

# 폭발 조사에 대한 과학적 접근

## A Scientific Approach to Explosion Investigation



한국 가스 안전 공사  
2013년 5월 31일  
서울, 한국

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리치먼드, 켄터키 미국

**폭발 조사에 대한 과학적 접근**  
A Scientific Approach to Explosion Investigation



**론 홉킨스**  
교수 (은퇴)  
화재 안전 공학 기술  
이스턴 켄터키 대학

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**Updated Electronic Copy**

Due to updated information a color copy is available for download.

[www.tracefireandsafety.com](http://www.tracefireandsafety.com)

I am sorry for the inconvenience.

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**Greetings and Best Wishes!**

National Association of Fire Investigators,  
International (NAFI)



Ron Hopkins, President  
National Association of Fire Investigators,  
International

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**National Association of Fire Investigators, International (NAFI)**

NAFI Membership:

6124 Worldwide

249 Korea



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**Certified Fire and Explosion Investigators (CFEI)**

CFEI's Worldwide 4815

CFEI's in Korea 223

Korea Gas Safety Corporation: 29  
Congratulations to those CFEI's



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**소개**  
**Introduction**

**Explosion Investigation and Analysis**

- Foundation
- Pay attention to details the large pieces will come in to place.
- Scientific Method



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Monday, May 6, 2013: A division of the California Public Utilities Commission recommended that the agency levy a \$2.25-billion penalty against Pacific Gas and Electric Company for the deadly 2010 explosion in San Bruno, CA, USA.

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**참고**  
**References**

- NFPA-921 Chapter 21
- Explosion Investigation and Analysis, Kennedy
- Gas Explosions in Buildings and Heating Plants, Harris
- Gas Explosion Handbook, GexCon
- Practical Bomb Scene Investigation, Thurman



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## Fire and Explosion Investigation and Analysis



### Why do we do what we do?

- Integral part of the Fire Protection Community.
- Ability to save lives and prevent future property damage through code and standard changes.
- Ability to make the community safer, through improved products and technology.

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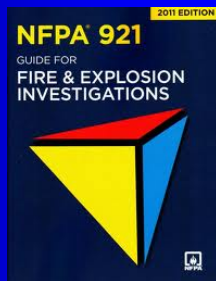
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## Impact of NFPA 921

NFPA 921, Guide for Fire and Explosion Investigations, NFPA; 2011 Edition



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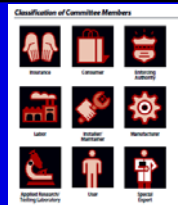
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## Impact of NFPA 921

Technical Committee on Fire Investigations was appointed in 1983

Inclusion of Science into the Investigation Process.



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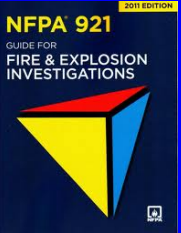
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### Impact of NFPA 921

- NFPA 921 is considered the “Standard of Care” for fire investigators in the United States.



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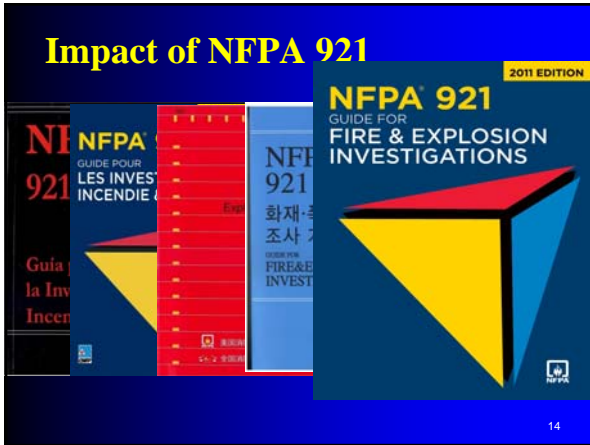
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### Impact of NFPA 921



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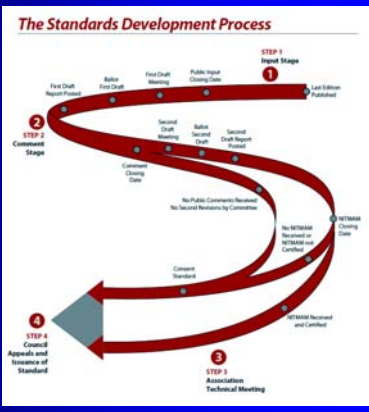
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### NFPA Standards Development Process



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### History of NFPA 921

- First Edition: 17 January, 1992
- Second Edition: 13 January, 1995
- Third Edition: 16 January, 1998
- Fourth Edition: 13 January, 2001
- Fifth Edition: 5 February 5, 2004
- Sixth Edition: 31 December, 2007
- Seventh Edition: 3 January, 2011
- Eighth Edition: January 2014\*



\* First Draft revisions have been published the comment period has closed and the Technical Committee has completed the Second Revision.

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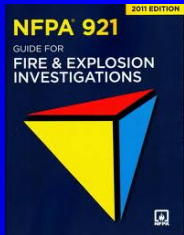
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### NFPA 921 Document Organization

- Part I: Basic Information to Know
- Part II: Fire Investigation Technology
- Part III: Incident Specific Topics



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### Part I: Basic Information to Know:



- Administration
- Referenced Publications
- Definitions
- Basic Methodology
- Basic Fire Science
- Fire Patterns
- Building Systems
- Electricity & Fire
- Building Fuel Gas Systems
- Fire Related Human Behavior
- Legal Considerations

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**Part II: Fire Investigation Technology**



- Safety
- Sources of Information
- Planning the Investigation
- Documentation of the Investigation
- Physical Evidence
- Origin Determination
- Fire Cause Determination
- Analyzing the Incident for Cause and Responsibility
- Failure Analysis and Analytical Tools

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**Part III: Incident Specific Topics**



- Explosions
- Incendiary Fires
- Fire & Explosion Deaths & Injuries
- Appliances
- Motor Vehicle Fires
- Wildfire Investigations
- Management of Major Investigations
- Marine Fire Investigations

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**폭발 조사에 대한 과학적 접근**  
A Scientific Approach to Explosion Investigation

**방법론 연구**  
A study of the Methodology



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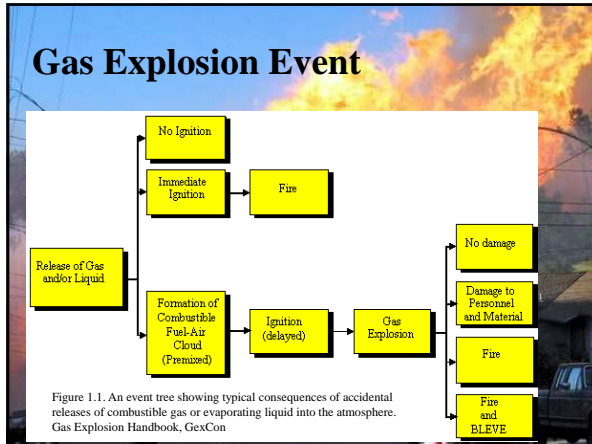
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### Objectives of an Explosion Investigation

*No different than a fire investigation*

1. Determine Origin
2. Identify the fuel
3. Identify the ignition source
4. Determine the Cause
5. Establish responsibility

NFPA 921 (2011) 21.14.1 General.



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### Scientific Method

NFPA 921 Chapter 4  
Basic Methodology

- Recognize the Need
- Define the Problem
- Collect Data
- Analyze the Data
- Develop a Hypothesis
- Test the Hypothesis
- Select Final Hypothesis





FIGURE 4.3 Use of the Scientific Method.

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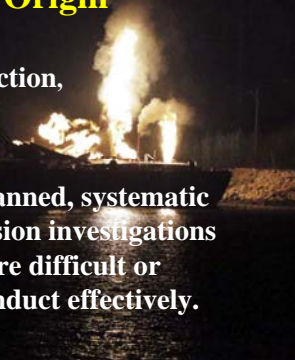
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**Determine the Origin**

Initial Scene Inspection,  
NFPA 921 21.14.3

Without a preplanned, systematic approach, explosion investigations become even more difficult or impossible to conduct effectively.



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**Tools to Determine the Explosion Origin**

(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) *Explosion Dynamics.* The analysis of the explosion dynamics, (NFPA 921 21.1 – 21.15)



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**Surveillance Video** (Witness Information?)

Natural Gas Explosion  
JJ's Restaurant  
Kansas City, Missouri  
February 19, 2013



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**Detailed Analysis**

Does this tell you  
Why or What?



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**Utilize Fire Investigation  
Technology Concepts**

- Safety
- Sources of Information
- Planning the Investigation
- Documentation of the Investigation
- Physical Evidence
- Origin Determination
- Fire Cause Determination
- Analyzing the Incident for Cause and Responsibility
- Failure Analysis and Analytical Tools

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**Origin Determination**

NFPA 921 Chapter 17  
Origin Determination

NFPA 921 21.14  
Investigating the  
Explosion Scene.




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

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### Collect Data



- Basic site data
- Determine pre-explosion conditions
- Documentation of post-explosion conditions
- Excavation, examination, and reconstruction of the scene
- Witness statements and observations
- Fire department information
- Alarm, detector, and security data

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### Analyze The Data, Origin Determination

#### Tools to Utilize

- Identify Damage Effects of the Explosion
- Explosion Dynamics Vector Diagrams
- Event Sequencing
- Construction and Occupancy Considerations
- Computer Modeling

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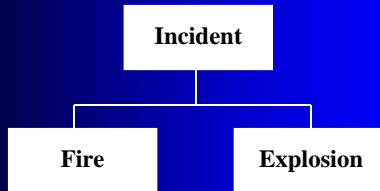
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### 1. Identify Explosion or Fire

NFPA 921 21.14.3.2



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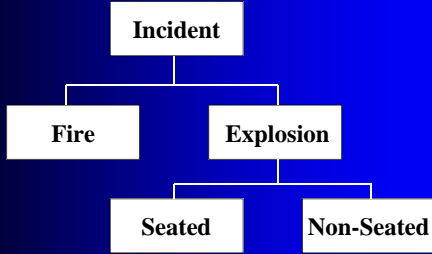
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## 2. Determine if the Explosion is Seated or Non-Seated



NFPA 921 21.14.3.4

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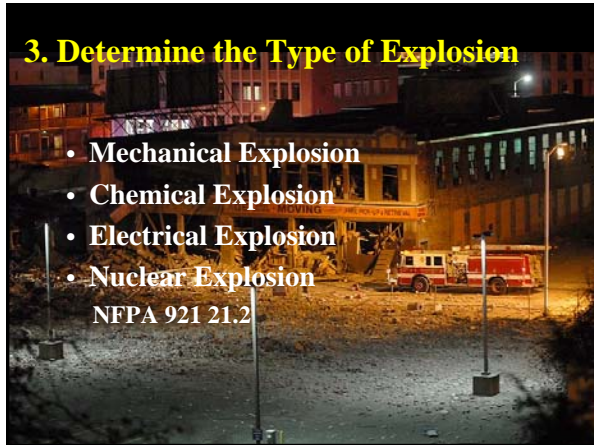
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## 3. Determine the Type of Explosion

- Mechanical Explosion
- Chemical Explosion
- Electrical Explosion
- Nuclear Explosion

NFPA 921 21.2



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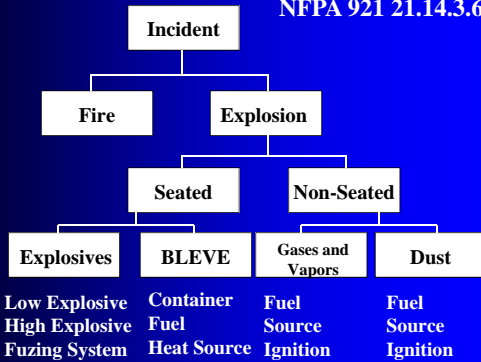
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## 4. Identify Potential General Fuel Type

NFPA 921 21.14.3.6



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**Identify Potential General Fuel Type**

NFPA 921 21.14.3.6



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**Identify Potential General Fuel Type**

NFPA 921 21.14.3.6



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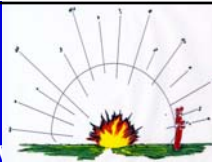
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**5. Identify Damage  
Effects of the Explosion**

- Blast Overpressure and Wave - Positive Phase
- Blast Pressure and Wave - Negative Phase
- Fragment impact
- Thermal energy
- Ground shock
- Dynamic drag loads



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### a. Characterize the Damage

Low Order and High Order  
Damage

- Shattered
- Bent
- Broken
- Flattened
- Look for Changes in the Nature of Damage



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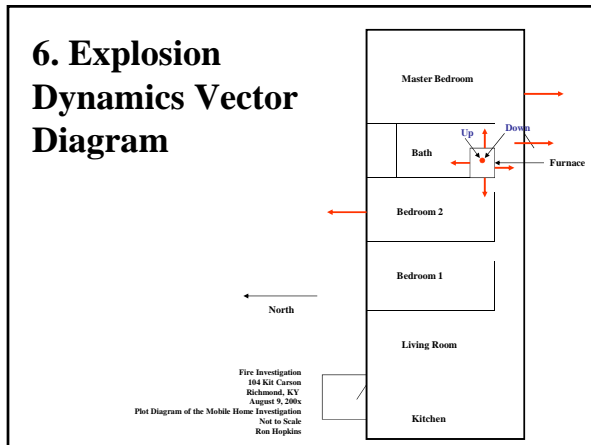
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### 6. Explosion Dynamics Vector Diagram



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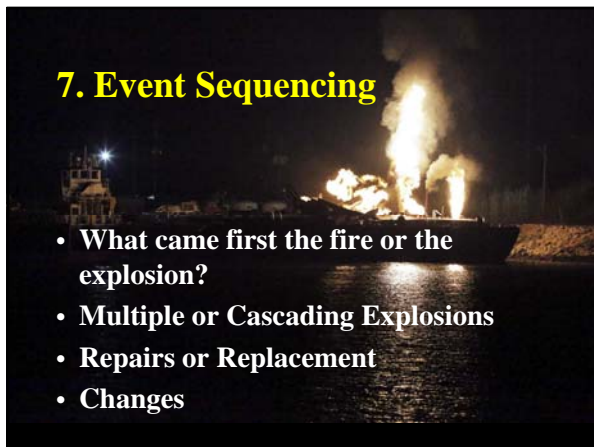
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### 7. Event Sequencing

- What came first the fire or the explosion?
- Multiple or Cascading Explosions
- Repairs or Replacement
- Changes



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## 8. Construction and Occupancy Considerations

- Explosion Venting
- Glass Exterior
- Process Information
- Type of Storage
- Blast Front Modifiers

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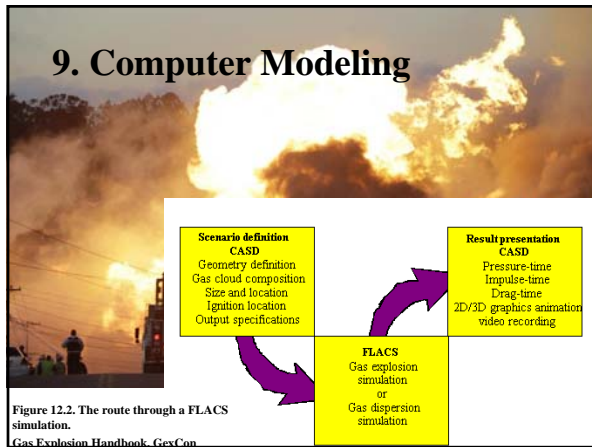
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## 9. Computer Modeling

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## Establish the Origin.

NFPA 921 21.14.3.7

### Select Final Hypothesis

- Area of Origin
- Point of Origin
- Origin insufficient to determine cause

If you do not determine the correct Explosion Origin, then you cannot determine the Explosion Cause.




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**Determine the Cause**

- Detailed Scene Investigation

NFPA 921 Figure 18.2 An Example of Applying the Scientific Method to Cause Determination.

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**Collect Data**

- Identify fuels in area of origin
- Identify potential ignition sources
- Identify oxidizing agent
- Identify circumstances

NFPA 921 Figure 18.2

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**Analyze Data**

- Analyze fuel (ignition temperature, quantity)
- Analyze ignition source (temperature, energy, time)
- Analyze oxidizer, especially if other than air
- Analyze potential ignition sequences

NFPA 921 Figure 18.2

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### Analyze Fuel Source, NFPA 921 21.16

- Knowledge, Authority, and Equipment to complete non destructive and destructive testing.
- Notification of Interested Parties



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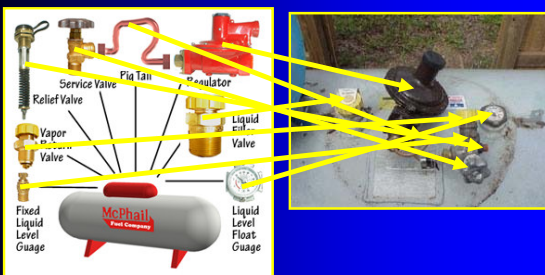
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### Container Appurtenances, (Tanks)



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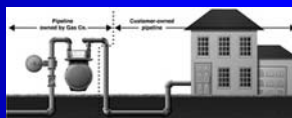
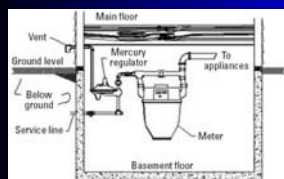
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### Residential NG Regulator and Meter



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**Gas Line Bar Hole Survey**

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**Establish Ignition Source**

Diffuse Phase Fuels  
(Gases, Vapors, Dusts)



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**Evidence Inspection**



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**Develop Cause Hypotheses**

- Separate hypothesis for each potential ignition source
- Consider absent ignition sources
- Propose a first fuel for each ignition source
- Consider alternate hypotheses

NFPA 921 Figure 18.2

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    Example of Applying the Scientific Method to Cause Determination
    1. Recognize the Need: A fire has occurred. The cause is unknown.
    2. Define the Problem: The origin has been determined. Determine the cause.
    3. Collect Data: Identify fuels in area of origin; Identify potential ignition sources; Identify oxidizing agent; Identify circumstances.
    4. Analyze Data: Analyze fuel (ignition temperature, quantity); Analyze ignition source (temperature, energy, time); Analyze oxidant, especially if other than air; Analyze potential ignition sequences.
    5. Develop Cause Hypotheses: Separate hypothesis for each potential ignition source; Consider absent ignition sources; Propose a first fuel for each ignition source; Consider alternate hypotheses.
    6. Test the Hypotheses: Is (or was) the hypothesized ignition source located at the origin? Can the hypothesized ignition source ignite the first fuel? Did the hypothesized ignition source have sufficient time? Is the hypothesized cause consistent with all known facts? Are contradictions resolved? Does another cause hypothesis explain the data equally well?
    7. Select Final Hypothesis: Cause of the fire; List of potential causes; Insufficient information to determine the cause.
    
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**Test the Hypotheses**

- Is (or was) the hypothesized ignition source located at the origin?
- Can the hypothesized ignition source ignite the first fuel?
- Did the hypothesized ignition source have sufficient time?

NFPA 921 Figure 18.2

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    Example of Applying the Scientific Method to Cause Determination
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### Test the Hypotheses

- Is the hypothesized cause consistent with all known facts?
- Are contradictions resolved?
- Does another cause hypothesis explain the data equally well?

NFPA 921 Figure 18.2

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graph TD
    A[Recognize the Need  
A fire has occurred  
The cause is unknown] --> B[Define the Problem  
The origin has been determined  
Determine the cause]
    B --> C[Collect Data  
Identify fuels in area of origin  
Identify potential ignition sources  
Identify oxidizing agent  
Identify circumstances]
    C --> D[Analyze Data  
Analyze fuel (ignition temperature, quantity)  
Analyze ignition source (temperature, energy, time)  
Analyze oxidizer, especially if other than air  
Analyze potential ignition sequences]
    D --> E[Develop Cause Hypotheses  
Separate hypotheses for each potential ignition source  
Consider absent ignition sources  
Propose a first fuel for each ignition source  
Consider alternate hypotheses]
    E --> F[Test the Hypotheses  
Is (or was) the hypothesized ignition source located at the origin?  
Can the hypothesized ignition source ignite the first fuel?  
Did the hypothesized ignition source have sufficient time?  
Is the hypothesized cause consistent with all known facts?  
Are contradictions resolved?  
Does another cause hypothesis explain the data equally well?]
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### Select Final Hypothesis

- Cause of the Explosion
- List of potential causes
- Insufficient information to determine the cause

NFPA 921 Figure 18.2

```
graph TD
    A[Recognize the Need  
A fire has occurred  
The cause is unknown] --> B[Define the Problem  
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Does another cause hypothesis explain the data equally well?]
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### 폭발 조사에 대한 과학적 접근 A Scientific Approach to Explosion Investigation

참여 주셔서 감사합니다  
Thank you for your participation.

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화재 안전 공학 기술  
이스턴 켄터키 대학

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**폭발 조사에 대한 과학적 접근**  
A Scientific Approach to Explosion Investigation

**질문이 있으십니까?**  
Questions?

**론 홉킨스**  
교수 (은퇴)  
화재 안전 공학 기술  
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