill fires from chainsaws and other engines	• A small amount of fuel at the point of origin • A full fuel tank • A hot exhaust • Evidence of fuel wash or spill on cowling under front of car • Tyre mark evidence in soft ground materials.
Generators, pumps and other stationary engines	• Evidence of equipment being used in area • Exhaust discharge into open air • Faulty exhaust, spark arrestor • Carbon fragments present at point of origin.
Welding, grinding, soldering and gas cutting	• Evidence of equipment being used in the area • Fragments or broken pieces of metal or slag in the vicinity • Welding rod or rod ends • Grinding sparks, which can be picked up by a magnet.

Escapes from campfires	It is very common for unattended campfires to escape and cause wildfires. • Evidence of camping activity • Evidence of campfire • Size and nature of fuels used will provide clues as to intensity of campfire • Evidence of spotting and/or fire spread from campfire will be apparent • Trees may continue to burn or smoulder and may cause ignition some time later in the surrounding fuels. Roots of trees may continue to burn or smoulder and cause ignition some time later in the surrounding fuels.
Lightning	During the summer months on humid and dry days, lightning can be the cause of igniting fires whilst thunderstorm activities are taking place. • Recent electrical storm activity • Improbability of human cause because of remoteness • Strike marks can occur on bark or trees or poles, or cause splinters in logs, stumps and roots • Charred splinters and/or bark may cause ignition in surrounding fuels • Trees may continue to burn or smoulder and may cause ignition some time later in the surrounding fuels • Roots of trees may continue to burn or smoulder and cause ignition some time later in the surrounding fuels • Earth may be disturbed, rocks shattered.
Escape from burning operations	This includes escapes from burning of domestic trash on the urban interface as well as stubble and weed. • Evidence of stubble, grass, heap or windrow burning • Nature and size of fuels burnt will provide clues as to intensity of fire • Evidence of spotting and/or fire spread will be apparent • Trees may continue to burn or smoulder and may cause ignition some time later in the surrounding fuels • Roots of trees may continue to burn or smoulder and cause ignition some time later in the surrounding fuels.
Discarded cigarettes	Although the likelihood of a discarded cigarette causing a wildfire is extremely remote, there is a chance of ignition if combined with the following factors: • Fuel must be very dry • Air relative humidity must be less than 25% • May be other evidence of human activity • Punky or dense fuel bed or very compacted fine fuel • Usually at least 30% of the length of the cigarette is required to be in contact with the fuel.

Power lines and/or electric fences	This may be the cause of the fire if the fire origin is on a fence line or immediately adjacent to a power line • Moist vegetation in contact with a fence or line which causes an arc close to very dry, fluffy or downy material which facilitates ignition • Broken insulators • Electrocuted birds or animals • Parts of transformer/fuse are present • Automobile accident into a power pole nearby.
Spontaneous ignition / un-piloted ignition	This may occur when hay is stacked while still wet or in circumstances where damp sawdust is left in large piles. • Heat is generated by the chemical decomposition of the materials • Moisture and heat will be present, but no oxygen • Black carbonised substance resembling charcoal will be left as residue • Burn patterns will indicate the fire started on the inside of the stack or pile rather than from the outside.
Incendiary (deliberate) fires	The following may be indicators of an incendiary fire: • A device may be found nearby • Evidence of human activity in the area • The method of ignition may not be apparent (no other ignition factor in the area) • Motive and opportunity.

Other possible causes

The chance of ignition from any of the following sources is extremely remote. However, it is important to explore each of these possibilities when examining the fire scene to determine cause.

Indicator	Description
Glass/lenses	The presence of glass or a partly water filled clear glass container may be responsible for the ignition of a fire by focusing light (heat) on light fuels.
Bullets/firearms	Steel core bullets can cause a fire from sparks or friction created at the point of contact - particularly on long unburnt stringy barked trees. Incendiary bullets usually contain either phosphorous or explosive compound in the head of the bullet that will explode and ignite on impact.
Fireworks	Residues from firecrackers are difficult to detect. Burned and unburned pieces of shredded paper may be scattered some distance from the point of explosion.

Indicator categories

Indicators are based on the appearance of a combustible or non-combustible object after its interaction with flame or heat. They are classified into approximately 14 categories. Each of these indicator categories can exhibit a different appearance, based on its directional value.

Category	NFPA (2008)
Protection	26.4.6.1
Grass Stem	26.4.3
Foliage freeze	26.4.5.2
Damage, degrees of	26.4.2
Depth of char	26.4.6.3
Angle of char	26.4.5.1 and 23.4.5.2
Spalling	26.4.6, 4.6 and 4.6.1
Curling	26.4.6.3
Sooting	26.4.6.2 and 23.4.6
Staining	26.4.6.2 and 23.4.6
Ash deposits	26.4.4.1
Cupping	26.4.4.2
V-patterns	26.4.1
Die-out patterns	26.4.4.3

Conduct external examination

The purpose of an external examination is to establish the following:

- The general direction of fire travel
- The boundaries of the fire
- The variations in the intensity of the fire and the general rate of spread
- The proximity of roads, tracks or any other features in the area
- Which roads or tracks, if any, were used by the person(s) responsible
- The general area of origin
- Whether there is any evidence within or adjacent to the fire scene that may be associated with the cause and/or the person(s) responsible
- Where an internal examination should commence.

Examine perimeter & access routes

Wherever possible, the fire area should be viewed from a vantage point or the air.

The perimeter of the fire, or at least that portion around the area of origin, including the access routes, should be thoroughly examined for:

- Prints from vehicles or feet
- Discarded materials
- Fires which did not develop.

Record observations

Notes and photographs should be taken and sketches made that detail the location of the fire, its perimeter and any relevant features or reference points.

Items or objects, which may be related to the cause of the fire or the person(s) responsible, should be identified, their position recorded in note form and on a sketch and in photographs.

Burn and char patterns, which indicate the location and direction of the path of the running edge, the flanks and the backing edge of the fire, should be identified. This will assist in determining where an internal examination should commence.

Depending on the nature of the initial stages of the fire, the size of the general area of origin may vary from one or two square metres up to twenty or thirty square metres.

Identify specific area of origin

The objective at this stage of the examination is to reduce the size of the area of origin.

The initial examination of the area of origin must be conducted in such a way so there is as little disturbance to the site as possible.

Measure relevant distances

The distances between features, such as the fire edge, roads, tracks, fences or particular items of interest should be measured and recorded in note form and on a sketch.

Conduct internal examination

The purpose of an internal examination is to determine the following:

- The point of origin
- The direction of fire spread
- The path of the fire and any features or circumstances that contributed to, or hindered, its spread
- Any items of interest that were destroyed or damaged by the fire
- The cause of the fire.

Police must be alerted when it is apparent the fire was lit with criminal intent or when life or property is damaged or destroyed.

Knowledge of the principles of fire spread and the ability to 'read' burn and char patterns in vegetation is essential

Identify running edge of fire

Burn and char patterns in the running section of a fire will exhibit more complete combustion and can be readily distinguished from those in a flanking or backing fire.

A starting point should be selected where the running section has been positively identified. From this point, the run of the fire can be followed back towards the general area of origin

Identify backing edge of fire

Once the burn and char patterns exhibit any changes, which suggest the fire was less intense, had altered direction, or had burnt back into the prevailing wind or slope, closer examination is necessary. These changes may indicate the backing or flanking edge of the fire.

Identify general area of origin

The area where changes in burn and char patterns occur is likely to contain the point of origin and evidence of the cause of the fire.

Extreme caution must be exercised once the changes in burn and char patterns become evident. There are often no second chances when examining a fire scene. Moving over an area may destroy evidence that was not first seen.

Protect general area of origin

To protect the general area of origin:

- Use a rope or barrier tape to cordon off the general area of origin.
- If necessary, place an officer at the site to prevent or direct entry into the area.

3. Explosions

Introduction

Historically, the term explosion has been difficult to define precisely. The generation and violent escape of gasses are the primary criteria of an explosion. For fire and explosion investigations, an explosion is the sudden conversion of potential energy (chemical or mechanical) into kinetic energy with the production and release of gas(es) under pressure. These high-pressure gasses then do mechanical work, such as moving, changing, or shattering nearby materials.

Effect of explosion

The evidence that indicates an explosion occurred includes damage or change brought about by the restriction of the expanding blast pressure front, producing physical effects on containers or nearby surfaces.

This effect can result from the confinement of the blast pressure front or the impact of an unconfined pressure or shock wave on an object, such as a person or structure.

Although an explosion is almost always accompanied by the production of a loud noise, the noise itself is not an essential element in the definition of an explosion.

The ignition of a flammable vapour/air mixture within a can, which bursts the can or even only pops off the lid, is considered an explosion.

NFPA 921, Chapter 21 - Explosions

Extract

21.1 General.

21.1.1 Historically, the term explosion has been difficult to define precisely. The evidence that indicates an explosion occurred includes damage or change brought about by the restriction of the expanding blast pressure front as an integral element, producing physical effects on containers or nearby surfaces.

21.1.2 This effect can result from the confinement of the blast pressure front or the impact of an unconfined pressure or shock wave on an object, such as a person or structure.

21.1.3 For fire and explosion investigations, an explosion is the sudden conversion of potential energy (chemical or mechanical) into kinetic energy with the production and release of gas(es) under pressure. These high-pressure gases then do mechanical work, such as moving, changing, or shattering nearby materials.

21.1.4 Although an explosion is almost always accompanied by the production of a loud noise, the noise itself is not an essential element in the definition of an explosion. The generation and violent escape of gases are the primary criteria of an explosion.

21.1.5 The ignition of a flammable vapor/air mixture within a can, which bursts the can or even only pops off the lid, is considered an explosion. The ignition of the same mixture in an open field, while it is a deflagration, may not be an explosion as defined in this document, even though there may be the release of high-pressure gas, a localized increase in air pressure, and a distinct noise. The failure and bursting of a tank or vessel from hydrostatic pressure of a noncompressible fluid such as water is not an explosion, because the pressure is not created by gas. Explosions are gas dynamic.

21.1.6 In applying this chapter, the investigator should keep in mind that there are numerous factors that control the effects of explosions and the nature of the damage produced. These factors include the type, quantity, and configuration of the fuel; the size and shape of the containment vessel or structure; the type and strength of the materials of construction of the containment vessel or structure; and the type and amount of venting present. (See Section 21.5.)

21.1.7 Sections of this chapter present explosion analysis techniques and terms that have been developed primarily from the analysis of explosions involving diffuse fuel sources, such as combustible industrial and fuel gases, dusts, and the vapors from ignitable liquids in buildings of lightweight construction. The reader is cautioned that application of these principles to structures of other construction types may require additional research to other references on explosions. The analysis of explosions involving condensed-phase (solid or liquid) explosives, particularly detonating (high) explosives, may also require specialized knowledge that goes beyond the scope of this text.

21.2 Types of Explosions.
There are two major types of explosions with which investigators are routinely involved: mechanical and chemical, with several subtypes within these types. These types are differentiated by the source or mechanism by which the explosive pressures are produced.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.2.1 Mechanical Explosions. Mechanical explosions are explosions in which a high-pressure gas creates internal pressure within a confining container and produces a purely physical reaction. These reactions do not involve changes in the basic chemical nature of the substances in the container. A purely mechanical explosion is the rupture of a gas storage cylinder, a tank under high pressure, or a boiler, resulting in the release of the stored high-pressure gas or vapor, such as compressed air, carbon dioxide, oxygen, or steam.

21.2.2 BLEVEs. The boiling liquid expanding vapor explosion (BLEVE) is the type of mechanical explosion that will be encountered most frequently by the fire investigator. These are explosions involving vessels that contain liquids under pressure at temperatures above their atmospheric boiling points. The liquid need not be flammable. BLEVEs are a subtype of mechanical explosions but are so common that they are treated here as a separate explosion type. A BLEVE can occur in vessels as small as disposable lighters or aerosol cans and as large as tank cars or industrial storage tanks.

21.2.2.1 A BLEVE frequently occurs when the temperature of the liquid and vapor within a confining tank or vessel is raised by an exposure fire to the point where the increasing internal pressure can no longer be contained and the vessel explodes. *(See Figure 21.2.2.1.)* This rupture of the confining vessel releases the pressurized liquid and allows it to vaporize almost instantaneously. If the contents are ignitible, there is almost always a fire. If the contents are noncombustible, there can still be a BLEVE, but no ignition of the vapors. Ignition usually occurs either from the original external heat that caused the BLEVE or from some electrical or friction source created by the blast or shrapnel.

FIGURE 21.2.2.1 An LP-Gas Cylinder That Suffered a BLEVE as a Result of Exposure to an External Fire.

21.2.2.2 A BLEVE may also result from a reduction in the strength of a container as a result of mechanical damage or localized heating above the liquid level. This rupture of the confining vessel releases the pressurized liquid and allows it to vaporize almost instantaneously. A common example of a BLEVE not involving an ignitible liquid is the bursting of a steam boiler. The source of overpressure is the steam created by heating and vaporizing water. When the pressure of the steam can no longer be confined by the boiler, the vessel fails and an explosion results. No chemical, combustion, or nuclear reaction is necessary. The steam under pressure is the energy source. The chemical nature of the steam (H_2O) is not changed.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.2.2.3 BLEVEs may also result from mechanical damage, overfilling, runaway reaction, overheating vapor-space explosion, and mechanical failure. See Figure 21.2.2.3, which shows the extent of possible damage from a BLEVE.

Result of Heating Created by an Internal Chemical Reaction.

21.2.3 Chemical Explosions.
21.2.3.1 In chemical explosions, the generation of high-pressure gas is the result of exothermic reactions wherein the fundamental chemical nature of the fuel is changed. Chemical reactions of the type involved in an explosion usually propagate in a reaction front away from the point of initiation.

21.2.3.2 Chemical explosions can involve solid combustibles or explosive mixtures of fuel and oxidizer, but more common to the fire investigator will be the propagating reactions involving gases, vapors, or dusts mixed with air. Such combustion reactions are called propagation reactions because they occur progressively through the reactant (fuel), with a definable flame front separating the reacted and unreacted fuel.

21.2.4 Combustion Explosions. The most common of the chemical explosions are those caused by the burning of combustible hydrocarbon fuels. These are combustion explosions and are characterized by the presence of a fuel with air as an oxidizer. A combustion explosion may also involve dusts. In combustion explosions, the elevated pressures are created by the rapid burning of the fuel and rapid production of large volumes of combustion by-products and heated gases. Because these events are likely to be encountered by the fire investigator, combustion explosions are considered here as a separate explosion type.

21.2.4.1 Combustion reactions are classified as either deflagrations or detonations, depending on the velocity of the flame front propagation through the fuel. Deflagrations are combustion reactions in which the velocity of the reaction is less than the speed of sound in the unreacted fuel medium. Detonations are combustion reactions in which the velocity of the reaction is faster than the speed of sound in the unreacted fuel medium.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.2.4.2 Several subtypes of combustion explosions can be classified according to the types of fuels involved. The most common of these fuels are as follows:
(1) Flammable gases
(2) Vapors of ignitable (flammable and combustible) liquids
(3) Combustible dusts
(4) Smoke and flammable products of incomplete combustion (backdraft explosions)

21.2.5 Electrical Explosions. High-energy electrical arcs may generate sufficient heat to cause an explosion. The rapid heating of the surrounding gases results in a mechanical explosion that may or may not cause a fire. The clap of thunder accompanying a lightning bolt is an example of an electrical explosion effect. Electrical explosions require special expertise to investigate and are not covered in this document.

21.2.6 Nuclear Explosions. In nuclear explosions, the high pressure is created by the enormous quantities of heat produced by the fusion or fission of the nuclei of atoms. The investigation of nuclear explosions is not covered by this document.

21.3 Characterization of Explosion Damage.
For descriptive and investigative purposes, it can be helpful to characterize incidents, particularly in structures, on the basis of the type of damage noted. The terms high-order and low-order explosion have been used to characterize explosion damage. The terms high-yield and low-yield explosion have also been used. Use of the terms high-order and low-order damage is recommended to reduce confusion with similar terms used to describe the energy release from explosives. (See Section 21.12) The differences in damage are more a function of the rate of pressure rise and the strength of the confining or restricting structure than the maximum pressures being reached. It should be recognized that the use of the terms low-order damage and high-order damage may not always be appropriate, and a site may contain evidence spanning both categories.

21.3.1 Low-Order Damage. Low-order damage is characterized by walls bulged out or laid down, virtually intact, next to the structure. Roofs may be lifted slightly and returned to their approximate original position. Windows may be dislodged, sometimes without glass being broken. Debris produced is generally large and is thrown short distances. Low-order damage is produced by slow rates of pressure rise. (See Figure 21.3.1)

FIGURE 21.3.1 Low-Order Damage in a Dwelling.

Source – NFPA 921, Chapter 21, 2008.

Extract

High-Order Damage. High-order damage is characterized by shattering of the structure, producing small, pulverized debris. Walls, roofs, and structural members are splintered or shattered, with the building completely demolished. Debris is thrown great distances, possibly hundreds of feet. High-order damage is the result of rapid rates of pressure rise. *(See Figure 21.3.2.)*

FIGURE 21.3.2 High-Order Damage Shown by Shattered and Splintered Remains of a Four-Bedroom House.

21.4 Effects of Explosions.

An explosion is a gas dynamic phenomenon that, under ideal theoretical circumstances, will manifest itself as an expanding spherical heat and pressure wave front. The heat and pressure waves produce the damage characteristic of explosions. The effects of explosions can be observed in four major groups: blast pressure wave effect, shrapnel effect, thermal effect, and seismic effect.

21.4.1 Blast Pressure Front Effect.

21.4.1.1 General. The explosion of a material produces a large quantity of gases. These gases expand at a high speed and move outward from the point of origin. The gases and the displaced air moved by the gases produce a pressure front that is primarily responsible for the damage and injuries associated with explosions.

21.4.1.1.1 The blast pressure front occurs in two distinct phases, based on the direction of the forces in relation to the point of origin of the explosion. These are the *positive pressure phase* and the *negative pressure phase*.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.4.1.1.2 A typical pressure history from an idealized detonation, measured at a point away from the point of detonation, is shown in Figure 21.4.1.1.2 and consists of positive and negative phases. The area under the pressure–time curve is called the *impulse* of the explosion.

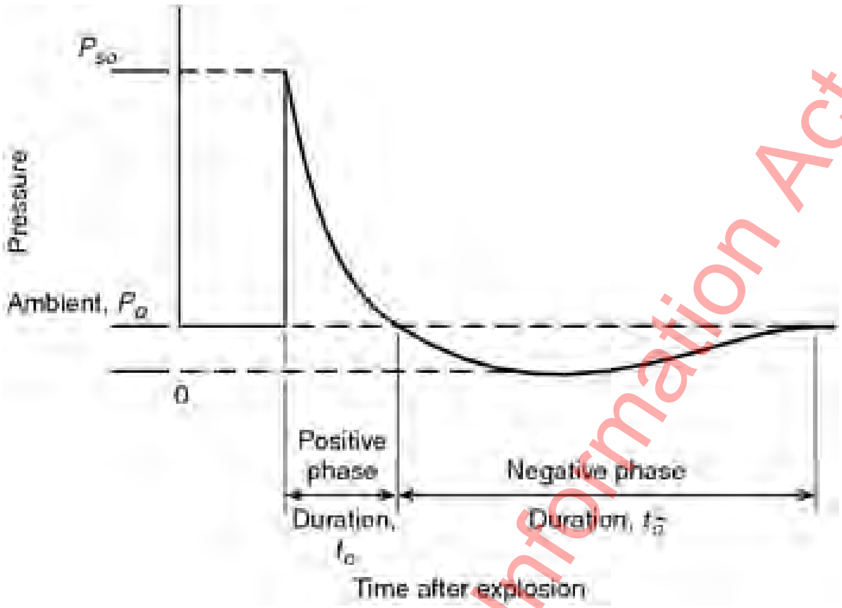


FIGURE 21.4.1.1.2 Typical Pressure History from an Idealized Detonation, Measured at a Point Away from the Point of Detonation

21.4.1.2 Positive Pressure Phase. The positive pressure phase is that portion of the blast pressure front in which the expanding gases are moving away from the point of origin. The positive pressure phase is more powerful than the negative pressure phase and is responsible for the majority of pressure damage. The negative pressure phase may be undetectable by witnesses or by postblast examination in diffuse-phase (gas/vapor) explosions.

21.4.1.3 Negative Pressure Phase.

21.4.1.3.1 As the extremely rapid expansion of the positive pressure phase of the explosion moves outward from the origin of the explosion, it displaces, compresses, and heats the ambient surrounding air. A low air pressure condition (relative to ambient) is created at the epicenter or origin. When the positive pressure phase dissipates, air rushes back to the area of origin to equilibrate the low air pressure condition, creating the negative pressure phase.

21.4.1.3.2 The negative pressure phase can cause secondary damage and move items of physical evidence toward the point of origin. Movement of debris during the negative pressure phase may conceal the point of origin. The negative pressure phase is usually of considerably less power than the positive pressure phase but may be of sufficient strength to cause collapse of structural features already weakened by the positive pressure phase.

21.4.1.4 Shape of Blast Front. Under ideal theoretical conditions, the shape of the blast front from an explosion would be spherical. It would expand evenly in all directions from the epicenter. In the real world, the confinement or obstruction of the blast pressure wave changes and modifies the direction, shape, and force of the front itself.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.4.1.4.1 Venting of the confining vessel or structure may cause damage outside of the vessel or structure. The most damage can be expected to be in the path of the venting. For example, the blast pressure front in a room may travel through a doorway and damage items or materials directly in line with the doorway in the adjacent room. The same relative effect may be seen directly in line with the structural seam of a tank or drum that fails before the sidewalls.

21.4.1.4.2 The blast pressure front may also be reflected off solid obstacles and redirected, resulting in a substantial increase or possible decrease in pressure, depending on the characteristics of the obstacle struck.

21.4.1.4.3 After propagating reactions have consumed their available fuel, the force of the expanding blast pressure front decreases with the increase in distance from the epicenter of the explosion.

21.4.1.5 Rate of Pressure Rise Versus Maximum Pressure. The type of damage caused by the blast pressure front of an explosion is dependent not only on the total amount of energy generated but also, and often to a larger degree, on the rate of energy release and the resulting rate of pressure rise.

21.4.1.5.1 Relatively slow rates of pressure rise will produce the pushing or bulging type of damage effects seen in low-order damage. The weaker parts of the confining structure, such as windows or structural seams, will rupture first, thereby venting the blast pressure wave and reducing the total damage effects of the explosion.

21.4.1.5.2 In explosions where the rate of pressure rise is very rapid, there will be more shattering of the confining vessel or container, and debris will be thrown great distances, as the venting effects are not allowed sufficient time to develop. This is characteristic of high-order damage.

21.4.1.5.3 Where the pressure rise is less rapid, the venting effect will have an important impact on the maximum pressure developed. See NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, for equations, data, and guidance on calculating the theoretical effect of venting on pressure during a deflagration. Such calculations assume a structure or vessel that can sustain such a high pressure. The maximum theoretical pressure that can be developed by a deflagration can, under some circumstances, be as high as 7 to 9 atmospheres [in the range of 827 kPa (120 psi)]. In commonly encountered situations, such as fugitive gas explosions in residential or commercial buildings, the maximum pressure will be limited to a level slightly higher than the pressure that major elements of the building enclosure (e.g., walls, roof, and large windows) can sustain without rupture. In a well-built residence, this pressure will seldom exceed 21 kPa (3 psi).

21.4.2 Shrapnel Effect.

21.4.2.1 When the containers, structures, or vessels that contain or restrict the blast pressure fronts are ruptured, they are often broken into pieces that may be thrown over great distances. These pieces of debris are called shrapnel or missiles. They can cause great damage and personal injury, often far from the source of the explosion. In addition, shrapnel can often sever electric utility lines, fuel gas or other flammable fuel lines, or storage containers, thereby adding to the size and intensity of post explosion fires or causing additional explosions.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.4.2.2 The distance to which missiles can be propelled outward from an explosion depends greatly on their initial direction. Other factors include their weight and aerodynamic characteristics. An idealized diagram for missile trajectories is shown in Figure 21.4.2.2 for several different initial directions. The actual distances that missiles can travel depend greatly on aerodynamic conditions and occurrences of ricochet impacts.

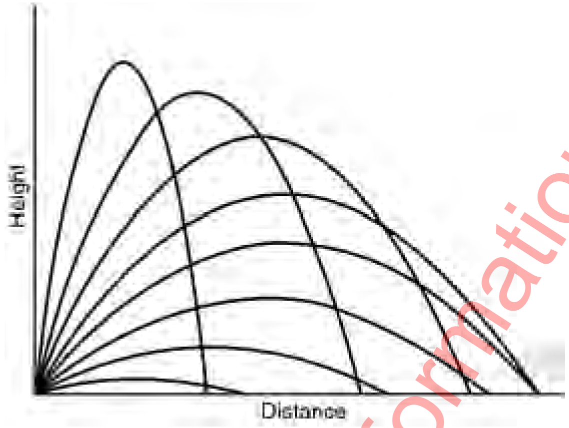


FIGURE 21.4.2.2 Idealized Missile Trajectories for Several Initial Flight Directions.

21.4.3 Thermal Effect. Combustion explosions release quantities of energy that heat combustion gases and ambient air to high temperatures. This energy can ignite nearby combustibles or can cause burn injuries to anyone nearby. These secondary fires increase the damage and injury from the explosion and complicate the investigation process. Often, it is difficult to determine which occurred first, the fire or the explosion.

21.4.3.1 All chemical explosions produce great quantities of heat. The thermal damage *(see effective temperature in 6.8.2.4)* depends on the nature of the explosive fuel as well as the duration of the high temperatures. Detonating explosions produce extremely high temperatures of very limited duration, whereas deflagration explosions produce lower temperatures, but for much longer periods.

21.4.3.2 Fireballs and firebrands are possible thermal effects of explosions, particularly BLEVEs involving flammable vapors. Fireballs are the momentary ball of flame present during or after the explosive event. High-intensity, short-duration thermal radiation may be present with a fireball. Firebrands are hot or burning fragments propelled from the explosion. All these effects may serve to initiate fires away from the center of the explosion.

21.4.4 Seismic Effect. As the blast pressure wave expands, and as the damaged portions of large structures are knocked to the ground, significant localized seismic or earth tremors can be transmitted through the ground. These seismic effects, usually negligible for small explosions, can produce additional damage to structures and underground utility services, pipelines, tanks, or cables.

Source – NFPA 921, Chapter 21, 2008.

Extract

221.5 Factors Controlling Explosion Effects.

Factors that can control the effects of explosions include the type and configuration of the fuel; nature, size, volume, and shape of any containment vessel or object affected; location and magnitude of ignition source; venting of the containment vessel; relative maximum pressure; and rate of pressure rise. The nature of these factors and their various combinations in any one explosion incident can produce a wide variety of physical effects with which the investigator will be confronted. Various phenomena affect the characteristics of a blast pressure front as it travels away from the source. These phenomena are described in 21.5.1 and 21.5.2.

21.5.1 Blast Pressure Front Modification by Reflection. As a blast pressure front encounters objects in its path, the blast pressure front may amplify due to its reflection. This reflection in some cases will cause the overpressure to increase and will sometimes amplify it as much as eight times at the surface of reflection, depending on the angle of incidence. This effect is negligible with deflagrations, where the pressure in an entire vessel equalizes at approximately the speed of sound in air (i.e., a strong shock wave is not present).

21.5.2 Blast Pressure Front Modification by Refraction and Blast Focusing. Atmospheric inhomogeneities can cause non-ideal blast pressure front behavior at times. When a blast pressure front encounters a layer of air at a significantly different temperature, it may cause it to bend, or refract. This occurs because the speed of sound is proportional to the square root of temperature in air. A low-level temperature inversion can cause an initially hemispherical blast front to refract and to focus on the ground around the center of the explosion. Severe weather-related wind shear can cause focusing in the downwind direction. This effect is negligible with deflagrations.

21.6 Seated Explosions.

21.6.1 General. The *seat* of an explosion is defined as the crater or area of greatest damage, located at the point of initiation (epicenter) of an explosion. Material may be thrown out of the crater. This material is called *ejecta* and may range from large rocks to fine dust. The presence of a seat indicates the explosion of a concentrated fuel source in contact with or in close proximity to the seat.

21.6.1.1 These seats can be of any size, depending on the size and strength of the explosive material involved. They typically range in size from a few centimeters (inches) to 7.6 m (25 ft) in diameter. They display an easily recognizable crater of pulverized soil, floors, or walls located at the center of otherwise less damaged areas. Seated explosions are generally characterized by high pressure and rapid rates of pressure rise.

21.6.1.2 Only specific types or configurations of explosive fuels can produce seated explosions. These include explosives, steam boilers, tightly confined fuel gases or liquid fuel vapors, and BLEVEs occurring in relatively small containers, such as cans or barrels.

21.6.1.3 In general, it is accepted that explosive velocities should exceed the speed of sound (detonations) to produce seated explosions, unless the damage is produced by shrapnel from a failing vessel.

21.6.2 Explosives. Explosions fueled by many explosives are most easily identified by their highly centralized epicenters, or seats. High explosives especially produce such high-velocity, positive pressure phases at detonation that they often shatter their immediate surroundings and produce craters or highly localized areas of great damage.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.6.3 Boiler and Pressure Vessels. A boiler explosion often creates a seated explosion because of its high energy, rapid rate of pressure release, and confined area of origin.

21.6.3.1 Boiler and pressure vessel explosions will exhibit effects similar to explosives, though with lesser localized overpressure near the source.

21.6.3.2 Each of these explosions involves a rapid release of energy from a containment vessel, resulting in a pressure wave that decays with distance.

21.6.4 Confined Fuel Gas and Liquid Vapor. Fuel gases or ignitible liquid vapors — when confined to such small vessels as tanks, barrels, or other containers — can also produce seated explosions.

21.6.5 BLEVE. A boiling liquid expanding vapor explosion will produce a seated explosion if the confining vessel (e.g., a barrel or small tank) is of a small size and if the rate of pressure release when the vessel fails is rapid enough.

21.7 Nonseated Explosions.

Nonseated explosions occur most often when the fuels are dispersed or diffused at the time of the explosion because the rates of pressure rise are moderate and because the explosive velocities are subsonic. It should be kept in mind that even supersonic detonations may produce nonseated explosions under certain conditions.

21.7.1 Fuel Gases. Fuel gases, such as natural gas and liquefied petroleum (LP) gases, most often produce nonseated explosions. This is because these gases often are confined in large containers, such as individual rooms or structures, and their explosive speeds are subsonic.

21.7.2 Pooled Flammable/Combustible Liquids. Explosions from the vapors of pooled flammable or combustible liquids are nonseated explosions. The large areas that they cover and their subsonic explosive speeds preclude the production of small, high-damage seats.

21.7.3 Dusts. Although dust explosions are often among the most violent and damaging of explosions, they most often occur in confined areas of relatively wide dispersal, such as grain elevators, materials-processing plants, and coal mines. These large areas of origin preclude the production of pronounced seats.

21.7.4 Backdraft or Smoke Explosion. Backdraft or smoke explosions almost always involve a widely diffused volume of combustible gases and particulate matter. Their explosive velocities are subsonic, thereby precluding the production of pronounced seats.

21.8 Gas/Vapor Explosions.

The most commonly encountered explosions are those involving gases or vapors, especially fuel gases or the vapors of ignitible liquids. Violent explosions can be encountered with lighter-than-air gases, such as natural gas, but are reported less frequently than with gases or vapors having vapor densities higher than 1.0 (heavier than air). Table 21.8 provides some useful properties of common flammable gases. NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, provides a more complete introduction to the fundamentals of these explosions.

Source – NFPA 921, Chapter 21, 2008.

Table 21.8 Combustion Properties of Common Flammable Gases

Extract

Gas	MJ/m^3 (gross)	Btu/ft^3 (gross)	Limits of Flammability Percent by Volume in Air		Specific Gravity (air = 1.0)	Air Needed to Burn 1 m^3 of Gas in m^3	Air Needed to Burn 1 ft^3 of Gas in ft^3	Ignition Temp	
			Lower	Upper				°C	°F
Natural gas									
High inert type[a]	35.7–39.2	958–1051	4.5	14.0	0.660–0.708	9.2	9.2	—	—
High methane type[b]	37.6–39.9	1008–1071	4.7	15.0	0.590–0.614	10.2	10.2	482–632	900–1170
High Btu type[c]	39.9–41.9	1071–1124	4.7	14.5	0.620–0.719	9.4	9.4	—	—
Blast furnace gas	3.0–4.1	81–111	33.2	71.3	1.04–1.00	0.8	0.8	—	—
Coke oven gas	21.4	575	4.4	34.0	0.38	4.7	4.7	—	—
Propane (commercial)	93.7	2516	2.15	9.6	1.52	24.0	24.0	493–604	920–1120
Butane (commercial)	122.9	3300	1.9	8.5	2.0	31.0	31.0	482–538	900–1000
Sewage gas	24.9	670	6.0	17.0	0.79	6.5	6.5	—	—
Acetylene	208.1	1499	2.5	81.0	0.91	11.9	11.9	305	581
Hydrogen	12.1	325	4.0	75.0	0.07	2.4	2.4	500	932

Anhydrous ammonia	14.4	386	16.0	25.0	0.60	8.3	8.3	651	1204
Carbon monoxide	11.7	314	12.5	74.0	0.97	2.4	2.4	609	1128
Ethylene	59.6	1600	2.7	36.0	0.98	14.3	14.3	490	914
Methyl acetylene, propadiene, stabilized[d]	91.3	2450	3.4	10.8	1.48	—	—	454	850

Source – NFPA 921, Chapter 21, 2008.

[a]Typical composition CH_4 71.9–83.2%; N_2 6.3–16.20%.
[b]Typical composition CH_4 87.6–95.7%; N_2 0.1–2.39%.
[c]Typical composition CH_4 85.0–90.1%; N_2 1.2–7.5%.
[d]MAPP® Gas from the NFPA *Fire Protection Handbook*, 19th ed., Table 8.7.3.

Extract

21.8.1 Minimum Ignition Energy for Gases and Vapors. Gaseous fuel–air mixtures are the most easily ignitable fuels capable of causing an explosion. Ignition temperatures in the 370°C to 590°C (700°F to 1100°F) range are common. Minimum ignition energies begin at approximately 0.25 mJ.

21.8.2 Interpretation of Explosion Damage. The explosion damage to structures (low-order and high-order) is related to a number of factors. These include the fuel–air ratio, vapor density of the fuel, turbulence effects, volume of the confining space, location and magnitude of the ignition source, venting, and the characteristic strength of the structure.

21.8.2.1 Fuel–Air Ratio. Often the nature of damage to the confining structure can be an indicator of the fuel–air mixture at the time of ignition.

21.8.2.1.1 Some fire investigation literature has indicated that an entire volume should be occupied by a flammable mixture of gas and air for there to be an explosion. This is not the case, because relatively small volumes of explosive mixtures capable of causing damage may result from gases or vapors collecting in a given area. (See 21.8.2.2.)

21.8.2.1.2 Explosions that occur in mixtures at or near the lower explosive limit (LEL) or upper explosive limit (UEL) of a gas or vapor produce less violent explosions than those near the optimum concentration (i.e., usually just slightly rich of stoichiometric). This is because the less-than-optimum ratio of fuel and air results in lower flame speeds and lower maximum pressures. In general, these explosions tend to push and heave at the confining structure, producing low-order damage.

21.8.2.1.3 The flame speed is the local velocity of a freely propagating flame relative to a fixed point. It is the sum of the burning velocity and the translational velocity of the flame front. The maximum laminar flame speeds for methane and propane are 3.5 m/sec (11.5 ft/sec) and 4 m/sec (13.1 ft/sec), respectively.

21.8.2.1.4 The burning velocity is the rate of flame propagation relative to the velocity of the unburned gas ahead of it. The fundamental burning velocity is the burning velocity for laminar flame under stated conditions of composition, temperature, and pressure of the unburned gas. Fundamental burning velocity is an inherent characteristic of a combustible and is a fixed value, whereas flame speed can vary widely, depending on the existing parameters of temperature, pressure, confining volume and configuration, combustible concentration, and turbulence.

21.8.2.1.5 The burning velocity is the velocity at which a flame reaction front moves into the unburned mixture as it chemically transforms the fuel and oxidant into combustion products. It is only a fraction of the flame speed. The transitional velocity is the sum of the velocity of the flame front caused by the volume expansion of the combustion products due to the increase in temperature and any increase in the number of moles and any flow velocity due to motion of the gas mixture prior to ignition. The burning velocity of the flame front can be calculated from the fundamental burning velocity, which is reported in NFPA 68, Guide for Venting of Deflagrations, at standardized conditions of temperature, pressure, and composition of unburned gas. As pressure and turbulence increase substantially during an explosion, the fundamental burning velocity will increase, further accelerating the rate of pressure increase. NFPA 68 lists data on the various materials.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.8.2.1.6 Explosions of mixtures near the LEL do not tend to produce large quantities of postexplosion fire, as nearly all of the available fuel is consumed during the explosive propagation.

21.8.2.1.7 Explosions of mixtures near the UEL tend to produce postexplosion fires because of the fuel-rich mixtures. The delayed combustion of the remaining fuel produces the postexplosion fire. Often, a portion of the mixture over the UEL has fuel that does not burn until it is mixed with air during the explosion's venting phase or negative pressure phase, thereby producing the characteristic postexplosion fire.

21.8.2.1.8 When optimum (i.e., most violent) explosions occur, it is almost always at mixtures near or just above the stoichiometric mixture (i.e., slightly fuel rich). This is the optimum mixture. These mixtures produce the most efficient combustion and, therefore, the highest flame speeds, rates of pressure rise, maximum pressures, and consequently the most damage. Postexplosion fires can occur if there are pockets of overly rich mixture.

21.8.2.1.9 For common lighter-than-air gases in residential buildings, an explosion involving an optimum concentration will sometimes result in some destructive shattering effects of wooden structural materials.

21.8.2.2 Vapor Density. The vapor density of the gas or vapor fuel can have a marked effect on the nature of the explosion damage to the confining structure. This is especially true in dwellings and other buildings. While air movement from both natural and forced convection is the dominant mechanism for moving gases in a structure, the vapor density can affect the movement of a gas or vapor as it escapes from its container or pipeline.

21.8.2.2.1 While a gas leak is in progress, heavier-than-air gases and vapors [i.e., specific gravity (air) (vapor density) greater than 1.0], such as from ignitible liquids and LP-Gases, tend to flow to lower areas. Lighter-than-air gases, such as natural gas, tend to rise and flow to upper areas. For example, signs of postblast burning in pocketed areas between ceiling joists may be indicative of a lighter-than-air fuel rather than heavier-than-air gases or vapors. *(See 6.17.9.)* Due to their higher mobility and tendency to escape upward, lighter-than-air gases are less likely to produce hazardous situations than heavier-than-air gases, which can flow into basements, crawl spaces, wells, and tanks.

21.8.2.2.2 A natural gas leak in the first story of a multistory structure may well be manifested in an explosion with an epicenter in an upper story. The natural gas, being lighter than air, will have a tendency to rise through natural openings and may even migrate inside walls. The gas will continue to disperse in the structure until an ignition source is encountered.

21.8.2.2.3 An LP-Gas leak on the first story of a house, if it is not ignited there, can travel away from the source and, due to its density, will tend to migrate downward. During the leak and for some time thereafter, the gas may be at a higher concentration in low areas.

21.8.2.2.4 Ignition of the gas will occur only if the concentration is within the flammable limits and in contact with a competent ignition source (one with enough energy).

Source – NFPA 921, Chapter 21, 2008.

Extract

21.8.2.2.5 Whether lighter- or heavier-than-air gases are involved, there may be evidence of the passage of flame where the fuel–air layer was. Scorching, blistering of paintwork, and showing of "tidemarks" are indicators of this type of phenomena. The operation of heating and air-conditioning systems, temperature gradients, and the effects of wind on a building can cause mixing and movement that can reduce the effects of vapor density. Vapor density effects are greatest in still-air conditions.

21.8.2.2.6 Full-scale testing of the distribution of flammable gas concentrations in rooms has shown that near stoichiometric concentrations of gas will develop between the location of the leak and either (1) the ceiling for lighter-than-air gases or (2) the floor for heavier-than-air gases. It was also reported that a heavier-than-air gas that leaked at floor level will create a greater concentration at floor level and that the gas will slowly diffuse upward. A similar but inverse relationship is true for a lighter-than-air gas leaked at ceiling height. Ventilation, both natural and mechanical, can change the movement and mixing of the gas and can result in gas spreading to adjacent rooms.

21.8.2.2.7 The vapor density of the fuel is not necessarily indicated by the relative elevation of the structural explosion damage above floor level. It was once widely thought that if the walls of a particular structure were blown out at floor level, the fuel gas would be heavier than air, and, conversely, if the walls were blown out at ceiling level, the fuel would be lighter than air. Since explosive pressure within a room equilibrates at the speed of sound, a wall will experience a similar pressure-time history across its entire height. The level of the explosion damage within a conventional room is a function of the construction strength of the wall headers and bottom plates, the least resistive giving way first.

21.8.2.3 Turbulence. Turbulence within a fuel–air mixture increases the flame speed and, therefore, greatly increases the rate of combustion and the rate of pressure rise. Turbulence can produce rates of pressure rise with relatively small amounts of fuel that can result in high-order damage even though there may have only been a lean limit [i.e., lower flammable limit (LFL)] mixture present. The shape and size of the confining vessel can have a profound effect on the severity of the explosion by affecting the nature of turbulence. The presence of many obstacles in the path of the combustion wave has been shown to increase turbulence and greatly increase the severity of the explosion, mainly due to increasing the flame speed of the mixture involved. Other mixing and turbulence sources, such as fans and forced-air ventilation, may increase the explosion effects.

21.8.2.4 Nature of Confining Space. The nature of containment— its size, shape, construction, volume, materials, and design — will also greatly change the effects of the explosion. For example, a specific percentage by volume of natural gas mixed with air will produce completely different effects if it is contained in a 28.3 m^3 (1000 ft^3) room than if it is contained in a 283.2 m^3 (10,000 ft^3) room at the time of ignition. This variation in effects is true even though the velocity of the flame front and the maximum overpressure achieved will be essentially the same.

21.8.2.4.1 A long, narrow corridor filled with a combustible vapor–air mixture, when ignited at one end, will be very different in its pressure distribution, rate of pressure rise, and its effects on the structure than if the same volume of fuel–air were ignited in a cubical compartment.

21.8.2.4.2 In general, the smaller the volume of the vessel, the higher the rate of pressure rise for a given fuel–air mixture, and the more violent the explosion.

Source - NFPA 921, Chapter 21, 2008.

Extract

21.8.2.4.3 During the explosion, turbulence caused by obstructions within the containment vessel can increase the damage effects. This turbulence can be caused by solid obstructions, such as columns or posts, machinery, or wall partitions, which increase flame speed, and thus increase the rate of pressure rise.

21.8.2.5 Location and Magnitude of Ignition Source. The highest rate of pressure rise will occur if the ignition source is in the center of the confining structure. The closer the ignition source is to the walls of the confining vessel or structure, the sooner the flame front will reach the wall and be cooled by heat transfer to the walls. The result is a loss of energy and a corresponding lower rate of pressure rise and a less violent explosion. The energy of the ignition source generally has a minimal effect on the course of an explosion, but unusually large ignition sources (e.g., blasting caps or explosive devices) can significantly increase the speed of pressure development and, in some instances, can cause a deflagration to transition into a detonation.

21.8.2.6 Venting. With gas-, vapor-, or dust-fueled explosions, the venting of the containment vessel will also have a profound effect on the nature of explosion damage. For example, it is possible to cause a length of steel pipe to burst in the center if it is sufficiently long, in spite of the fact that it may be open at both ends. The number, size, and location of doors and windows in a room may determine whether the room experiences complete destruction or merely a slight movement of the walls and ceiling.

21.8.2.6.1 Venting of a confining vessel or structure may also cause damage outside of the vessel or structure. The most damage can be expected in the path of venting. For example, the blast pressure front in a room may travel through a doorway and may damage items or materials directly in line with the doorway in the adjacent room. The same relative effect may be seen directly in line with the structural seam of a tank or drum that fails before the sidewalls.

21.8.2.6.2 With detonations, venting effects are minimal, as the high speeds of the blast pressure fronts are too fast for any venting to relieve the pressures.

21.8.3 Underground Migration of Fuel Gases. It is quite common for fuel gases that have leaked from underground piping systems to migrate underground, enter structures, and fuel fires or explosions there. Because the soil surrounding underground pipes and utility lines has been more disturbed than adjacent soil, it is generally less dense and more porous. Both lighter-than-air and heavier-than-air fugitive fuel gases will tend to follow the exterior of such underground constructions and can enter structures in this manner. Often these fugitive gases will permeate the soil, migrate upward, and dissipate harmlessly into the air. However, if the surface of the ground is then obstructed by rain, snow, freezing, or new paving, the gases may migrate laterally and enter structures.

21.8.3.1 Fuel gases migrating underground have been known to enter buildings by seeping into sewer lines, underground electrical or telephone conduits, drain tiles, or even directly through basement and foundation walls, none of which are as gastight as water or gas lines.

21.8.3.2 In addition, gases can move through underground conduits for hundreds of feet and then fuel explosions or fires in distant structures. *(See 9.9.7.)*

21.8.3.3 Natural gas and propane have little or no natural odors of their own. In order for them to be readily detected when leaking, foul-smelling malodorant compounds are added to the gases. Odorant verification should be a part of any explosion investigation involving or potentially involving fuel gas, especially if it appears that there were no indications of a leaking gas being detected by people present. The odorant's presence, in the proper amount, should be verified. *(See 9.2.4.)*

Source - NFPA 921, Chapter 21, 2008.

Extract

21.8.4 Multiple Explosions. A migration and pocketing effect is also often manifested by the production of multiple explosions, generally referred to as *secondary explosions* (and sometimes *cascade explosions*). Gas and vapors that have migrated to adjacent stories or rooms can collect or pocket on each level. When an ignition and explosion takes place in one story or room, subsequent explosions can occur in adjoining areas or stories.

21.8.4.1 The migration and pocketing of gases often produces areas or pockets with different fuel–air mixtures. One pocket could be within the explosive range of the fuel, while a pocket in an adjoining room or story could be over the upper explosive limit (UEL). When the first mixture is ignited and explodes, damaging the structure, the dynamic forces of the explosion, including the positive and negative pressure phases, tend to mix air into the fuel-rich mixture and bring it into the explosive range. This mixture in turn will explode if an ignition source of sufficient energy is present. In this way, a series of vapor/gas explosions is possible.

21.8.4.2 Multiple explosions are a very common occurrence. However, often the explosions occur so rapidly that witnesses report hearing only one, but the physical evidence, including multiple epicenters, indicates more than one explosion.

21.8.4.3 A secondary or cascade explosion into an adjacent compartment can be more violent than the primary explosion in certain situations. This violence is generally due to the first explosion acting as a very strong ignition source, creating additional turbulence and possible precompression in the compartment.

21.9 Dust Explosions.

21.9.1 General. Finely divided solid materials (e.g., dusts and fines), when dispersed in the air, can fuel particularly violent and destructive explosions. Even materials that are not normally considered to be combustible, such as aspirin, aluminum, or milk powders, can produce explosions when burned as dispersed dusts.

21.9.1.1 Dust explosions occur in a wide variety of materials: agricultural products, such as grain dusts and sawdust; carbonaceous materials, such as coal and charcoal; chemicals; drugs, such as aspirin and ascorbic acid (i.e., vitamin C); dyes and pigments; metals, such as aluminum, magnesium, and titanium; plastics; and resins, such as synthetic rubber.

21.9.1.2 NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, provides a more complete introduction to fundamentals of dust explosions.

21.9.2 Particle Size. Since the combustion reaction takes place at the surface of the dust particle, the rates of pressure rise generated by combustion are largely dependent on the surface area of the dispersed dust particles. For a given mass of dust material, the total surface area, and consequently the violence of the explosion, increases as the particle size decreases. The finer the dust, the more violent is the explosion. In general, an explosion hazard concentration of combustible dusts can exist when the particles are 420 microns or less in diameter.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.9.3 Concentration. The concentration of the dust in air has a profound effect on its ignitibility and violence of the blast pressure wave. As with ignitible vapors and gases, there are minimum explosive concentrations of specific dusts required for a propagating combustion reaction to occur. Minimum concentrations can vary with the specific dust from as low as 20 g/m^3 to 2000 g/m^3 (0.015 oz/ft^3 to 2.0 oz/ft^3) with the most common concentrations being less than 1000 g/m^3 (1.0 oz/ft^3).

21.9.3.1 Unlike most gases and vapors, however, there is generally no reliable maximum limit of concentration. The reaction rate is controlled more by the surface-area-to-mass ratio than by a maximum concentration.

21.9.3.2 Similar to gases and vapors, the rate of pressure rise and the maximum pressure that occur in the dust explosion are higher if the pre-explosion dust concentration is at or close to the optimum mixture. The combustion rate and maximum pressure decrease if the mixture is fuel rich or fuel lean. The rate of pressure rise and total explosion pressure are very low at the lower explosive limit and at very high fuel-rich concentrations.

21.9.4 Turbulence in Dust Explosions. Turbulence within the suspended dust–air mixture greatly increases the rate of combustion and thereby the rate of pressure rise. The shape and size of the confining vessel can have a profound effect on the severity of the dust explosion by affecting the degree of turbulence, such as the pouring of grain from a great height into a largely empty storage bin.

21.9.5 Moisture. Generally, increasing the moisture content of the dust particles increases the minimum energy required for ignition and the ignition temperature of the dust suspension. The initial increase in ignition energy and temperature is generally low, but, as the limiting value of moisture concentration is approached, the rate of increase in ignition energy and temperature becomes high. Above the limiting values of moisture, suspensions of the dust will not ignite. The moisture content of the surrounding air, however, has little effect on the propagation reaction once ignition has occurred.

21.9.6 Minimum Ignition Energy for Dust.

21.9.6.1 Dust explosions have been ignited by open flames, smoking materials, lightbulb filaments, welding and cutting, electric arcs, static electric discharges, friction sparks, heated surfaces, and spontaneous heating.

21.9.6.2 Ignition temperatures for most material dusts range from 320°C to 590°C (600°F to 1100°F). Layered dusts generally have lower ignition temperatures than the same dusts suspended in air. Minimum ignition energies are higher for dusts than for gas or vapor fuels and generally fall within the range of 10 mJ to 40 mJ, higher than most flammable gases or vapors.

21.9.7 Multiple Explosions. Dust explosions in industrial scenarios usually occur in a series. The initial ignition and explosion are most often less severe than subsequent secondary explosions. However, the first explosion puts additional dust into suspension, which results in additional explosions. The mechanism for this is that acoustical and structural vibrations and the blast front from one explosion will propagate faster than the flame front, lofting dust ahead of it and entraining it in the air. In facilities such as grain elevators, these secondary explosions often progress from one area to another, or from building to building.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.10 Backdraft or Smoke Explosions.

21.10.1 When fires occur within rooms or structures that are relatively airtight, it is common for fires to become oxygen depleted. In these cases, high concentrations of heated airborne particulates and aerosols, carbon monoxide, and other flammable gases can be generated due to incomplete combustion. These heated fuels will collect in a structure where there is insufficient oxygen to allow combustion to occur and insufficient ventilation to allow them to escape.

21.10.2 When this accumulation of fuels mixes with air, such as by the opening of a window or door, they can ignite and burn sufficiently fast to produce low-order damage, though usually with less than 13.8 kPa (2 psi) overpressure in conventional structures. These are called *backdrafts* and *smoke explosions*.

21.11 Outdoor Vapor Cloud Explosions.
An outdoor vapor cloud explosion is the result of the release of gas, vapor, or mist into the atmosphere, forming a cloud within the fuel's flammable limits and causing subsequent ignition. The principal characteristic of the event is potentially damaging pressures within and beyond the boundary of the cloud due to deflagration or detonation phenomena.

21.11.1 This phenomenon also has been referred to as an *unconfined vapor air explosion* or *unconfined vapor cloud explosion*. While completely unconfined, vapor cloud explosions are possible. Most involve at least some partial restriction of pressure by manmade or natural structures.

21.11.2 Outdoor vapor cloud explosions have generally occurred at process plants and in flammable liquid or flammable gas storage areas or have involved large transport vehicles (e.g., railroad tank cars). Large amounts of fuel (hundreds of pounds or more) are generally involved.

21.12 Explosives.
Explosives are any chemical compound, mixture, or device, the primary purpose of which is to function by explosion. Explosives are categorized into two main types: low explosives and high explosives (not to be confused with low-order damage and high-order damage).

21.12.1 Low Explosives.

21.12.1.1 Low explosives are characterized by deflagration (subsonic blast pressure wave) or a relatively slow rate of reaction and the development of low pressure when initiated. Common low explosives are smokeless gunpowder, flash powders, solid rocket fuels, and black powder. Low explosives are designed to work by the pushing or heaving effects of the rapidly produced hot reaction gases.

21.12.1.2 It should be noted that some low explosives (i.e., double-base smokeless powder) can achieve detonation under circumstances where confinement is adequate to produce sufficient reaction speed, where the ignition source is very strong, or where instabilities in combustion occur.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.12.2 High Explosives.

21.12.2.1 High explosives are characterized by a detonation propagation mechanism. Common high explosives are dynamites, water gel, TNT, ANFO, RDX, and PETN. High explosives are designed to produce shattering effects by virtue of their high rate-of-pressure rise and extremely high detonation pressure [on the order of 6,900,000 kPa (1,000,000 psi)]. These high, localized pressures are responsible for cratering and localized damage near the center of the explosion.

21.12.2.2 The effects produced by diffuse phase (i.e., fuel–air) explosions and solid explosives are very different. In a diffuse phase explosion (usually deflagration), structural damage will tend to be uniform and omnidirectional, and there will be relatively widespread evidence of burning, scorching, and blistering. In contrast, the rate of combustion of a solid explosive is extremely fast in comparison to the speed of sound. Therefore, pressure does not equalize through the explosion volume and extremely high pressures are generated near the explosive. The pressure and the resultant level of damage rapidly decay with distance away from the center of the explosion. At the location of the explosion, there should be evidence of crushing, splintering, and shattering effects produced by the higher pressures. Away from the source of the explosion, there is usually very little evidence of intense burning or scorching, except where hot shrapnel or firebrands have landed on combustible materials.

21.12.3 Investigation of Explosive Incidents. The investigation of incidents involving explosives requires very specialized training. Explosives are strictly regulated by local and federal laws, so most explosives incidents will be investigated by law enforcement or regulatory agencies. It is suggested that only investigators with the appropriate training endeavor to conduct such investigations. Those without this training should contact law enforcement or other agencies for assistance.

21.13 Investigating the Explosion Scene.

21.13.1 General. The objectives of the explosion scene investigation are no different from those for a regular fire investigation: determine the origin, identify the fuel and ignition source, determine the cause, and establish the responsibility for the incident. A systematic approach to the scene examination is equally or even more important in an explosion investigation than in a fire investigation. Explosion scenes are often larger and more disturbed than fire scenes. Without a preplanned, systematic approach, explosion investigations become even more difficult or impossible to conduct effectively.

21.13.1.1 Typical explosion incidents can range from a small pipe bomb in a dwelling to a large process explosion encompassing an entire facility. While the investigative procedures described in 21.13.1.2 through 21.13.4 are more comprehensive for the large incidents, the same principles should be applied to small incidents, with appropriate simplification.

21.13.1.2 When damage is very extensive and includes much structural damage, an explosion dynamics expert and a structural expert should be consulted early in the investigation to aid in the complex issues involved.

21.13.2 Securing the Scene. The first duty of the investigator is to secure the scene of the explosion. First responders to the explosion should establish and maintain physical control of the structure and surrounding areas. Unauthorized persons should be prevented from entering the scene or touching blast debris remote from the scene itself because the critical evidence from an explosion (whether accidental or criminal) may be very small and may be easily disturbed or moved by people passing through. Evidence is also easily picked up on shoes and tracked out. Properly securing the scene also tends to prevent additional injuries to unauthorized persons or to the curious who may attempt to enter an unsafe area.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.13.2.1 Establishing the Scene. As a general rule, the outer perimeter of the incident scene should be established at 1[illegible] times the distance of the farthest piece of debris found. Significant pieces of blast debris can be propelled great distances or into nearby buildings or vehicles, and these areas should be included in the scene perimeter. If additional pieces of debris are found, the scene perimeter should be widened.

21.13.2.2 Obtain Background Information. Before beginning any search, all relevant information should be obtained pertaining to the incident. This information should include a description of the incident site and systems or operations involved and of conditions and events that led to the incident. The locations of any combustibles and oxidants that were present and what abnormal or hazardous conditions existed that might account for the incident need to be determined. Any pertinent information regarding suspected explosive materials and causes will of course be of interest and will aid in the search as well.

21.13.2.2.1 In developing the evidence, the investigator should examine witness accounts, maintenance records, operational logs, manuals, weather reports, previous incident reports, and other relevant records. Recent changes in equipment, procedures, and operating conditions can be especially significant.

21.13.2.2.2 Obtaining drawings of the building or process will greatly improve documentation of the scene, especially if notes can be made on them.

21.13.2.3 Establish a Scene Search Pattern. The investigator should establish a scene search pattern. With the assistance of investigation team members, the scene should be searched from the outer perimeter inward toward the area of greatest damage. The final determination of the location of the explosion's epicenter should be made only after all of the scene has been examined.

21.13.2.3.1 The search pattern itself may be spiral, circular, or grid shaped. Often the particular circumstances of the scene will dictate the nature of the pattern. In any case, the assigned areas of the search pattern should overlap so that no evidence will be lost at the edge of any search area. It is often useful to search areas more than once. When this search pattern is done, a different searcher should be used to help ensure that evidence is not overlooked.

21.13.2.3.2 The number of actual searchers will depend on the physical size and complexity of the scene. The investigator in charge should keep in mind, however, that too many searchers can often be as counterproductive as too few. Searchers should be briefed as to the proper procedures for identifying, logging, photographing, and marking and mapping the location of evidence. Consistent procedures are imperative whenever there are several searchers involved.

21.13.2.3.3 The location of evidence may be marked with chalk marks, spray paint, flags, stakes, or other marking means. After photographing, the evidence may be tagged, moved, and secured. *(See 15.2.6.8 and Section 16.3.)*

21.13.2.4 Safety at the Explosion Scene. All of the fire investigation safety recommendations listed in Chapter12 also apply to the investigation of explosions. In addition, there are some special safety considerations at an explosion scene.

21.13.2.4.1 Structures that have suffered explosions are often more structurally damaged than merely burned buildings. The possibility of floor, wall, ceiling, roof, or entire building collapse is much greater and should always be considered.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.13.2.4.2 In the case of fuel gas or dust explosions, secondary explosions are the rule rather than the exception. Early responders need to remain alert to that possibility. Leaking gas or pools of flammable liquids need to be made safe before the investigation is begun. Toxic materials in the air or on material surfaces need to be neutralized. The use of appropriate personal safety equipment is recommended.

21.13.2.4.3 Explosion scenes that involve bombings or explosives have added dangers. Investigators should be on the lookout for additional devices and undetonated explosives. The modus operandi (M.O.) of some bombers or arsonists includes using secondary explosive devices specifically targeted for the law enforcement or fire service personnel who will be responding to the bombing incident.

21.13.2.4.4 A thorough search of the scene should be conducted for any secondary devices prior to the initiation of the postblast investigation. If undetonated explosive devices or explosives are found, it is imperative that they not be moved or touched. The area should be evacuated and isolated, and explosives disposal authorities summoned.

21.13.3 Initial Scene Assessment.

21.13.3.1 General. Once the explosion scene has been established, the investigator should make an initial assessment of the type of incident with which he or she is dealing. If at any time during the investigation the investigator determines that the explosion was fueled by explosives or involved an improvised explosive device (IED), he or she should discontinue the scene investigation, secure the scene, and contact the appropriate law enforcement agency. Table 21.13.3.1 provides the investigator with a basic general guide for comparing the characteristics of explosion damage and fuels. It can aid in including or eliminating some kinds of explosions or fuels from the initial investigative assessment. For example, if the evidence indicates that high-order damage occurred, it can be assumed that the explosion was not the result of a backdraft. There are some cases where certain particle sizes may exceed 420 microns and still present an explosion hazard. This is the case for some fibrous materials such as flock, which have very high length-to-diameter ratios.

Source – NFPA 921, Chapter 21, 2008.

Table 21.13.3.1 Typical Explosion Characteristics (source: NFPA 921, Chapter 21, 2008)

Typical Characteristics	Lighter-than-Air Gases	Heavier-than-Air Gases	Liquid Vapors	Dusts	Explosives	Backdrafts	BLEVEs
Low-order damage	3	4	4	2	2	5	2
High-order damage	2	1	1	2	3	0	2
Secondary explosion	3	3	2	4	0	1	0
Gas/vapor/dust pocketing	3	2	2	2	0	0	0
Deflagration[a]	4	4	4	4	1	5	4[b]
Detonation	1	1	1	1	4	0	1[b]
Underground migration	2	2	2	0	0	0	0
BLEVEs	2	3	5	0	0	0	5
Postexplosion fires	3	3	4	3	1	5	3
Pre-explosion fires	2	2	2	3	2	5	4
Seated explosions	0[c]	0[c]	0[c]	0	4[d]	0	2
Minimum ignition energy (mJ)[e]	0.17–0.25	0.17–0.25	0.25	10–40	[e]		[f]

0: Never. 1: Seldom. 2: Sometimes. 3: Often. 4: Nearly always. 5: Always.
[a]Deflagrations may transition into detonations under certain conditions.
[b]The strength of the confining vessel may allow the pressure wave at failure to be supersonic.
[c]Gases and vapors may produce seats if confined in small vessels, and if the materials on which they explode can be sufficiently compressed or shattered.
[d]All high explosives and some low explosives will produce seated explosions if the materials on which they explode can be sufficiently compressed or shattered.
[e]Ignition energies vary widely. Most modern high explosives are designed to be insensitive to ignition. Energies for detonations are nine orders of magnitude larger than the minimum ignition energies.
[f]BLEVEs are not combustion explosions and do not require ignitions.

Extract

21.13.3.2 Identify Explosion or Fire. The first task in the initial assessment is to determine whether the incident was a fire, explosion, or both, and which came first. Often the evidence of an explosion is not obvious, for example, where a weak explosion of fuel gases is involved.

21.13.3.2.1 The investigator should look for signs of an overpressure condition existing within the structure, including displacement or bulging of walls, floors, ceilings, doors and windows, roofs, other structural members, nails, screws, utility service lines, panels, and boxes. Localized fragmentation and pressure damage should be noted as attributable to condensed phase explosive fuel reaction.

21.13.3.2.2 The investigator should look for and assess the nature and extent of heat damage to the structure and its components and decide whether it can be attributed to fire alone.

21.13.3.3 High- or Low-Order Damage. The investigator should attempt to determine whether the nature of damage indicates high-order or low-order damage. *(See Section 21.3.)* This determination will help classify the type, quantity, and mixture of the fuel involved.

21.13.3.4 Seated or Nonseated Explosion. The investigator should determine whether the explosion was seated or nonseated. This will help classify the type of possible fuel involved. *(See Section 21.6.)*

21.13.3.5 Identify Type of Explosion. The investigator should identify the type of explosion involved (e.g., mechanical, combustion, other chemical reaction, or BLEVE).

21.13.3.6 Identify Potential General Fuel Type.

21.13.3.6.1 The investigator should identify which types of fuel were potentially available at the explosion scene by identifying the condition and location of utility services, especially fuel gases and sources of ignitible dusts or liquids.

21.13.3.6.2 The investigator should analyze the nature of damage in comparison to the typical damage patterns available from the following:

(1) Lighter-than-air gases
(2) Heavier-than-air gases
(3) Liquid vapors
(4) Dusts
(5) Explosives
(6) Backdrafts
(7) BLEVEs

21.13.3.7 Establish the Origin. The investigator should attempt early on to establish the origin of the explosion. The origin will usually be identified as the area of most damage, and will sometimes include a crater or other localized area of severe damage in the case of a seated explosion. In the case of a diffuse fuel–air explosion, the origin will be the confining volume or room of origin.

Source – NFPA 921 Chapter 21, 2008.

Extract

21.13.3.8 Establish the Fuel Source and Explosion Type. The investigator should identify which types of fuel were available at the explosion scene by identifying the condition and location of utility services, especially fuel gases, processing by-product dusts, or ignitible liquids. The investigator should analyze the nature of damage in comparison to the typical damage patterns attributable to the following:

(1) Lighter-than-air gases
(2) Heavier-than-air gases
(3) Liquid vapors
(4) Dusts
(5) Explosives
(6) Backdrafts
(7) BLEVEs

21.13.3.9 Establish Ignition Source.

21.13.3.9.1 The investigator should attempt to identify the ignition source involved. At times, this can be very difficult. Examination should be made for potential sources — such as hot surfaces, electrical arcing, static electricity, open flames, sparks, chemicals, and so forth — where fuel–air mixtures are involved.

21.13.3.9.2 Where explosives are involved, the initiation source may be a blasting cap or other pyrotechnic device. Wires and device components will sometimes survive.

21.13.4 Detailed Scene Assessment. Armed with general information from the initial scene assessment, the investigator may now begin a more detailed study of the blast damage and debris. As in any fire incident investigation, the investigator should record his or her investigation and findings by accurate note taking, photography, diagramming, and mapping. It is important to use proper collection and preservation techniques. *(See 15.2.6.8 and Section 16.3.)*

21.13.4.1 Identify Damage Effects of Explosion. The investigator should make a detailed examination and analysis of the specific explosion or overpressure damage. Damaged articles should be identified as having been affected by one or more of the following typical explosion forces:

(1) Blast pressure wave — positive phase
(2) Blast pressure wave — negative phase
(3) Shrapnel impact
(4) Thermal energy
(5) Seismic energy

21.13.4.1.1 The investigator should examine and classify the type of damage present — whether it was shattered, bent, broken, or flattened — and also look for changes in the pattern. At distances away from a detonation explosion epicenter, the pressure rise will be fairly moderate and the effects will resemble those of a deflagration explosion, while materials in the immediate vicinity of the detonation epicenter will exhibit splintering and shattering (i.e., brittle failure).

21.13.4.1.2 The investigator should make a detailed examination and analysis of the specific explosion or overpressure damage. Damaged articles should be identified as having been affected by one or more of the damaging effects of explosions: blast pressure fronts, shrapnel impact, thermal effects, and seismic effects.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.13.4.1.3 The scene should be examined carefully and fragments of any foreign material should be recovered, as well as debris from the seat itself. The fragments may require forensic laboratory analysis for their identification, but whether they are fragments of the original vessel or container or portions of an improvised explosive device, they may be critical to the investigation.

21.13.4.1.4 Table 21.13.4.1.4(a) and Table 21.13.4.1.4(b) can be used as simplified guides to estimate the peak blast overpressure from the observed building damage and casualty data. These data are from peak overpressure applied to the structure's exterior. The effects of overpressure on the inside of the structure are considered to be similar, but the overpressure values may be different in some cases, depending on the construction involved.

Source – NFPA 921, Chapter 21, 2008.

Table 21.13.4.1.5(a) Human Injury Criteria (Includes Injury from Flying Glass and Direct Overpressure Effects)

Overpressure (psi)	Injury	Comments	Source
0.6	Threshold for injury from flying glass*	Based on studies using sheep and dogs	a
1.0–2.0	Threshold for skin laceration from flying glass	Based on U.S. Army data	b
1.5	Threshold for multiple skin penetrations from flying glass (bare skin)*	Based on studies using sheep and dogs	a
2.0–3.0	Threshold for serious wounds from flying glass	Based on U.S. Army data	b
2.4	Threshold for eardrum rupture	Conflicting data on eardrum rupture	b
2.8	10% probability of eardrum rupture	Conflicting data on eardrum rupture	b
3.0	Overpressure will hurl a person to the ground	One source suggested an overpressure of 1.0 psi for this effect	c
3.4	1% eardrum rupture	Not a serious lesion	d
4.0–5.0	Serious wounds from flying glass near 50% probability	Based on U.S. Army data	b
5.8	Threshold for body-wall penetration from flying glass (bare skin)*	Based on studies using sheep and dogs	a
6.3	50% probability of eardrum rupture	Conflicting data on eardrum rupture	b
7.0–8.0	Serious wounds from flying glass near 100% probability	Based on U.S. Army data	b

10.0	Threshold lung hemorrhage	Not a serious lesion [applies to a blast of long duration (over 50 m/sec)]; 20–30 psi required for 3 m/sec duration waves	d
14.5	Fatality threshold for direct blast effects	Fatality primarily from lung hemorrhage	b
16.0	50% eardrum rupture	Some of the ear injuries would be severe	d
17.5	10% probability of fatality from direct blast effects	Conflicting data on mortality	b
20.5	50% probability of fatality from direct blast effects	Conflicting data on mortality	b
25.5	90% probability of fatality from direct blast effects	Conflicting data on mortality	b
27.0	1% mortality	A high incidence of severe lung injuries [applies to a blast of long duration (over 50 m/sec)]; 60–70 psi required for 3 m/sec duration waves	d
29.0	99% probability of fatality from direct blast effects	Conflicting data on mortality	b

For SI units, 6.9 kPa = 1 psi.
*Interpretation of tables of data presented in reference.
[a]Fletcher, Richmond, and Yelverton, 1980.
[b]F. Lees, *Loss Prevention in the Process Industries*, 1996.
[c]Brasie and Simpson, 1968.
[d]U.S. Department of Transportation, 1988.

Table 21.13.4.1.5(b) Property Damage Criteria

Overpressure (psi)	Damage	Source
0.03	Occasional breaking of large glass windows already under strain	a
0.04	Loud noise (143 dB). Sonic boom glass failure	a
0.10	Breakage of small windows, under strain	a
0.15	Typical pressure for glass failure	a
0.30	“Safe distance” (probability 0.95 no serious damage beyond this value) Missile limit Some damage to house ceilings 10% window glass broken	a
0.4	Minor structural damage	a, c
0.5–1.0	Shattering of glass windows, occasional damage to window frames. One source reported glass failure at 1 kPa (0.147 psi)	a, c, d, e
0.7	Minor damage to house structures	a
1.0	Partial demolition of houses, made uninhabitable	a
1.0–2.0	Shattering of corrugated asbestos siding	a, b, d, e
	Failure of corrugated aluminum–steel paneling	
	Failure of wood siding panels (standard housing construction)	
1.3	Steel frame of clad building slightly distorted	a
2.0	Partial collapse of walls and roofs of houses	a
2.0–3.0	Shattering of nonreinforced concrete or cinder block wall panels [10.3 kPa (1.5 psi) according to another source]	a, b, c, d

2.3	Lower limit of serious structural damage	a
2.5	50% destruction of brickwork of house	a
3.0	Steel frame building distorted and pulled away from foundations	a
3.0–4.10	Collapse of self-framing steel panel buildings	a, b, c
	Rupture of oil storage tanks	
	Snapping failure — wooden utility tanks	
4.0	Cladding of light industrial buildings ruptured	a
4.8	Failure of reinforced concrete structures	e
5.0	Snapping failure — wooden utility poles	a, b
5.0–7.0	Nearly complete destruction of houses	a
7.0	Loaded train wagons overturned	a
7.0–8.0	Shearing/flexure failure of brick wall panels [20.3 cm to 30.5 cm (8 in. to 12 in.) thick, not reinforced]	a, b, c, d
	Sides of steel frame buildings blown in	d
	Overturning of loaded rail cars	b, c
9.0	Loaded train boxcars completely demolished	a
10.0	Probable total destruction of buildings	a
30.0	Steel towers blown down	b, c
88.0	Crater damage	e

[a]F. Lees, Loss Prevention in the Process Industries, 1996. [c]U.S. Department of Transportation, 1988. [e]McRae, 1984.
[d]U.S. Air Force, 1983. [b]Brasie and Simpson, 1968.

Extract

21.13.4.1.5 It is noted that the estimation of structural damage from an explosion is a very complex topic. A thorough treatment involves maximum pressure and impulse of the explosion, as well as the natural period and strength characteristics of the confining structure. Generally, one can expect a peak overpressure of 6.9 kPa to 13.8 kPa (1 psi to 2 psi) to cause the failure of most light structural assemblies, such as nonreinforced wood siding, corrugated steel panels, or masonry block walls. In comparison, much higher overpressures can be tolerated when the structural design is reinforced, particularly with materials of good ductility (e.g., steel).

21.13.4.2 Identify Preblast and Postblast Fire Damage. Fire or heat damage should be identified as having been caused by a pre-existing fire or by the thermal effect of the explosion. Debris that has been propelled away from the point of origin should be examined to determine whether it has been burned. Debris of this nature that is burned may be an indicator that a fire preceded the explosion.

21.13.4.2.1 Probably the most common sign of an overpressure condition is window glass thrown some distance from the windows of the structure. The residue of smoke or soot on fragments of window glass or other structural debris reveals that the explosion followed a fire by some time, whereas perfectly clean pieces of glass or debris thrown large distances from the structure indicate an explosion preceding the fire.

21.13.4.2.2 The direction of flow of melted and resolidified debris may tell the investigator the position or attitude of the debris at the time of heat exposure.

21.13.4.3 Locate and Identify Articles of Evidence. Investigators should locate, identify, note, log, photograph, and map any of the many and varied articles of physical evidence. Because of the propelling nature of explosions, the investigator should keep in mind that significant pieces of evidence may be found in a wide variety of locations, such as outside the exploded structure, embedded in the walls or other structural members of the exploded structure, on or in nearby vegetation, inside adjacent structures or vehicles, or embedded in these adjacent structures. In the case of bombing incidents or incidents involving the explosion of tanks, appliances, or equipment, significant pieces of evidence debris may have pierced the bodies of victims or be contained in their clothing.

21.13.4.3.1 The clothing of anyone injured in an explosion should be obtained for examination and possible analysis. The investigator should ensure that photographs are taken of the injuries and that any material removed from the victims during medical treatment or surgery is preserved. This is true whether the person survives or not.

21.13.4.3.2 Investigators should note the condition and position of any damaged and displaced structural components, such as walls, ceilings, floors, roofs, foundations, support columns, doors, windows, sidewalks, driveways, and patios.

21.13.4.3.3 Investigators should note the condition and position of any damaged and displaced building contents, such as furnishings, appliances, heating or cooking equipment, manufacturing equipment, victims' clothing, and personal effects.

21.13.4.3.4 Investigators should note the condition and position of any damaged and displaced utility equipment, such as fuel gas meters and regulators, fuel gas piping and tanks, electrical boxes and meters, electrical conduits and conductors, heating oil tanks, parts of explosive devices, or fuel vessels.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.13.4.4 Identify Force Vectors. Investigators should identify, diagram, photograph, and note those pieces of debris that indicate the direction and relative force of the explosion. Keep in mind that the force necessary to shatter a wall is more than that necessary to merely dislodge or displace it. The force necessary to shatter a window is less than that to displace a wall, but more than that necessary to blow out a window intact. The greater the force, the farther is the distance that similar pieces of debris will be thrown from the epicenter.

21.13.4.4.1 The investigator should log, diagram, and photograph varying missile distances and directions of travel for similar debris, such as window glass. Larger, more massive missiles should be measured and weighed for comparison of the forces necessary to propel them.

21.13.4.4.2 The distance as well as the direction of significant pieces of evidence from the apparent epicenter of the explosion may be critical. The location of all significant pieces should be completely documented on the explosion scene diagram, along with notes as to both distance and direction. This procedure allows the investigator to reconstruct the trajectories of various components.

21.13.4.4.3 Other directional indicators may be present in some cases. Fuel-gas explosions may exhibit impingement heat damage effects on articles in the path of the flame front. Clothing and skin of personnel may show directional patterns as well. Dust explosions may exhibit similar phenomena, and also include imbedded burned or unburned dust particles on the articles of impingement.

21.14 Analyze Origin (Epicenter).
After identifying the force vectors, the investigator should trace backward from the least to the most damaged areas, following the general path of the explosion force vectors. This process is known as an *explosion dynamics analysis*. It can be accomplished most efficiently by plotting on a diagram of the exploded structure the various directions of debris movement and, if possible, an estimate of the relative force necessary for the damage or movement of each significant piece of debris, as indicated in Figure 21.14. A dimensional diagram is desirable in cases where an engineering analysis of the damage effects is anticipated.

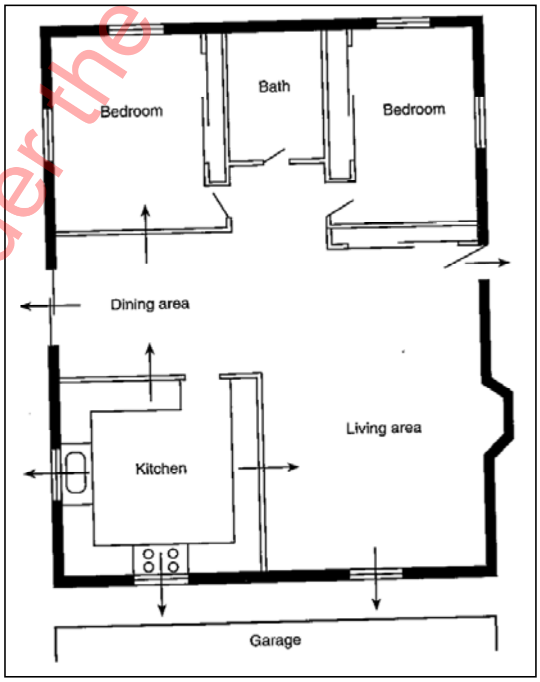


FIGURE 21.14 Diagram Showing Displacement of Walls, Doors, and Windows Due to Explosion

Source – NFPA 921, Chapter 21, 2008.

Extract

21.14.1 The analysis of the explosion dynamics is based on the debris movement away from the epicenter of the explosion in a roughly spherical pattern and on the decreasing force of the explosion as the distance from the epicenter increases.

21.14.2 Often, more than one explosion dynamics diagram is necessary. The first diagram might show a relatively large area that may indicate a specific area or room for further study as the origin. A second, smaller-scale diagram might then be constructed to analyze the explosion dynamics of the area of origin itself. This smaller-scale diagram is especially useful when dealing with a seated explosion.

21.14.3 Often, especially when dealing with nonseated explosions, such as fugitive fuel gas explosions, the investigator may be unable to pinpoint the epicenter any more precisely than to a specific room or area.

21.14.4 The explosion dynamics analysis is often complicated by evidence of a series of explosions, each with its own epicenter. This situation calls for a detailed comparison of the force vectors. Movement of more solid debris, such as walls, floors, and roofs, is generally less in subsequent explosions than in the first. The first forceful explosion tends to vent the structure, allowing more of the positive pressure phase of subsequent explosions to be released.

21.14.5 This finding is true, however, only when the secondary explosions are of the same or lesser force than the first. Dust explosions are a notable exception to this phenomenon, with subsequent explosions almost always being more powerful than the first.

21.15 Analyze Fuel Source.

Once the origin or epicenter of the explosion has been identified, the investigator should determine the fuel. This determination is made by a comparison of the nature and type of damage to the known available fuels at the scene.

21.15.1 All available fuel sources should be considered and eliminated until one fuel can be identified as meeting all of the physical damage criteria. For example, if the epicenter of the explosion is identified as a 1.8 m (6 ft) crater of pulverized concrete in the center of the floor, fugitive natural gas can be eliminated as the fuel, and only fuels that can create seated explosions should be considered.

21.15.2 Chemical analysis of debris, soot, soil, or air samples can be helpful in identifying the fuel. With explosives or liquid fuels, gas chromatography, mass spectrography, or other chemical tests of properly collected samples may be able to identify their presence.

21.15.3 Air samples taken in the vicinity of the area of origin can be used in identifying gases or the vapors of liquid fuels. For example, commercial “natural gas” is a mixture of methane, ethane, propane, nitrogen, and butane. The presence of ethane in an air sample may show that commercial “natural gas” was there rather than naturally occurring “swamp, marsh, or sewer” gas, which is all methane.

21.15.4 Once a fuel is identified, the investigator should determine its source. For example, if the fuel is identified as a lighter-than-air gas and the structure is serviced by natural gas, the investigator should locate the source of gas that will most likely be at or below the epicenter, possibly from a leaking service line or malfunctioning gas appliance.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.15.5 All gas piping, including from the street mains or LP-Gas storage tanks, up to and through the service regulator and meter, up to and including all appliances, should be examined and leak tested if possible. *(See* NFPA 54, *National Fuel Gas Code, Annex D, or the National Fuel Gas Code Handbook.)* Leak testing inside a building that has had a fire or gas explosion should be performed using air or an inert gas.

21.15.6 Odorant verification should be part of any explosion investigation involving, or potentially involving, flammable gas, especially if there are indications that leaking gas was not detected by people present. Its presence should be verified. Stain tubes can be used in the field, and gas chromatography can be used as a lab test for accurate results.

21.16 Analyze Ignition Source.
When the origin and fuel are identified, the means of ignition should be analyzed. This analysis is often the most difficult part of the overall explosion investigation because, especially with fugitive fuel gases, multiple ignition sources are present. In the event of multiple possible ignition sources, the investigator should take into consideration all the available information, including witness statements. A careful evaluation of every possible ignition source should be made. Factors to consider include the following:

(1) Minimum ignition energy of the fuel
(2) Ignition energy of the potential ignition source
(3) Ignition temperature of the fuel
(4) Temperature of the ignition source
(5) Location of the ignition source in relation to the fuel
(6) Simultaneous presence of the fuel and ignition source at the time of ignition
(7) Witness accounts of conditions and actions immediately prior to and at the time of the explosion

21.17 Analyze to Establish Cause.

21.17.1 General. Having identified the origin, fuel, and ignition source, the investigator should proceed to analyze and determine what brought together the fuel and ignition at the origin. The circumstances that brought these elements together at that time and place are the cause. *(See Section 18.5.)*

21.17.1.1 Part of this analysis may include considerations of how the explosion could have been prevented, such as failure to conform to existing codes or standards. It should be noted that, due to the destructive effects of fire and explosions, the cause cannot always be determined.

21.17.1.2 Many techniques are suggested in 21.17.2 through 21.17.6 to aid in establishing causation. The choice of the technique(s) used will depend on the unique circumstances of the incident.

21.17.2 Time Line Analysis. Based on the background information gathered (e.g., statements and logs), a sequence of events should be tabulated for the time both prior to the explosion and during the explosion. Consistencies and inconsistencies with causation theories can then be surmised and a "best fit" theory established. *(See Section 20.2 for more information on time line analysis.)*

21.17.3 Damage Pattern Analysis. Various types of damage patterns, principally debris and structural damage, can be documented for further analysis.

Source – NFPA 921, Chapter 21, 2008.

Extract

21.17.3.1 Debris Analysis.

21.17.3.1.1 Investigators should identify, diagram, photograph, and note those pieces of debris that indicate the direction and relative force of the explosion. In general, the greater the explosive energy, the farther similar pieces of debris will be thrown from the center of the explosion. However, different drag and lift (i.e., aerodynamic) characteristics of various fragment shapes will tend to favor some pieces going farther.

21.17.3.1.2 The distance as well as the direction of significant pieces of evidence from the apparent center of the explosion may be critical. The location of all significant pieces should be completely documented on the explosion scene diagram, along with notes as to both distance and direction. This procedure allows the investigator to reconstruct the trajectories of various components. In some cases, it is desirable to weigh and make geometric measurements of significant missiles, especially large ones. These measurements can then be used in a more complete engineering analysis of trajectories.

21.17.3.2 Relative Structural Damage Analysis. Investigators should diagram the relative damage to the areas surrounding the explosion site. Such a diagram can be called an *iso-damage contour map*. Criteria for contours may be simple overpressure levels in some cases, or the relative damage ratings for structures. Several techniques are employed for this purpose. Such an analysis will give additional clues to explosion propagation and can be used for further input to a more complete engineering analysis.

21.17.4 Correlation of Blast Yield with Damage Incurred. There are several methods that analysts use to correlate the degree of damage and projectile distance with the type and amount of fuel involved. Due to the great differences in chemical dynamics between solid explosives and gas/vapor deflagrations, it is not possible to directly correlate the amount of fuel involved in one to the weight of explosive used in the other. Weight equivalencies for common condensed-phase explosives can be found in the literature. *(See Annex A.)*

21.17.5 Analysis of Damaged Items and Structures. Frequently, the determination of the cause in explosion incidents requires a multidisciplinary approach to relate damage to the fuels involved. The use of special experts may be necessary. *(See Section 14.5.)*

21.17.6 Correlation of Thermal Effects. A collection of articles exhibiting heat damage from an explosive event may be evidence of a fireball or fire during the sequence of events. These articles may be further proof that the explosion involved a BLEVE, a fuel jet fire, or other phenomenon, depending on the character of those articles. Specialized analysis of thermal damage effects can be conducted by a person trained in this area. From this material, an isothermal diagram (i.e., heat damage map) can be developed.

Source – NFPA 921, Chapter 21, 2008.

4. Electrical Appliances

NFPA 921, Chapter 24 - Appliances

Note: Remember that the mains voltage figures in these extracts will be 120 Volts, whereas the mains electricity voltage in domestic and most commercial applications in New Zealand is 240 Volts. However the content of this material is still useful in the New Zealand context.

Extract

24.1 Scope.

24.1.1 This chapter covers the analysis of appliances as it relates to the investigation of the cause of fires. The chapter concentrates on appliances as ignition sources for fires but, where applicable, also discusses appliances as ignition sources for explosions. This chapter assumes that the origin of the fire has been determined and that an appliance at the origin is suspected of being an ignition source. Until an adequate origin determination has been done, it is not recommended that any appliances be explored as a possible ignition source.

24.1.2 Addressed in this chapter are appliance components, which are common to many appliances found in the home and business. Sections of this chapter also deal with specific but common residential-type appliances and with how they function.

24.2 Appliance Scene Recording.
The material presented in Chapter 15 should be used where appropriate to record the scene involving an appliance. Material presented in this section is supplemental and has specific application to appliances.

24.2.1 Recording Specific Appliances. Once a specific appliance(s) has been identified in the area of origin, it should be carefully examined before it is disturbed in any way. The appliance should be photographed in place from as many angles as possible. Photographs should be close-ups of the appliance as well as more distant photographs that will show the appliance relative to the area of origin, the nearest combustible material(s), and a readily identified reference point (e.g., window, doorway, piece of furniture). This reference point will greatly aid later reconstruction efforts in placing the exact location of the appliance at the time of the fire. If an appliance has been moved since the start of the fire, then the same photographs should be taken where it was found. If it can be established where the appliance was located at the time of the fire, such as by observing a protected area that matches the appliance base, or by talking to someone familiar with the fire scene prior to the fire, the appliance should be moved to its pre-fire location and the same photographs taken. This movement by the investigator may not be done until all other necessary documentation is completed.

24.2.2 Measurements of the Location of the Appliance. The scene should be photographed and diagrammed as described in Section 15.4. The location of the appliance within the area of origin is particularly important. The investigator should take measurements that will establish the location of the appliance.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.2.3 Positions of Appliance Controls. Special attention in the photography and diagramming should be paid to the position of all controls (e.g., dials, switches, power settings, thermostat setting, valve position), position of movable parts (e.g., doors, vents), analog clock hand position, power supply (e.g., battery and ac house current), fuel supply, and any other item that would affect the operation of the appliance or indicate its condition at the time of the fire.

24.2.4 Document Appliance Information. The manufacturer, model number, serial number, date of manufacture, warnings, recommendations, and any other data or labels located on the appliance should be documented. This information should be photographed, and notes should be taken, as these items may be difficult to photograph. Having notes will ensure that this valuable information is preserved. It is frequently necessary to move the appliance to obtain these data, and this should be done with minimal disturbance to the appliance and to the remainder of the fire scene. In no case should the appliance be moved prior to completion of the actions in 24.2.3.

24.2.5 Gathering All of the Parts from the Appliance. Where the appliance has been damaged by the fire or suppression activities, every effort should be made to gather all of the parts from the appliance and keep them together. After exposure to fire, many of the components may be brittle and may disintegrate with handling, which is why it is important to document their conditions at this point. Where it is considered helpful and will not result in significant damage to the remains of the appliance, some reconstruction of the parts may be done for documentation and analysis purposes. This reconstruction could include replacing detached parts and moving the appliance to its original location and position. Attempting to operate or test an appliance should not be done during the fire scene examination, as this may further damage the appliance, possibly destroying the critical clues within the appliance and its components. All testing at this point should be strictly nondestructive and only for the purpose of gathering data on the condition of the appliance after the fire. Examples of nondestructive testing include using a volt/ohmmeter to check resistance or continuity of appliance circuits.

24.3 Origin Analysis Involving Appliances.

Chapter 6 and Chapter 17 deal with determining the origin of a fire in greater detail. The additional techniques and methodology presented here should be utilized when a fire involves an appliance. This is the case when the fire is confined to the appliance or when it is thought that a fire started by the appliance spread to involve other contents of the room.

24.3.1 Relationship of the Appliance to the Origin. It should be established that the appliance in question was in the area of origin. Those appliances that were clearly located outside the area of origin generally can be excluded as fire causes. In some cases, an appliance(s) remote from the area of origin may have something to do with the cause of the fire and should be included in the investigation. Examples of these are the use of an extension cord or the presence of a standing pilot on a gas appliance. Where doubt exists as to the area of origin, it should be classified as undetermined. When the origin is undetermined, the investigator should examine and document the appliances in any suspected areas of origin.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.3.2 Fire Patterns. Fire patterns should be used carefully in establishing an appliance at the point of origin. Definite and unambiguous fire patterns help to show that the appliance was at the point of origin. Other causes of these patterns should be eliminated. The degree of damage to the appliance may or may not be an adequate indication of origin. Where the overall relative damage to the scene is light to moderate and the damage to the appliance is severe, then this may be an indicator of the origin. However, if there is widespread severe damage, other causes such as drop down, fuel load (i.e., fuel gas leak), ventilation, and other effects should be considered and eliminated. If the degree of damage to the appliance is not appreciably greater than the rest of the fire origin, then the appliance should not be chosen solely by virtue of its presence.

24.3.3 Plastic Appliance Components. Appliances that are constructed of plastic materials may be found at the fire scene with severe damage. The appliance may be severely distorted or deformed, or the combustible material may be burned away, leaving only wire and other metallic components. This condition of an appliance in and of itself is not an adequate indicator of the point of origin. This is especially true where there was sufficient energy from the fire in the room to cause this damage by radiant heating and ignition. Conditions approaching, or following, flashover can have sufficient energy to produce these effects some distance from the point of origin.

24.3.4 Reconstruction of the Area of Origin. Reconstruction of the area of origin may be necessary to locate and document those patterns and indicators that the investigator will be using to establish the area of origin. As much of the material from the appliance as possible should be returned to its original location and then recorded with photographs and a diagram. The help of a person familiar with the scene prior to the fire may be necessary.

24.4 Cause Analysis Involving Appliances.

The material presented in Chapter 18 should be used where appropriate to analyze an appliance that may have caused a fire. Material presented in this section is supplemental or has specific application to appliances.

24.4.1 How the Appliance Generated Heat.

24.4.1.1 Before it can be concluded that a particular appliance has caused the fire, it should first be established how the appliance generated sufficient heat energy to cause ignition. The type of appliance will dictate whether this heat is possible under normal operating conditions or as a result of abnormal conditions. The next step is to determine the first material ignited and how ignition took place. The most likely ignition scenario(s) will remain after less likely or impossible ignition scenarios have been eliminated. If no likely ignition scenario exists, either accidental or intentional, then the cause should be classified as undetermined.

24.4.1.2 Patterns on the appliance may indicate the source of the ignition energy. However, hot spots or other burn patterns may be the result of other factors not related to the cause and need to be carefully considered. Patterns on nearby surfaces may provide information on the ignition source.

24.4.2 The Use and Design of the Appliance. The use and operation of an appliance should be well understood before it is identified as the fire cause. Some appliances are simple or very familiar to fire investigators and may not require in-depth study. However, appliance design can be changed by the manufacturer, or an appliance can be damaged or altered by the user, and, therefore, each appliance warrants investigation. More complicated appliances may require the help of specialized personnel to gain a full understanding of how they work and how they could generate sufficient energy for ignition.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.4.3 Electrical Appliances as Ignition Sources. Many appliances use electricity as the power source, and electricity should be considered as a possible source for ignition. The material presented in Chapter 18 should be carefully considered and applied in this situation. Only under a specific set of conditions can sufficient heat be generated by electricity as a result of an overload or fault within or by an appliance and subsequently cause ignition.

24.4.4 Photographing Appliance Disassembly. When it is necessary to disassemble an appliance (or its remains) recovered from a fire scene, each step should be documented by photography. *(See 16.10.1.)* This is done to establish that the investigator did not haphazardly pull the artifact apart, causing pieces to be further damaged or lost. The documentation should show the artifact at the start and at each stage of disassembly, from multiple angles if possible, keeping careful track of loose pieces. Some investigators find it helpful to videotape this process. The investigator should have at least one specific reason for disassembling an artifact, and once an answer has been found, the disassembly process should stop. When an artifact cannot be easily disassembled or if the disassembly would be too destructive, the use of X-rays should be considered.

24.4.5 Obtaining Exemplar Appliances. To understand an appliance more fully, to test its operation, or to explore failure mechanisms, the investigator may need to obtain an exact duplicate (i.e., an exemplar). For this, the model and serial numbers may be required, and the manufacturer may need to be contacted to determine the history of this appliance. It may be that the manufacturer does not make the particular appliance any more or has changed it in some way. The investigator will need to determine whether the exemplar located is similar enough to the artifact to be useful.

24.4.6 Testing Exemplar Appliances. Exemplar appliances can be operated and tested to establish the validity of the proposed ignition scenario. If the ignition scenario requires the failure or malfunction of one or more appliance components, this can also be tested for validity on the exemplar. Where extensive or repeated testing is foreseen, the investigator will probably need more than one exemplar. The testing should show not just that the appliance is capable of generating heat, but that such heat is of sufficient magnitude and duration to ignite combustible material.

24.5 Appliance Components.

Appliances are diverse in what they do and how they are constructed. Therefore, this section will provide a description of each of the common parts or components that might be found in various appliances. Where information is given in later sections about particular appliances, there will be references to the components that are used in those appliances.

24.5.1 Appliance Housings.

24.5.1.1 Introduction. Housings of appliances can be made of various materials. The nature of these materials can affect what happens to the appliances during fires and what the remains will look like after a fire. Most housings are made of metal or plastic, but other materials such as wood, glass, or ceramics might be found also.

24.5.1.1.1 Many appliances utilize painted steel finishes. This typically includes refrigerators, dryers, fluorescent fixtures, baseboard heaters, and the like.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.1.1.2 Care should be exercised when evaluating heat damage patterns on painted steel surfaces. Many paints darken with heat exposure. Additional or greater heat exposure can cause some heat-darkened painted surfaces to lighten in color. Further heat exposure may cause the paint to decompose to a gray or white powder. This gray or white powder can be disturbed or removed by fire fighting, handling, or by the formation of rust. An apparently lighter surface color may reflect more thermal damage than a darker area.

24.5.1.2 Steel. Steel is used for the housings of many appliances because of its strength, durability, and ease of forming. Stainless steel is used where high luster and resistance to rusting is needed, such as in kitchen appliances or wherever appearance and sanitation are important. Other types of steel may be used and coated with plastic or enamel to achieve the desired appearance. Galvanized steel may be used where resistance to rusting is needed but appearance is not important, such as inside a washing machine.

24.5.1.2.1 Steel will not melt in fires except under very unusual circumstances of extremely high temperatures for extended times or by electrical arcs. Ordinarily, steel will be oxidized by fires, and the surface will be the dull blue-gray color resulting from ferrous oxide (FeO). The brown rust color does not appear until the steel item has been wet long enough to rust to the reddish color of ferric oxide (Fe_2O_3). When steel is deeply oxidized by long exposure in a fire, the oxide layer often will be thick enough to flake off. In severe cases, the flaking off may go through the steel and create a hole. In fires of short duration, the surfaces of polished or plated steel can show various color fringes, depending on the degree of heating. After a fire, bare galvanized steel will have a whitish coating from oxidation of the zinc. Often, the surfaces of steel housings will have a mottled appearance ranging from blue-gray to rust to white to black to reddish. The odd colors are usually from residues of decorative or protective coatings on the steel in addition to the oxides. The particular colors and the patterns depend on many factors, and not much importance should be put on the color and patterns without substantiating evidence.

24.5.1.2.2 On rare occasions, a steel housing may be found with a hole made by alloying with zinc or aluminum. Most of the time, when one of these metals drips onto steel during a fire, the surface oxides keep the metals separated. During a long fire, the molten metal might penetrate the oxide layers and alloy with the steel. If there is need to know the cause of the hole, analysis of the steel at the edge of the hole would show alloying elements or absence of them.

24.5.1.2.3 A steel housing does not necessarily keep internal components from reaching very high temperatures. If a closed steel box is exposed to a vigorous fire for a long enough time, the inside of the box can become hot enough to cook materials, to gray ashes, or to melt copper.

24.5.1.3 Aluminum. Aluminum housings are commonly made from formed sheets or castings. Extruded pieces might be found on or in the appliance as trim or supports for other components. Aluminum has a fairly low melting temperature of 660°C (1220°F) if pure; alloys melt at slightly lower temperatures. The extent of damage to the aluminum housing can indicate the severity of the fire or heat source at that point.

24.5.1.4 Other Metals. Other metals, such as zinc or brass, might be used in housings. They would be likely to be just decorative pieces or to be supports for other components. Zinc melts at the relatively low temperature of 419°C (786°F) and so is almost always found as a lump of gray metal. Brass is used in many electrical terminals. Brasses have ranges of melting temperatures in the neighborhood of 950°C (1740°F). Brass items are often found to be partly melted or just distorted after a fire. Because it is an alloy, brass softens over a range of temperatures rather than melting at a specific temperature.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.1.5 Plastic. Plastic housings are used increasingly for a wide range of appliances that do not operate at high temperatures. Most plastics are made of carbon plus some other elements. Some plastics melt at low temperatures and then char and decompose at higher temperatures. Others do not melt but do char and decompose at higher temperatures. Nearly all plastics can form char when heated and will burn in existing fires. Many kinds of plastics will continue to burn by themselves if ignited. Other plastics will not continue to burn from a small ignition source at room temperature because of their chemical compositions or because of added fire retardants. Many plastic housings of recent manufacture have considerable fire retardant added, and they usually will not continue to burn from a small source of ignition. Each appliance in question would need to be checked for ease of burning of the plastic. In some cases, that check can be done by qualified personnel if enough of the material remains or if the identical appliance can be obtained.

24.5.1.5.1 After a brief fire, the plastic housing of an appliance may be melted and partially charred. If the pattern of damage shows that the heat source was inside, further examination of the remains is warranted. The plastics might show instead that the heat was from the outside and that the inside is less heated than the exterior. If the plastic housing has melted down to a partly charred mass, x-ray pictures can reveal encapsulated metal parts and wires. When a plastic housing has been mostly melted and burned by exterior fire, the underside of the appliance might still be intact or a metal base plate unheated.

24.5.1.5.2 When a fire is severe, all plastics might be consumed. Total consumption of the plastic does not by itself indicate that the fire started in the appliance.

24.5.1.5.3 Phenolic plastics are used for certain parts that must have resistance to heat, such as coffee pot handles and circuit breaker cases. Phenolics do not melt and will not burn by themselves. They can be consumed to a gray ash in a sustained fire. When a device that has been made with a molded phenolic body is moderately heated, the gray ash might be just a thin layer on the outside. Gray ash on the inside surfaces with little or no gray ash on the exterior may indicate internal heating.

24.5.1.5.4 When portions of an appliance melt and resolidify as a result of a fire, the direction of flow of the material can indicate the orientation of the appliance at the time that the melted component material cooled.

24.5.1.6 Wood. Wood still has occasional use in appliance housings. Wood can be fully consumed in a fire or can show a pattern of burning when only partly consumed. The pattern can help to show whether the fire came from inside or outside of the appliance.

24.5.1.7 Glass. Glass is used for transparent covers and doors on appliances. Glass might also be used in some decorations. Glass readily cracks when heated nonuniformly and can soften and sag or drip. Flame temperatures are higher than the softening temperatures of glass, so the degree of softening of glass is more a function of duration and continuity of exposure than of fire temperature.

24.5.1.8 Ceramics. Ceramics may be used for some novelty housings and are used as supports for some electrical components. Ceramics do not melt in fires, but a decorative glaze on them could melt.

24.5.2 Power Sources. Power sources for common appliances are usually the alternating current that is supplied by the power companies. There are a few other sources that will be considered. This section will not include voltages higher than 240 or three-phase power. For more detailed information on electrical power and devices, see Section 8.1 through 8.11.10.

Source - NFPA 921, Chapter 24, 2008.

Power cords – New Zealand

Power companies in the New Zealand supply electrical power at 50 Hz and 240 V ac (often called 230 V). Most appliances are designed to operate by plugging them into a 240 V outlet

Extract

24.5.2.1.1 Electrical cords that carry power to the appliance may be made of two or three conductors. The conductors are stranded to provide good flexibility. Some double-insulated appliances and most appliances made before 1962 had only two-conductor cords. Newer large appliances usually have three-conductor cords with the third conductor for grounding as a safety feature. The stranded conductors of cords usually survive fires, but the remains will usually be embrittled if the insulation was burned away during the fire. Careless handling of brittle stranded conductors can cause them to break apart. Cords should be checked for arcing damage. See Chapter 8 for information on electrical conductors and damage to them.

24.5.2.1.2 Plugs for connecting the power cord to the outlet have somewhat different designs, depending on the amperage of the appliance. Plugs made prior to 1987 for 20 A or less were two straight prongs of the same width. Newer plugs have the neutral prong wider than the "hot" prong. The plug may have a third prong for grounding. Factory-made plugs have the conductors attached to the prongs inside a molded plastic body. That body may melt or be entirely burned away in a fire. The conductors and brass prongs will usually survive a fire, but sometimes the brass parts may be melted. After a fire with only minor burning near the plug, the face of the plug will be nearly unheated because of being protected against the receptacle. That finding can show that the appliance was plugged in. Also, even after a more severe fire, the prongs may be less oxidized where they were protected in the receptacle during the fire.

24.5.2.1.3 Plugs for higher voltages or amperages will have larger prongs and different positioning.

24.5.2.2 Voltages Less than 120. Many appliances that plug into a wall receptacle actually operate at 6, 12, or other voltages less than 120 V. Normally, a step-down transformer is used to produce the lower voltage. The transformer will usually be part of the appliance, but sometimes it is a separate unit that plugs directly into the receptacle and feeds the appliance with a thin two-wire cord. Shorting of wiring at 6 V is not likely to cause a fire, but it can do so under circumstances where the energy (i.e., heat) can be concentrated in a small area close to a combustible material.

24.5.2.3 Batteries. Batteries are used for portable appliances and some security devices. Batteries can range from car batteries to common dry cells to small button batteries for cameras and watches. Batteries provide about 1.5 V of direct current. Batteries of 6 V or 9 V are actually made of four or six dry cells, respectively, in one package. Remains of batteries that were present in an appliance can usually be found after a fire. They usually will be damaged too much to indicate whether they provided power for ignition. However, what they were connected to could be important. One battery can provide enough power to ignite some materials under certain conditions. In most battery-powered devices, though, the normal circuitry will prevent the energy of the battery from being sufficiently concentrated at one spot at one time to achieve ignition.

24.5.2.4 Overcurrent Protection. Protection against excessive, damaging current is provided by fuses or circuit breakers in many appliances. After a minor fire, the remains of the protective device might show whether it operated. After a severe fire, the metal parts of the protective device might be found to show at least that it was present.

Source - NFPA 921, Chapter 24, 2008.

Remember: The mains electricity voltage in domestic and most commercial applications is 240 Volts. The NFPA information on voltages less than 120 can be applied to a similar range of appliances in New Zealand. However, electrical distribution and supply systems do have significant differences.

Extract

24.5.2.4.1 The fusing element in a fuse can be one of several metals. In all fuses, the element has the proper cross-section and electrical resistance for the temperature to rise to the melting point if current exceeds a specific level for a specified duration. If the excess current is moderate (e.g., less than twice the rating), the fuse element will melt without vaporizing. If the current is very high, as with a dead short, the element will usually partly vaporize to give an opaque deposit on a window or glass tube of the fuse.

24.5.2.4.2 Most circuit breakers operate thermally or magnetically, depending on the level of overcurrent. Above a specific current level, a bimetal strip deflects enough to let a spring pull the contacts apart. With an instantaneous high current, such as with a dead short, the magnetic field pulls the mechanism so that the contacts open. A circuit breaker that is in a fire environment can trip as the internal mechanism comes up to the activating temperature. Circuit breakers in appliances have a reset button.

24.5.3 Switches. Switches are used to turn appliances on or off and to change the operating conditions. Switches are found in a wide range of sizes, types, and modes of operation. Examination of switches after a fire can determine whether the appliance was on or off or other aspects of its operation. The remains of switches might be very delicate. Other than noting and documenting the positions of knobs, levers, or shafts or checking electrical continuity in place, it is recommended that the investigator not open, operate, or disassemble any switches. That job should be left to someone with technical expertise. *(See 16.10.1.)*

24.5.3.1 Manual Switches.

24.5.3.1.1 Many switches are intended for the user to operate. These include on–off switches and those to change functions, wattage, or other features of the appliance. The design of the switches can include moving lever (e.g., toggle), push button, turning knob, or sliding knob. They have metal parts that can be examined after a fire. Where lightly damaged, the switch might still electrically test on or off or show which position it was in. Where severely damaged, the remains might show only whether the contacts were welded together. Switches will create a parting arc when they open. Therefore, apparent damage to the switch surface may be normal.

24.5.3.1.2 Electronic switches in many appliances may be too damaged by even minor fires to determine their pre-fire position or whether they malfunctioned. Examples of those switches include touch pads on microwave ovens and remote-controlled TVs.

24.5.3.2 Automatic Switches. Many switches in appliances are automatic and are not intended for the user to operate. Those switches generally keep the appliance operating within its design parameters and prevent unsafe operation. Those kinds of switches may be operated by electrical current, temperature, or motion.

24.5.3.2.1 Fuses and Circuit Breakers. Fuses and circuit breakers are automatic switches that operate by overcurrent. Circuit breakers can be reset, but fuses and fusible links need to be replaced.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.3.2.2 Temperature Switches. Automatic switches that operate by temperature and are intended to keep the appliance operating within certain temperature limits are called *thermostats*. Automatic switches that are intended to prevent the appliance from exceeding certain parameters are called *cutoffs*, *limit switches*, or *safeties*.

24.5.3.2.2.1 Switches that operate by temperature can be based on expanding metal, bimetal bending, fluid pressure, or melting. These switches are usually used to prevent an appliance from operating outside a fixed range of temperatures or to prevent it from exceeding a set temperature (cutoff switches). They ordinarily have enough metal parts to be recognizable after a severe fire, although it may not be possible to determine whether the switch was functional at the time of the fire.

24.5.3.2.2.2 A few switches use expanding metal, where a long rod is positioned in the warm area. If that area becomes too hot, the rod expands and pushes contacts open. More common is the bimetal type, where two dissimilar metals are bonded together in a flat piece. One metal expands more than the other with increasing temperature, so while the temperature rises, the piece bends. That motion can open contacts to turn off the appliance. These switches are slow make-and-break, which is more likely to cause either erosion or welding of the contacts. After a severe fire, the bimetal may be bent far out of position, which is a result of heating from the fire and does not indicate a defective thermostat.

24.5.3.2.2.3 A bimetal disc operates on differential expansion, but the disc snaps from a dish shape in one direction to a dish in the other direction. The edge of the circular disc is fixed, and so the center snaps back or forth at particular temperatures to open or close the contacts.

24.5.3.2.2.4 Some switches operate by expansion of a fluid in a bulb that is located in the hot area. The pressure of that fluid is passed to bellows, often back at a control panel, through a metal tube, commonly copper. The bellows push open the contacts.

24.5.3.2.2.5 These various mechanical switches can be arranged either to open contacts so as to shut the appliance off, or to close contacts so as to turn something else on, such as a cooling fan, that will counter the high temperature. High-temperature cutoff switches may be present in an appliance, but they should not open the circuit except when the temperature becomes too high in the appliance. The contacts of switches should be examined by competent persons. If contacts in cutoffs are eroded by arcing from repeated opening, that can indicate that the appliance was operating in an overheated condition for an extended time, which may indicate a defect in the appliance.

24.5.3.2.2.6 Mechanical switches can fail by overloads, which overheat certain internal parts, or by welding of the contacts. The latter can happen at normal currents as slow make-and-break contacts pass current without being firmly in contact. Poor connections internally, such as where wiring is attached or where brass parts are riveted, can cause destructive heating and failure of the switch. The faces of contacts of thermostats will normally be somewhat pitted because they open and close frequently. Faces of contacts in devices used as safety cutoffs should not be significantly pitted, because the devices should not operate except when there is overheating.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.3.2.2.7 The contacts of a switch are more subject to surface pitting, erosion, and possibly welding when they slowly open and close. For that reason, most switches, especially for carrying substantial currents, are made to snap open or closed, which can be accomplished with a bimetal disc, a flat spring, or a magnet. When welded contacts are found after a fire, that fact does not by itself prove that failure of the switch caused the fire. Heat damage in the appliance could have caused a current surge if power were still available. Electrically welded contacts will have normal shapes, but the faces will be stuck together. If the contacts are found melted together into one lump, the cause is more likely to be severe fire exposure. The contacts are made of metals that have melting temperatures lower than that of copper, and they may melt together from fire exposure.

24.5.3.2.2.8 There are some cutoff devices that operate by internal melting of a material, which lets a spring push the contacts open. These are single-use devices that should be replaced if they operate, although they are sometimes deliberately bypassed, allowing the appliance to operate without protection. The appliance should be checked to verify the presence of such a device, and the device should be checked for signs of tampering or a history of previous replacement.

24.5.3.2.2.9 Many appliances have switches that operate from motion of some part of the appliance. Limit switches on appliances that have moving parts are intended to keep the part from moving too far. Forced-air furnaces may have a switch that operates by airflow pushing a vane up to allow the furnace to continue. Major appliances often have door switches, either to turn the appliance off as the door is opened, or to turn a light on. Motors in major appliances can usually have a centrifugal switch to disengage the starting winding as the motor comes up to speed. Those switches also may control a heating circuit so as not to allow heating unless the motor is running. As with all switches that operate from some mechanical action, these switches can fail to operate if the components that they depend on become misaligned or if the switch comes loose in its holder.

24.5.3.2.2.10 Many portable electric heaters have a tip-over switch that often is built into the thermostat. The switch has a weighted arm that hangs down and opens the contacts if the appliance is tipped so that the arm is not in its normal position.

24.5.4 Solenoids and Relays. Solenoids and relays are used in appliances to control a high-power circuit with one of lower power and often of low voltage. Activation of the low-power circuit energizes a coil or an electromagnet that causes an iron shaft or lever to move. That motion opens or closes the high-power circuit. Remains of solenoids or relays normally remain after a fire. Severe damage might make it impossible to determine whether they were operational or which position they were in at the time of the fire. The contacts should be examined to find whether they were stuck together during the fire.

24.5.5 Transformers. Transformers are used to reduce voltages from the normal 120 V and to isolate the rest of the appliance from the supply circuit. Some transformers are energized whenever the appliance is plugged in, so that the primary windings are always being heated by some amount of current. In other appliances, the transformer is not energized until the switch is turned on. The appliance is designed to keep heating of the transformer at a minimum under normal electrical loads. However, with long-term use, and if ventilation of the appliance is restricted, the temperature may increase and deteriorate the windings. As windings begin to short to each other, the impedance drops and more current flows, causing greater heating. More current flows can also lead to severe heating before the windings either fail by melting the wire or create a ground fault that could open the circuit protection. In some cases, the heated insulation or other combustibles in or on the transformer might be ignited before the electrical heating stops.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.5.1 Appliance transformers are usually made of steel cores and copper windings, both of which will survive fires even when severely heated. Examination of a transformer from a burned appliance might show that the interior windings are less heated and might even be of bright copper color. That finding shows that the heating was external and not from the transformer itself. A transformer from a severely burned appliance might have the windings baked to where they have the appearance of oxidized copper, with no surviving insulation down to the core. The remains of the windings would be somewhat loose on the core. That can happen from long exposure in any fire and does not prove that the windings overheated and caused the fire. Overheating of the windings can be determined when there is a clear pattern of internal heating, arcing turn to turn, and a pattern of fire travel out from that source. It is possible for a transformer to overheat even when protected by a fuse, because the fuse should have a sufficient electrical rating to carry the operating currents plus a safety factor.

24.5.5.2 Some transformers may be totally enclosed in steel and would not be likely to be able to ignite adjacent combustibles before being turned off by protection or internal failure. Other transformers are open and often have paper and plastics, which can be ignited, in their construction.

24.5.6 Motors. Motors are common in appliances to provide mechanical action. They generally range from ⅕hp to ¼hp motors in washing machines or other large appliances to tiny motors in small devices. Most common motors are designed to operate at certain speeds. If the rotor is stopped while the motor is still energized, the impedance falls, and current flow increases. That can cause the motor windings to get hot enough to ignite the insulation and any plastics that are part of the construction.

24.5.6.1 Motors often have protection built into them that is intended to stop the current if the temperature gets too high for safe operation. That protection can be in the form of a fuse link, a single-acting thermal cutoff (TCO), a self-resetting thermal protector, or a manual resettable thermal protector. Some motors have both a resettable thermal protector and a single-acting TCO in them. A suspected motor and any protective device should be examined by competent personnel before deciding whether the motor caused the fire.

24.5.6.2 Windings of motors can be examined to find whether they are relatively unheated inside, which would indicate that heating came from the outside. If the windings are thoroughly baked, with oxidized strands all through, but materials around the motor are not so thoroughly heated, that indicates that the windings overheated. If there is much fire around the motor, the windings are likely to be thoroughly baked, whether the fire started in the motor or not.

24.5.6.3 Small motors that drive cooling fans or other devices are usually not sources of ignition. They do not have enough torque to generate much heat by friction. Some small motors are enclosed in metal cases, making ignition by internal heating unlikely. Shaded pole motors are often of open construction, and could ignite combustibles that are in contact with them if the windings get hot enough.

24.5.7 Heating Elements. Heating elements can be expected to get hot enough to ignite combustibles if the combustibles are in contact with the element. The design and construction of the appliance will usually keep combustibles away from the element. An exception is in cooking appliances, where the hot element is exposed for use. Elements can be sheathed, as is found in ovens and ranges, or they can be open wires that can get orange-hot during use. Open heating elements are usually wires or ribbons made from a nickel–chromium–iron alloy. Those that are designed to operate at glowing temperatures will get a dull gray surface oxide layer. In some appliances, a fan removes heat from the element fast enough to keep it from glowing. Those heating elements might retain their bright shiny surfaces after much use.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.7.1 When a wire element burns out, the ends at the break might be left dangling. An end could contact the grounded metal of the appliance and form a new circuit. Depending on how much resistance was left in the segment of the element, the contact ground fault could allow the appliance to continue to function, to overheat, or to open the protection.

24.5.7.2 Sheathed elements consist of a resistance wire surrounded by an insulator (e.g., magnesium oxide) and encased in a metal sheath. The sheath is usually made from steel, but many baseboard or other space heaters have sheaths made from aluminum. Melting of an aluminum sheath is more likely to be a result of external fire than of internal heating; however, if melting and heating of the sheath, cooling fans, or adjacent materials show a clear pattern of coming from the element, that is good evidence that the element overheated. The element can be tested for electrical continuity and resistance. A burned-out element might indicate overheating or it might be simply old age. X-rays can assist in diagnosing the internal condition of the element.

24.5.7.3 A few electrical heaters have failed by ground faulting between the element and the sheath through the insulation, leaving characteristic eruptions of melted metal at various points along the sheath. Although heaters are normally designed so that no combustible materials are easily ignited by the element, the spatter from such arcing might ignite close combustibles if the spatters get through the protective grille.

24.5.8 Lighting. Lighting is used in many appliances to illuminate dials, work areas, or internal cavities. Lights are normally of low wattage and are not likely to be able to ignite anything ordinarily in or on the appliance. Most lighting will be incandescent, but fluorescent lights may be used to illuminate work spaces on the appliance. Fluorescent lights have ballasts (essentially a transformer) that can overheat. However, except for old ones, they have thermal protection and are usually enclosed in the appliance, where they are not likely to ignite anything. Fluorescent lamp tubes do not normally become hot enough to ignite adjacent combustibles, but some incandescent lamps may get hot enough to ignite combustibles that they touch.

24.5.8.1 Fluorescent Lighting Systems. Fluorescent lighting systems use one or more glass tubes filled with an auxiliary or starting gas and mercury at low pressure. An electrical discharge is created down the length of the glass tube. The mercury gas is excited, liberating UV light, which is converted to visible light by a coating on the inside of the lamp known as the phosphor or fluorescent powder.

24.5.8.1.1 Fluorescent lighting systems can be divided into two groups. The first group contains systems where the lamps have heated filaments at their ends. This group is composed of the preheat and rapid start systems. The second group is composed of the instant start system where the discharge is created by applying higher voltages across the lamp without separately heated filaments.

24.5.8.1.2 Fluorescent lamps require a ballast for operation. The ballast performs at least two functions. The first function is to generate sufficient voltage to cause the electrical discharge to progress down the lamp through the auxiliary gas and the mercury vapor. The second function is to limit the current flowing through the lamp in order to keep the lamp from burning out immediately.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.8.1.3 There are two main types of fluorescent ballasts, the magnetic ballast and the electronic ballast. Magnetic ballasts typically incorporate either a reactor or a transformer, often with one or more capacitors. Since 1968, almost all fluorescent ballasts installed in new fixtures were required to incorporate protection against overheating. These ballasts were identified as being Class P ballasts. Replacement ballasts for non–Class P ballasts were not required to be Class P until 1984. Most Class P magnetic ballasts incorporate a self-resetting thermal protector next to the transformer. Some ballasts manufactured prior to 1984 incorporated a single-shot one-time operating thermal protector in them. Most magnetic fluorescent ballasts have a date code unique to each manufacturer stamped into the metal of their case.

24.5.8.1.4 Electronic ballasts typically use a printed circuit board with electronic components and smaller magnetic components to operate the fluorescent lamps at higher frequencies in order to provide higher efficiency. Some electronic ballasts incorporate resetting thermal protectors, while others incorporate fuses for protection.

24.5.8.1.5 Both magnetic and electronic fluorescent ballasts are commonly filled with an asphalt-based potting compound to provide better heat transfer, to reduce noise, and to hold the internal parts in place. The potting compound can soften and flow out of the ballast as the result of either internal heating or from external heat from a fire. The finding after a fire of evidence that the potting compound flowed out of the ballast enclosure is not proof that a ballast had a pre-fire failure or overheating. Ballasts are usually enclosed in a steel body of the light fixture. Any potting compound exiting the ballast due to internal heating is likely to be caught in the fixture enclosure. Potting compound that does drip out of the fixture will not ignite other materials unless the potting compound is already burning.

24.5.8.1.6 Some fire-producing failures of fluorescent ballasts include arc penetrations into combustible ceiling materials and extreme coil overheating conducting heat into adjacent combustibles. Fluorescent ballasts should not be disassembled at the fire scene. Suspect ballasts should be preserved along with their fixtures and wiring for laboratory examination by qualified experts. Commonly, ballasts are x-rayed prior to their disassembly. The fluorescent fixtures should also be examined for evidence of lampholder failures and arcing inside the fixture enclosure.

24.5.8.2 High Intensity Discharge Lighting Systems. High intensity discharge (H.I.D.) lighting systems are lighting sources that utilize a lamp that has a short tube filled with various metal vapors. An electric discharge is created along the length of the tube, exciting the atoms of the metal vapor, thereby creating light. High intensity discharge lamps operate at higher pressures than fluorescent lamps. High intensity discharge lighting systems include mercury vapor, metal halide, and high pressure sodium systems. High intensity discharge lighting systems are typically utilized in commercial structures such as warehouses, manufacturing areas, and retail occupancies.

24.5.8.2.1 High intensity discharge lighting systems typically utilize a ballast and a power capacitor to provide the starting voltage to the lamp, and to limit the current flowing through the lamp. These ballasts may be of the magnetic type or of the electronic type. The magnetic type of ballast is typically not surrounded by potting compound. Some high intensity discharge lighting ballasts are protected by fuses or thermal protectors. Most high intensity discharge ballasts are mounted inside a fixture enclosure above the lampholder and reflector assembly.

24.5.8.2.2 High intensity discharge lighting system ballasts can fail, resulting in arcing faults involving the ballast windings. Certain fixtures have sufficient voids and openings to allow metal droplets or sparks from the arcing faults to escape the fixture housing.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.8.2.3 Most mercury and metal halide lamps use a cylinder of fused silica/quartz with electrodes at either end. This cylinder is called an arc tube. When at room temperature, this tube is typically below atmospheric pressure. This arc tube is supported in a frame inside a glass outer enclosure or jacket. The lamps are marked with a date code reflecting their date of manufacture. The date codes are unique to each manufacturer. During normal operation, the arc tube in a metal halide lamp can reach temperatures in the range of 900°C to 1100°C (1652°F to 2012°F) and internal pressures of 5 to 30 atmospheres. The mercury vapor arc tubes can operate in the range of 600°C to 800°C (1112°F to 1472°F) and pressures of about 3 to 5 atmospheres. High pressure sodium lamps operate at lower pressures typically close to 1 atmosphere.

24.5.8.2.4 Under certain conditions, including operating the lamp beyond rated life or during certain ballast failures, the arc tube of a metal halide lamp may fail during operation while at operating temperature and pressure. Hot pieces or particles from the arc tube may breach the outer glass jacket and escape the lamp. Some metal halide fixtures have lenses or shields designed to contain any escaping pieces or particles. Metal halide lamps are available with internal shields designed to stop the fractured pieces of the arc tube from breaching the outer glass jacket. Arc tube ruptures of mercury vapor lamps have been known to occur.

24.5.8.2.5 The investigation of a suspected high intensity discharge lighting fixture requires the evaluation of the fixture's electrical supply, wiring, ballast, capacitors, lamp, and any lens present. The fixtures should not be disassembled at the fire scene, but carefully preserved for laboratory examination. The evaluation of a metal halide or mercury vapor lamp requires as much of the lamp remains be found as possible. All pieces of the arc tube should be preserved and shielded from any additional damage or wear. The edges of the glass jacket and of the arc tube remains should not be handled, disturbed, or cleaned prior to laboratory examination. The lamp's frame pieces and lamp base should also be collected and carefully preserved. Since the quartz arc tube can be fractured mechanically by building collapse, firefighting, and overhaul, the presence of a fractured arc tube by itself is not proof that an arc tube rupture occurred prior to the ignition of the fire. It is often helpful to obtain additional exemplar lamps and fixtures from the scene for comparison purposes and to obtain the operating history of the lamps.

24.5.9 Miscellaneous Components. There are miscellaneous devices, such as dimmers and speed controllers, that might be found as components of appliances. Generally, many of these devices are now solid state, fully electronic devices. Older appliances may contain nonelectronic devices, such as rheostats or wire resistors. Electronic components are usually destroyed by fire unless the fire was brief. In most cases, the remains of dimmers or other electronic devices that use printed circuit boards will not be helpful in finding the cause because of their susceptibility to fire damage.

24.5.9.1 Timers can be built in or can be used as separate devices. They are driven by small clock motors with mechanical actuation of switches. Remains of any timers that were present can usually be found after a fire, but they may be badly damaged. Small timer motors last a long time and will not overheat to cause a fire. Failure of the timers is usually caused by the gears wearing out or loosing teeth. Electronic timers may not leave recognizable remains after being heated by fire.

24.5.9.2 Thermocouples are used to measure temperature differences. They function by creating a voltage at a junction of dissimilar metals, which is compared to the rest of the circuit or to a reference junction. The temperatures can be read on meters or on digital devices.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.5.9.3 A thermopile is a series of thermocouples arranged so that the voltages at the series of junctions add to a large enough voltage to operate an electromagnet. Thermopiles have been used in gas appliances to keep a valve open when the pilot flame is burning but to let the valve close if the pilot flame is out. Newer gas appliances use electric igniters instead of standing pilots.

24.6 Common Residential Appliances.

A brief description of the operation and components of common residential appliances is provided to assist the investigator in understanding how these appliances work.

24.6.1 Range or Oven. The heat is provided either by electricity passing through resistance heating coils or by burning natural gas or propane. In the oven, the interior temperature is controlled by a thermostat and a valve or switch on the fuel or power supply. On a gas range, the fuel flow rate and heat intensity is usually controlled with the burner fuel supply valve. An electric range typically utilizes a timing device that controls the cycling time of the heating element. This device is manually adjusted so that a high setting results in the longest (possibly continuous) on cycle. Ignition of the fuel gas in a gas range or oven may be by a standing pilot flame or by an electrical device that produces an arc for ignition.

24.6.2 Coffee Makers. The coffee maker design popular for home use consists of a water reservoir, heating tube, carafe, and housing. When started, the heating tube boils the water flowing through it from the reservoir. This boiling forces hot water to the area where the ground coffee is kept in a filter, and the coffee then drips into the carafe. The carafe in many designs sits on a warming plate. The warming plate is usually heated by the same resistance heater that heats the heating tube. The resistance heater is controlled by a thermostat that cycles it off when it reaches the upper limit of the thermostat. The heater will cycle on once it has cooled to a point determined by the thermostat. To prevent overheating by the heater, a TCO may be employed. If the maximum temperature of the TCO is reached, it is designed to open the heater circuit and prevent further heating. Some coffee maker designs may include multiple TCOs, automatic timing circuits that turn the coffee maker off after a fixed period, or a clock or automatic brew mode that turns the coffee maker on at a preset time. The TCO(s) should be checked to determine whether it has been bypassed.

24.6.3 Toaster. The toaster uses electrical resistance heaters to warm or toast food. It is a relatively simple appliance that utilizes an adjustable sensor to control the on time. By pushing down a lever, the food is lowered on a tray into the toaster, and the heaters are turned on. The sensor is usually a bimetal strip that might sense the temperature in the toaster, but more commonly the bimetal has its own heater and is nearly independent of the temperature in the toaster. At the conclusion of the heating cycle, a mechanical latch partly releases the tray and turns off the bimetal heater. As the bimetal cools, a second latch fully releases the tray, which then lifts the food. Some newer designs use an electronic timer that controls an electromagnetic latch.

24.6.4 Electric Can Opener. The electric can opener uses an electric motor to turn a can under a cutting wheel to open the can. Generally they will run only when a lever is manually held down. This seats and holds the cutting wheel in place and closes the power switch to the motor. The electric motor may or may not be protected against overheating by a thermal cutoff switch.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.6.5 Refrigerator. The common refrigerator and freezer utilize a refrigeration cycle and ventilation system to keep the inside compartments at suitable temperatures. The refrigeration system consists of an evaporator (i.e., heat exchanger in the compartment), a condenser (i.e., heat exchanger outside the compartment), a compressor, a heat exchange medium (typically a fluorocarbon or Freon®), and tubing to connect these components. Warm air from inside the enclosure is used to evaporate the heat exchange medium; the coolant vapor moves to the compressor where it is compressed and condensed back to a liquid in the condenser. When the coolant condenses, it gives off the heat it picked up in the enclosure. As a result, the air around the evaporator is cooled and the air around the condenser is heated. The cool air is circulated within the refrigerator, and the hot air dissipates into the room in which the appliance is located. This cooling cycle is controlled by a timing device that regulates the length of the cycles, or it may have a thermostat device that controls the cycle.

24.6.5.1 The compressor is typically powered by an electric motor that is usually protected with a thermal cutoff. The compressor is usually located in a sealed container, which can prevent an overheated compressor from igniting nearby combustibles because it acts as a heat sink. Additional systems in a refrigerator include lighting, ice maker, ice and water dispenser, and a fan for the condenser and possibly one for the evaporator.

24.6.5.2 The refrigerator may also have heating coils in various areas for automatic defrosting and to prevent water condensation on outside surfaces. Automatic defrosters are designed to operate at regular intervals to prevent the accumulation of frost on inside surfaces, especially the inside of the freezer.

24.6.5.3 The antisweat (external condensation) heaters are located under exterior faces, and they operate at regular intervals to prevent condensation. Some models allow this feature to be disabled to conserve power. In both cases, these heaters are typically low-wattage electrical resistance heaters.

24.6.6 Dishwasher. A dishwasher uses a pump to spray and distribute hot water and soap onto the dishes. An electric resistance heater is typically located in the bottom of the unit, where it further heats the water being used. Once the washing and rinsing is complete, the water is drained, and the dishes are dried by the resistance heater, which is exposed to air after the water has drained. Some models allow the electric heater to be disabled during the drying cycle in order to save power. Other devices in the appliance include electrically operated valves and a timer control to regulate the various cycles. The electric pump motor may or may not be thermally protected. Some dishwashers have caused fires by electrical faulting in the push-button controls that then ignited the plastic housing.

24.6.7 Microwave Oven. A microwave oven utilizes a device known as a magnetron to generate and direct the radio waves (i.e., microwaves) into the enclosure. The frequency of these radio waves causes items placed in the oven to heat. To provide for even distribution of these waves, a device is used to scatter them inside the enclosure, and a food tray on the bottom may be rotated. The microwave oven will also have timing and control circuits, a transformer, and internal lighting. The transformer is used to produce the high voltage required by the magnetron. The magnetron will usually be provided with a TCO switch. There may be TCOs above the oven compartment to remove power in case of a fire in the oven.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.6.8 Portable Space Heater. Portable space heaters for residential use have many designs but are generally divided into two groups: convective and radiant. Some convective heaters use a fan to force room air past a hot surface or element while others use natural convection. A natural convection or radiant heater does not have a fan. A complete discussion of the many heater designs is not appropriate here, but the investigator should become familiar with the particular design in question. Familiarization can be achieved by reviewing operating manuals and design drawings and by examining an exemplar heater. These heaters employ a variety of control methods and devices. Generally, these devices are present to control the heater, prevent overheating, or shut the heater off if it is upset from its normal position.

24.6.9 Electric Blanket. An electric blanket consists of an electric heating element within a blanket. The controls are typically located separate from the blanket, on the power cord. The control is typically manually adjusted to control the on–off cycle time. In one or more places near the heating elements within the blanket are located TCOs to prevent overheating of the appliance, and there may be as many as 12 or 15 of these, depending on the appliance. An electric blanket is designed not to overheat when spread out flat. If it is wadded or folded up, heat may accumulate in the blanket and get it hot enough to char and ignite. Normally, the cutoffs prevent overheating.

24.6.10 Window Air Conditioner Unit. A window air conditioner unit is designed to be placed in the window of a residence to cool the room. The unit does this by means of a refrigeration cycle very similar to that used by refrigerators. *(See 24.6.5.)* Air from the room is circulated through the unit, past the evaporator, which cools the air, and is then discharged to the room. A fan powered by an electric motor does the work of circulating the air. The fan motor is usually protected from overheating by a TCO. These units have controls for selecting fan speed, cooling capacity, and temperature. These units are powered by a nominal 120 V circuit, or larger units may require nominal 240 V service.

24.6.11 Hair Dryer and Hair Curler.

24.6.11.1 Typical residential hair dryers use a high-speed fan to direct air past an electric resistance heating coil. Controls are typically limited to on or off. Some units may have more than one heater power (wattage) and fan speed settings. One or more resettable TCO switches are typically provided near the heaters to prevent them from overheating.

24.6.11.2 Hair curlers or hair curling wands use an electric resistance heater within the wand, around which hair is wrapped to curl it. Some models allow the addition of water to a compartment that can be used to generate steam. Typical controls include an on–off switch and a power setting. Most models include a light to indicate that the unit is operating. Typically these units have one or more TCOs near the heating element, which may or may not be resettable.

24.6.12 Clothes Iron. A modern clothes iron uses an electrical resistance heater, located near the ironing surface, to heat that surface. Many models require the addition of water, which is used to distribute the heat and to produce steam. The controls on typical irons range from a simple temperature selector and an on–off switch to electronically controlled units that turn themselves off. Irons are designed to heat in both the vertical and horizontal position. Most irons are provided with one or more TCO to prevent overheating.

Source - NFPA 921, Chapter 24, 2008.

Extract

24.6.13 Clothes Dryer.

24.6.13.1 All clothes dryers use electricity to rotate the clothing drum and to circulate air with a blower. Energy for the heat source may be by the combustion of a fuel gas or by electricity. All electric dryers are powered by either a nominal 120 V or a 240 V source. The clothing is dried by spinning it in a drum, through which heated air is circulated. Air is discharged from the dryer via a duct that is typically directed to the exterior of the house. Most dryers have filters to trap lint, which can build up in the dryer. However, if the trap is clogged or not working or if the material being dried gives off a large quantity of lint, this material can accumulate in other areas of the dryer and its vent, which can be a fire hazard. Frictional heating sufficient to cause ignition can result if a piece of clothing or other material becomes trapped between the rotating drum and a stationary part. Fires have been reported in dryers when vegetable oil-soaked rags or plastic materials such as lightweight dry cleaner bags have been placed in the dryer.

24.6.13.2 Typical dryers have timing controls, humidity sensors, heat source selectors, and intensity selectors to control the operation of the dryer. Thermal cutoffs are provided to prevent overheating of the dryer and components such as the blower motor and heating elements.

24.6.14 Consumer Electronics. Consumer electronics include appliances such as televisions, VCRs, radios, CD players, video cameras, personal computers, and so forth. These devices are similar in their components in that they typically include a power supply, circuit boards with many electronic components attached, and a housing. Some of these appliances, such as televisions and CD players, have components that require high voltage. Additionally, many of these appliances can be operated via remote control. A complete discussion of the many designs of these appliances is not appropriate here, but the investigator should become familiar with the particular design in question. Familiarization can be achieved by reviewing operating manuals and design drawings and by examining an exemplar appliance.

24.6.15 Lighting. Typical residential lighting is either the incandescent or fluorescent type. Incandescent lighting uses a fine metal filament within the bulb, which has been filled with an inert gas such as argon, or the bulb is evacuated and sealed. When an incandescent bulb is working, a major by-product is the generation of heat. Fluorescent lightbulbs use high voltage from a transformer (the ballast) to initiate and maintain an electric discharge through the light tube. The interior of the tube is coated with a material that fluoresces or gives off light when exposed to the electrical discharge energy. The light-generating process in this case generates little heat as a by-product, but the ballast typically will give off heat. Thermally protected fluorescent light ballasts have a resettable thermal switch to prevent the ballast from overheating. *(See 24.5.5.)*

Source - NFPA 921, Chapter 24, 2008.