“Dangers of Exposures to Cyanide & Toxic Gases in Confined Space Fires”

Edison Electrical Institute
Fall Occupational Safety & Health Committee Conference
Monday - September 24, 2018 to Wednesday September 26, 2018

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Chicago Fire Department (1976-2007 Retired)
Fellow – Institute of Medicine of Chicago
Instructor – National Fire Academy – DHS – FEMA - USFA
Objectives

1. Understand the dangers of smoke inhalation.
2. Discuss cyanide poisoning as important resources for professionals working in the electric power industry.
3. The dangers of cyanide production during fires and during extinguishment of fires producing chemical off gassing.
4. The dangers of confined space fire smoke cyanide.
5. Combustible materials off gassing of cyanide and chemicals.
6. Lessons learned about fire smoke cyanide contamination with fire fighters during fires in the American fire service.
7. The importance and safety on the use of SCBA equipment during fires and extinguishing combustible materials.
Disclosures

• Past-President and Founder of the Cyanide Poisoning Treatment Coalition (CPTC) 2007/08, President - 2005/07

• Deputy Chief and Assistant Deputy Fire Commissioner, Chicago Fire Department’s Bureau of Operations EMS Division, (1976 – 2007 Retired)

• Adjunct Faculty – National Fire Academy – US Department of Homeland Security

• Inspector – State of Nevada DHHS - BHCQC
THE AMERICAN FIRE SERVICE
THEN AND NOW
The Great Chicago Fire
October 8-10, 1871 – What Burned
The Great Chicago Fire
October 8-10, 1871

• Stared Just After 9 PM
• Property of the O’Leary Barn at 13 West De Koven St.
  • Sight of the Chicago Fire Academy
• Wooden House and Buildings
• 300 Killed
• 100,000 Homeless
• Entire Business District Destroyed
The Great Chicago Fire - How Did It Start?
The Great Chicago Fire
October 8-10, 1871 – What Burned

MRS. O’LEARY COW
STORY REFUTED
BY OLD REPORTER
What Do You See Here?
2010 – What is Wrong Here!

BEST OF 2010 IN PHOTOS

A Chicago firefighter breaks through the roof at 1752 W. Cullerton in November. The fire claimed the life a child and injured two others.
Impact of Fire Smoke Inhalation on Mortality

Fire deaths due to smoke inhalation outnumber fire deaths due to burns (2:1 ratio)
NFPA, John R. Hall, Jr., Fatal Effects of Fires” March 2011

Electrical Fires

31,960 - Estimated Annual Average Fires Involving Electrical Distribution or Lighting Equipment in (2010-2014)
- 400 Civilian Deaths
- 1,180 Injuries
- $1.2 Billion Direct Property Damage

- 10,740 (34%) Unclassified Electrical Failure or Malfunction (120 Deaths/400 Injuries)
- 7,550 (24%) Unspecified Short Circuit Arc (120 Deaths/290 Injuries)
- 3,490 (11%) Short Circuit Arc From Defective or Worn Insulation (30 Deaths / 100 Injuries)

NFPA, Richard Campbell, “Electrical Fires” March 2017
<table>
<thead>
<tr>
<th>Factor Contributing to Ignition</th>
<th>Fires</th>
<th>Civilian Deaths</th>
<th>Civilian Injuries</th>
<th>Direct Property Damage (in Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unclassified electrical failure or malfunction</td>
<td>10,740 (34%)</td>
<td>120 (30%)</td>
<td>400 (34%)</td>
<td>$446 (37%)</td>
</tr>
<tr>
<td>Unspecified short circuit arc</td>
<td>7,550 (24%)</td>
<td>120 (31%)</td>
<td>290 (24%)</td>
<td>$308 (25%)</td>
</tr>
<tr>
<td>Short circuit arc from defective or worn insulation</td>
<td>3,490 (11%)</td>
<td>30 (8%)</td>
<td>100 (8%)</td>
<td>$106 (9%)</td>
</tr>
<tr>
<td>Heat source too close to combustibles.</td>
<td>2,020 (6%)</td>
<td>40 (10%)</td>
<td>110 (10%)</td>
<td>$77 (6%)</td>
</tr>
<tr>
<td>Arc from faulty contact or broken conductor</td>
<td>1,590 (5%)</td>
<td>20 (4%)</td>
<td>30 (3%)</td>
<td>$53 (4%)</td>
</tr>
<tr>
<td>Unclassified mechanical failure or malfunction</td>
<td>1,070 (3%)</td>
<td>10 (2%)</td>
<td>30 (3%)</td>
<td>$39 (3%)</td>
</tr>
<tr>
<td>Equipment overloaded</td>
<td>1,000 (3%)</td>
<td>30 (7%)</td>
<td>80 (7%)</td>
<td>$40 (3%)</td>
</tr>
<tr>
<td>Short circuit arc from mechanical damage</td>
<td>840 (3%)</td>
<td>20 (5%)</td>
<td>20 (2%)</td>
<td>$31 (3%)</td>
</tr>
<tr>
<td>Arc or spark from operating equipment</td>
<td>750 (2%)</td>
<td>10 (2%)</td>
<td>20 (2%)</td>
<td>$31 (3%)</td>
</tr>
<tr>
<td>Unclassified misuse of material or product</td>
<td>550 (2%)</td>
<td>0 (1%)</td>
<td>50 (4%)</td>
<td>$17 (1%)</td>
</tr>
<tr>
<td>Worn out</td>
<td>440 (1%)</td>
<td>10 (2%)</td>
<td>10 (1%)</td>
<td>$13 (1%)</td>
</tr>
<tr>
<td>Unclassified factor contributing to ignition</td>
<td>390 (1%)</td>
<td>0 (1%)</td>
<td>10 (1%)</td>
<td>$11 (1%)</td>
</tr>
<tr>
<td>Storm</td>
<td>360 (1%)</td>
<td>10 (2%)</td>
<td>0 (0%)</td>
<td>$13 (1%)</td>
</tr>
<tr>
<td>Water caused short-circuit arc</td>
<td>350 (1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>$9 (1%)</td>
</tr>
<tr>
<td>Installation deficiency</td>
<td>330 (1%)</td>
<td>0 (0%)</td>
<td>10 (1%)</td>
<td>$16 (1%)</td>
</tr>
<tr>
<td>Equipment unattended</td>
<td>260 (1%)</td>
<td>0 (0%)</td>
<td>20 (1%)</td>
<td>$11 (1%)</td>
</tr>
<tr>
<td>High wind</td>
<td>220 (1%)</td>
<td>0 (0%)</td>
<td>10 (0%)</td>
<td>$12 (1%)</td>
</tr>
<tr>
<td>Animal</td>
<td>200 (1%)</td>
<td>0 (1%)</td>
<td>0 (0%)</td>
<td>$4 (0%)</td>
</tr>
<tr>
<td>Equipment not being operated properly</td>
<td>140 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>$0 (0%)</td>
</tr>
</tbody>
</table>
Water Is Clear & You Are 200 Feet Down
Would You Take Your Make Off?
Why Can’t We Get Firefighters and Industrial Professionals To Wear Their SCBAs
Kids Love Firemen – Firemen Love Kids
Toxins Compounds Found on Fire Fighter Gear

Pesticides
Metals
  Arsenic
  Mercury
  Magnesium
  Cobalt
Cadmium
Polybrominated Diphenyl Ethers (PBDE)
Polychlorinated Biphenyls (PCBs)
Polyaromatic Hydrocarbons (PAHs)
Plasticizers

Tabitha Nicole Huston, IDENTIFICATION OF SOILS ON FIREFIGHTER TURNOUT GEAR
FROM THE PHILADELPHIA FIRE DEPARTMENT, University of Kentucky December 14, 2014
Questions

• How many of you work or know of co-workers that work in electrical vaults or confined spaces with electric equipment?

• How many of you work or know of co-workers that responded to active fires in electrical vaults or confined spaces with electric equipment?

• How many of you work or know of co-workers that worked to repair electrical vault equipment or confined spaces after an electrical fire?
Let's Take A Look At Cyanide

• Substrates for hydrogen cyanide frequently found in modern buildings (natural and synthetic substances containing carbon and nitrogen, such as plastics, PVC, wire casings, wool)

• Release of hydrogen cyanide highly probable and to be expected in enclosed-space fires

• Cyanide can act independently from carbon monoxide
Anatomy of Fire Smoke

- **Particulates**
  - Dust
  - Soot
- **Irritants**
  - Hydrochloric acid
  - Sulfur dioxide
  - Oxides of nitrogen
  - Ammonia
- **Asphyxiants/Toxicants**
  - Carbon dioxide
  - Hydrogen cyanide
  - Carbon monoxide
  - Hydrogen sulfide
## Properties of Gases Typically Found In Smoke

<table>
<thead>
<tr>
<th>Gas</th>
<th>Flashpoint</th>
<th>Self-Ignition Temp.</th>
<th>Flammable Range in Air</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td>See notes</td>
<td>1,123°F</td>
<td>12-74%</td>
<td>CO is considered a gas only—and, therefore, doesn’t have flashpoint. The flammable range of CO is 12-74 only at the ignition temperature. The flammable range of CO decreases below its ignition temp. Below 300°F, the flammable range of CO is negligible.</td>
</tr>
<tr>
<td>(CO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acrolein (C₅H₅O)</td>
<td>-15°F</td>
<td>450°F</td>
<td>3-31%</td>
<td>Acrolein is a by-product from the incomplete combustion of wood, wood products, and other cellulosic materials. Polyethylene can also render acrolein.</td>
</tr>
<tr>
<td>Benzene (C₆H₆)</td>
<td>12°F</td>
<td>928°F</td>
<td>1-8%</td>
<td>Most plastics release benzene while burning. Benzene is also a common product from the burning of fuel oils.</td>
</tr>
<tr>
<td>Hydrogen Cyanide (HCN)</td>
<td>0°F</td>
<td>1,000°F</td>
<td>5-40%</td>
<td>HCN is produced when high temperatures break down nitrogen-containing products. HCN is quite flammable and is considered extremely toxic.</td>
</tr>
</tbody>
</table>

Source: [http://www.cdc.gov/niosh/npg/npg.html](http://www.cdc.gov/niosh/npg/npg.html)
Sources of Cyanide in Fires

The source of cyanide in enclosed-space fires — for example, tunnels, subways, and transportation vehicles (e.g., planes, cars, buses) is primarily from materials containing carbon and nitrogen, such as silk, wool, nylon, and certain plastics.

References
Fire Smoke as a Source of Cyanide

- Cyanide produced by combustion of both synthetic and natural substances

- Most common source of acute cyanide poisoning in the US

- Contributes significantly to smoke inhalation injury and death
The Impact of Cyanide as Isocyanates* in Estimating the Cyanide-associated Hazards of Fire Smoke

*Total isocyanate concentrations (μg/m³) in cone calorimeter tests.

A Special Case Study

Providence R.I. Firefighters
March 2006
Fire Scene: Building Structure

A Special Case Study
March 2006

- One-story commercial structure built in the 1970s
- Substandard construction methods according to NFPA’s* Standard 220
- Wall finishes identified as fiber reinforced plastic panels
- Underside of roof covered by foam insulation panels
- Rubber membrane material used as sealant
Fire Scene: Smoke Conditions

Fire Scene:
Roof Top Ventilator - Initial Source of Fire

Fire Scene: Extensive Damage
The Fire Victim

• 42-year-old male firefighter reported to be speaking incoherently after fire and appearing disoriented before leaving the scene

• Complained of headache, nausea, dizziness, difficult breathing with shortness of breath, fatigue, a rapid heart rate, and cough after returning to the station

• Later transported to the hospital
Observations and Remarkable Lab Findings

Observations

• Time exposed to smoke* 20–30 min
• Time without SCBA† 10–15 min
• Time elapsed between blood draw and fire 2 - hours

Lab Findings

• Lactate 1 mEq/L
• Carbon monoxide‡ 3%
• Cyanide 0.57 mg/L

*Includes intermittent exposures and exposures to light smoke. †SCBA, self-contained breathing apparatus. ‡Carboxyhemoglobin.

Over the Next 16 Hours: Two More Fires

• Fire responds to two multiple dwelling built in 1900s; routine operations

• Fire in single family residential home built in 1930; routine operations until a firefighter collapses
  • Treated on scene
  • Transported to local hospital

• Fuels known to release hydrogen cyanide upon combustion found at all 3 locations
Investigation and Medical Evaluations

• **Directive issued:** Every firefighter who responded to the 3 fires instructed to seek medical treatment

• 28 firefighters evaluated

• 27 confirmed cyanide exposures

• 5 identified with cyanide in blood > 0.5 mg/L
Key Findings – Cyanide +

• Concentrates of combustion products were found to vary tremendously from fire to fire.

• Asphyxiates
  • Carbon Monoxide
  • Carbon Dioxide
  • Hydrogen Sulfide

• Irritants
  • Ammonia
  • Hydrogen Chloride
  • Particulates
  • Nitrogen Oxides
  • Phenol
  • Sulfur Dioxide
Onset of Signs and Symptoms of Cyanide Intoxication via Inhalation

0–15 SECONDS: Transient hyperpnea

30–45 SECONDS: Convulsions

2–3 MINUTES: Respiratory depression and arrest

6–8 MINUTES: Cardiac arrest
What happens to a Firefighter after the line of duty death?

Immediate Death vs. Long Term Death related to occupational environments.

Do we look for the same things when a Firefighter dies of cancer, lung diseases, or other medical conditions?
Fire Fighters

- How many deadly chemicals does a Firefighter inhale in a 25 year career?
- Who is currently looking into toxic chemicals in fire smoke?

Electrical Professional

- How many deadly chemical does an Electrician inhale?
- Who is currently looking into toxic chemicals encountered during work?
Lets Talk About the Big “C” and Fire Fighters

CANCER!

Can this be the same for other industrial professionals?
1/3 Of Firefighters in Seattle Hired Before 1977 Have Developed Cancer

- 57 Year Old Professional Fire Fighter
- Joined When He Was 20
- CA in the Esophagus
- CA Progressed Into His Liver & Lymph Systems
Humans are primarily nasal breathers.

Tracheal Mucosa Insult.
975 Seattle Firefighters Hired Before 1977

- 347 Had Cancer, Had Been Treated for Cancer (33.8%)
- 47 Diagnosed Since 2008 (4.5%)
- 38.4% of Total Affected

Trevino, M.H., Seattle, WA
Thyroid Cancer / Nomex Hoods

- Fire Fighter Hoods Collect Chemicals and Particulates
- Thyroid located in the area that is closest to the skin.
- Susceptible to permeation of the carcinogens from the hood
- Washed after and active fire.
- Inspected and exchanged each year.
- Two to Three Should Be Assigned to Each Fireman
Cancer Incidents Among Firefighters

- Annual Duty Death Average 100 – more die per year from cancers.

- Firefighters are 200% more Likely to Get Cancer than General Population.
  - 300% Lung Cancer
  - 200% Throat Cancer
  - 150% Pancreatic AC
Groups Discussion Question?

- Who has died of cancer on in your company?
- How long he/she been in their profession?
- Was he/she ever exposed to fires or post electrical fires confined spaces to repair equipment?
- What type of cancer did he/she have?
- How old was he/she when they found out they had cancer?
- Is cancer a duty related death?
- Is health and safety risk managers looking at this closely?
Past Job Cultures - Hard to Change
Are We Slowly Killing Ourselves?

• Are we too Aggressive to get the power back on?
• Are PPE available, but not used?
• Are you a “Smoke Eaters” and don’t even know?
• Do you bring home toxic chemical on your work clothing?
• Are clean-ups, repairs, and being in confined spaces for hours / days an issue of occupational safety?
• Is there widespread tobacco use of employees?
• Are diet and health allowing you to live longer?
Cultural Change

• Our culture is already changing all around us:
  – Smoking
  – Alcohol Use
  – Health Screening

• Sources of the change in the fire service:
  – Legal mandates (OSHA, Federal Regulations)
  – Contractual requirements
  – “New blood”
  – Changing customs and the way we work
  – Science, technology, and knowledge
  – LEADERSHIP!
PROTECTING YOURSELF FROM CANCER

• Wear Your PPE’s!
• Clean your PPEs, especially your work clothing & helmets!
• Eat Healthy Foods
• Reduce Stress
• Exercise
• Don’t Use Tobacco
• Get Tested / Annual Checkups
• Take Minor Infections Seriously
• Find Peace and Faith
What is Smoke Inhalation?

Smoke inhalation is the primary cause of death in victims of indoor fires. The smoke kills by a combination of thermal damage, poisoning and pulmonary irritation caused by carbon monoxide, hydrogen cyanide and other combustion products.
Understanding Smoke Inhalation

- Three primary mechanisms of injury
  1. Thermal damage
  2. Pulmonary irritation
  3. Asphyxiation due to chemicals such as carbon monoxide or cyanide

- Manifestation of symptoms may be delayed until 24-36 hours after injury
  - Early symptoms may appear to be resolving
  - Full magnitude of injury should not be underestimated

Cyanide Lethality: Chemical Asphyxiation

Manifestations of Acute Inhalational Cyanide Poisoning

- Anxiety
- Headache
- Tachypnea
- Confusion
- Lethargy

- Agitation
- Bradypnea
- Seizures
- Coma

Incapacitation can occur within seconds and death can occur within minutes.
Suspect Cyanide Exposure in Any Closed-Space Fire

Cyanide Mechanism of Action

• Blocks aerobic metabolism and energy production: cellular hypoxia
  • Cells immediately starve for oxygen and die
  • No amount of supplemental oxygen can overcome the deficit in affected cells
  • Causes shift to anaerobic metabolism
• Byproducts of anaerobic metabolism (eg, lactic acid) accumulate
• Death from central respiratory arrest

Cyanide Lethality: Chemical Asphyxiation

Holstege CP, et al.
Progression of Symptoms of Acute Cyanide Poisoning

Cyanide Toxicity

Route of exposure

Duration of exposure

Concentration of exposure

Patient characteristics

Cyanide toxicity

Toxicity of Fire Smoke: Conclusions

• Cyanide is likely to be present in appreciable amounts in modern fire victims’ blood

• Frequent co-exposure to carbon monoxide and cyanide occurs

• Although carbon monoxide is likely a major toxicant in fires, cyanide can sometimes be the principal cause of death

• Addition of cyanide can result in much lower than expected OCHbl levels in fire victims

Alaire Y. Critical Reviews in Toxicology. 2002;32:259-289
Smoke Inhalation Treatment

(AFTERMATH Video)

TO HELL AND BACK

CYANIDE POISONING
National firefighter training program - first introduction to Toxic Twins: HCN & CO. Mandatory program, Advanced Haz Mat, National Fire Academy – USFA – FEMA - DHS
Summary: Next Time You Go Into Repair This Confined Space After A Fire – Will You Look At The Work Area Differently?
Question and Answer Session