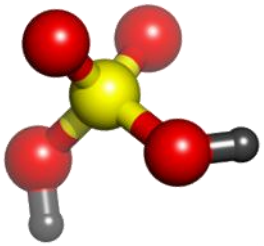

SAND2012-1755C
SAND2012-1755 C

Security Considerations with Industrial Fire Protection

Eric D. Branson
Sandia National Laboratories

Bandung, Indonesia

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories

Primary Course Objectives

- Provide a broad overview of industrial fire protection
- Apply engineering principles to generic industrial fire protection issues
- Discuss historical examples of industrial fire protection hazards

- Develop security related scenarios which may be compromised by fire, explosion, or inadvertent chemical release

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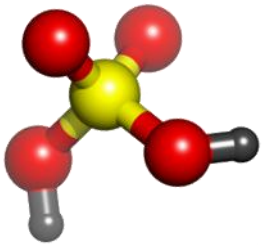

Key Terms

- Siting – fix or build something in a particular place
- Egress – pathways for entering and exiting
- Suppression – extinguishing or containing of fire
- Extinguishability – ability to completely disrupt fire process
- Compartmentation – ability to isolate particular areas from other area

Course Structure

- Introduction
- Perspectives and statistical overview
- Facility/Plant siting and location
- Construction considerations
  - Fire resistant construction
  - Smoke control
  - Fire suppression systems
- Storage of flammable liquids
- Ignition Sources
- Security considerations and scenarios

http://www.draegerdive.com

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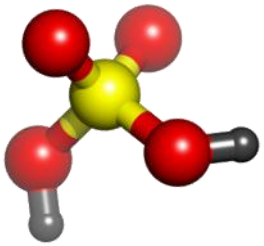

Introduction to Industrial Fire Protection

For common workplace conditions, fire safety may be achieved by simple methods

- Enforcement of approved fire codes and standards
  - National Fire Protection Association (NFPA)
    - http://www.nfpa.org/index.asp
  - International Building Codes (IBC)
    - http://www.iccsafe.org/Pages/default.aspx
- Local or national fire officials and chiefs

NFPA National Fire Protection Association
The authority on fire, electrical, and building safety

ICC INTERNATIONAL CODE COUNCIL
People Helping People Build a Safer World™

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Introduction to Industrial Fire Protection

- Industrial facilities have unique hazards
  - Chemical production or use
  - Storage of flammable or volatile materials
  - Access controls or personnel restrictions
- Unique operations require additional considerations included with simpler methods

superstock.com

news.thomasnet.com

kellerfencenorth.com

www.archiexpo.com

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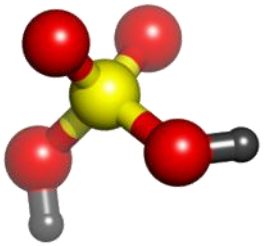

Introduction to Industrial Fire Protection

- Additional considerations require the use of an engineering approach
- Steps for an engineering approach include
  - Identification of possible accident scenarios
  - Analysis of consequences resulting in accidents
  - Evaluation of alternative protection methods

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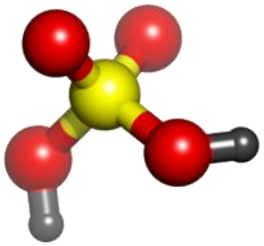
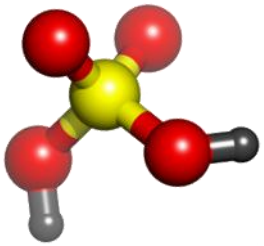


Introduction to Industrial Fire Protection

Scenario Identification

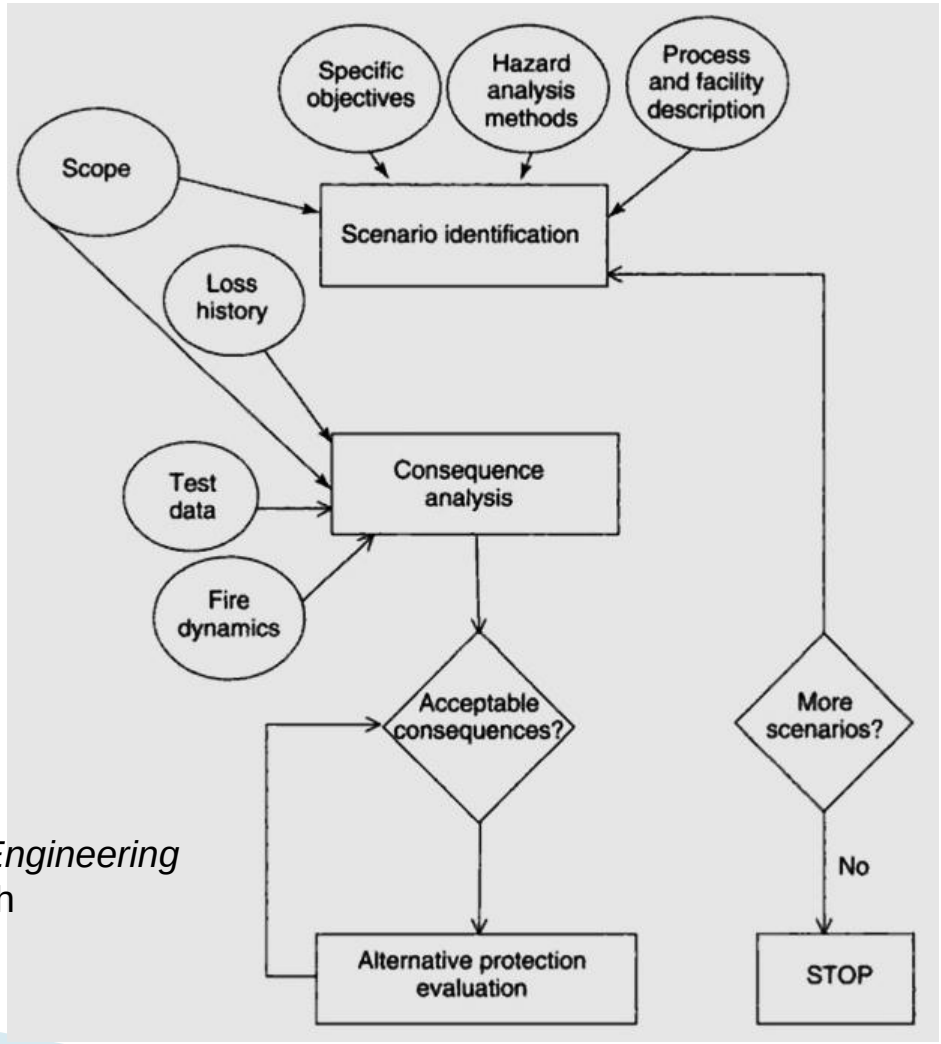
- Pre-incident situations (start-up, maintenance, shutdown)
- Ignition source
- Ignited material
- Flaming or smoldering combustion
- Fire spread and heat release rates of ignited material
- Fire spread to secondary combustibles



Introduction to Industrial Fire Protection

- Consequence Analysis
  - Property damage or loss
  - Personnel injury or fatality
  - Interruption of operation continuity
  - Explosion damage (i.e., surrounding community)
- Evaluation of alternative protection methods
  - Effectiveness (e.g., prevention of life/property loss)
  - Benefits (e.g., financial, continuity of operation, environmental)

Introduction to Industrial Fire Protection



Industrial Fire Protection Engineering
Robert G. Zalosh

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Perspectives and Statistical Overview

- Types of facilities involved in large monetary loss fires
  - US industrial fires with >$30M US property damage
  - European large-loss fires
- Types of fires and explosions in large industrial losses
- Industrial fires with most fatalities

http://www.safety-s2s.eu

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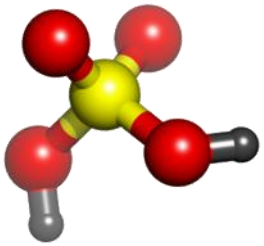

Perspectives and Statistical Overview

- Ignition sources in large loss fires
- Time of fire initiation
- Presence of automatic detection and suppressions systems
- Effectiveness of detection and suppression systems

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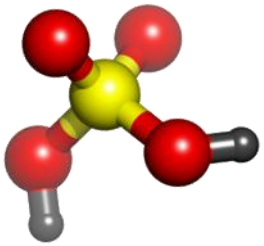
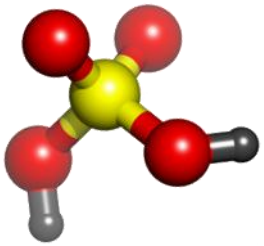


Perspectives and Statistical Overview

Type of Facility	Number of >$30M Losses	% of U.S. Large Loss Fires
Warehouses	17	27%
Petroleum Refineries	12	19%
Power Plants	5	8%
Chemical Plants	5	8%
Grain Elevators	3	
Textile Plants	2	
Telephone Exchanges	2	
Ink Manufacturing	2	
Aluminum Plants	2	

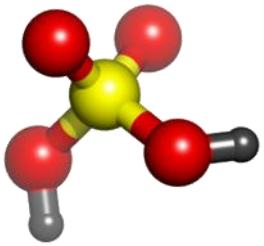
Historic data on US fires prior to 2003



Perspectives and Statistical Overview

Type of Fire/Explosion	% of Incidents	Example
Flammable Liquid	17%	GM Livonia, Sandoz Basel
Plastic Storage	12.5%	Ford Cologne Warehouse
Dust Explosion	9%	Malden Mills
Vapor Cloud Explosion	8%	Phillips Petroleum
Gas Explosion	5%	Ford Rouge Powerhouse
Electrical Cable	5%	Ameritech Hinsdale
Aerosol Products	5%	K Mart
Gas Fires	5%	Gas Turbine Fire, VA

Historic data on US fires prior to 2003



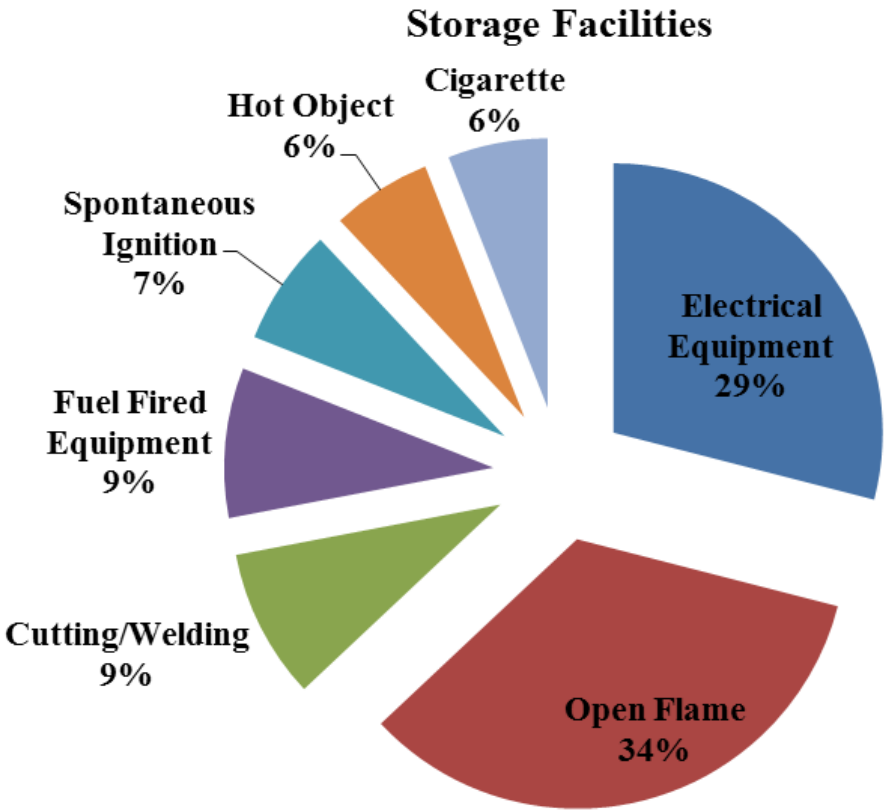
Perspectives and Statistical Overview

Type of Facility	# of Incidents	# of Fatalities	Example
Petrochemical Plant	10	726 – 967	Pemex, Mexico City
Factories	9	549 – 606	Garment Factory in Bangladesh
Offshore Oil/Gas Platforms	2	203	Piper Alpha, North Sea
Fireworks Facility	5	145	Jennings, Oklahoma USA

- Multiple Fatality (>20)
- Industrial fires and explosions between 1981 - 2000

Perspectives and Statistical Overview

Ignition sources in large loss fires



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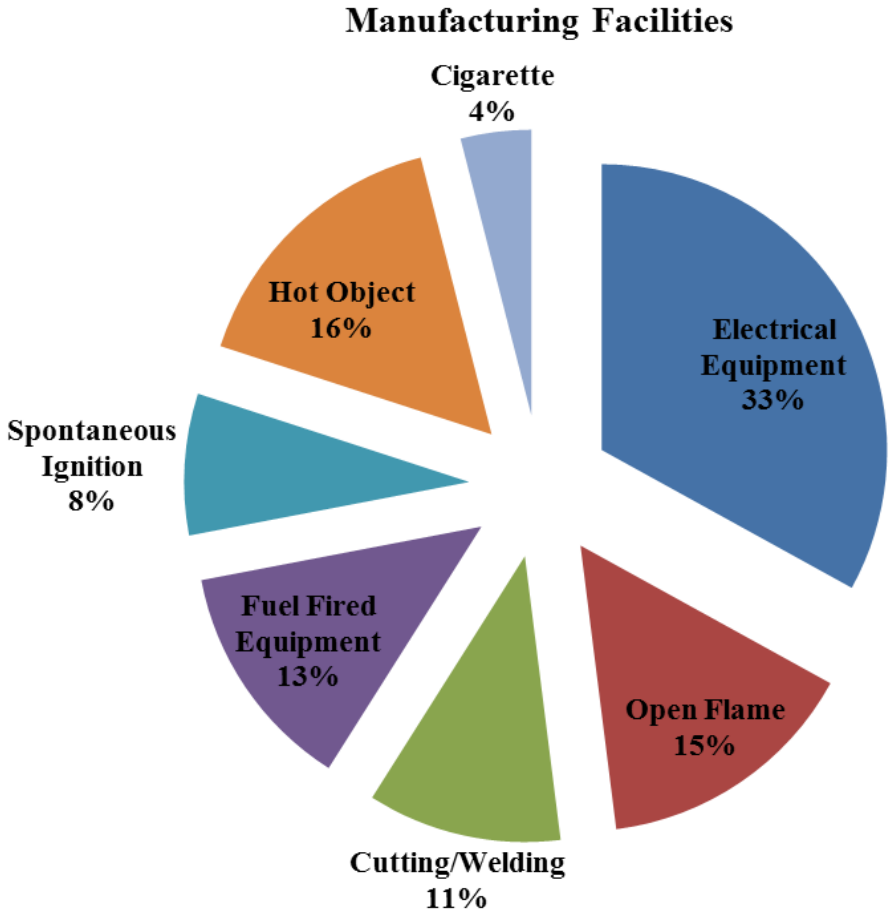
Perspectives and Statistical Overview

Ignition sources in large loss fires



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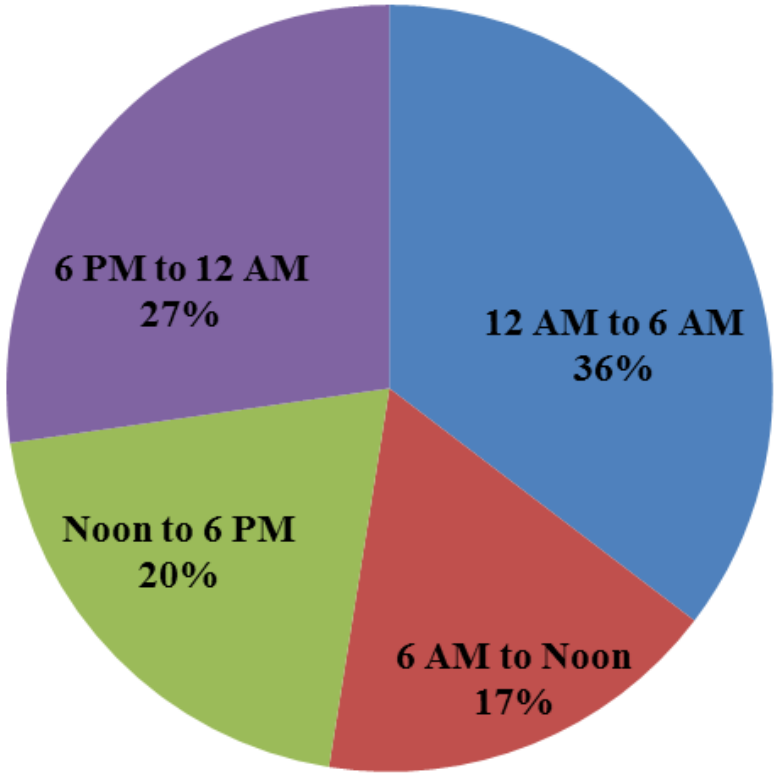
Perspectives and Statistical Overview

Time Distribution of large loss fires from NFPA data on 338 Fires in 1985



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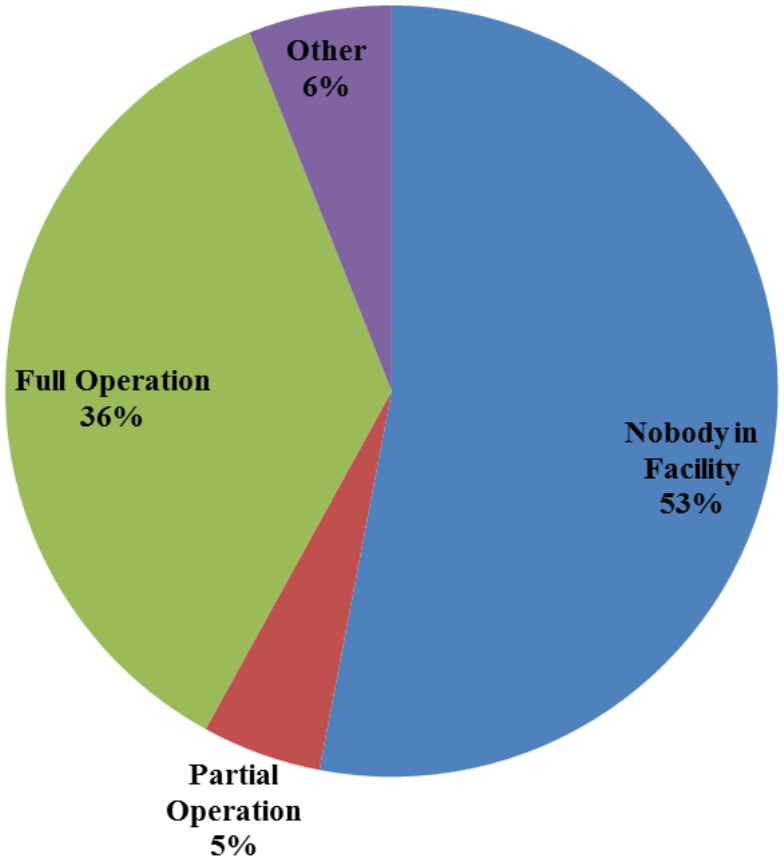
Perspectives and Statistical Overview

Operational status of facilities in large loss fires



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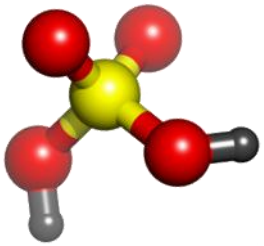
Perspectives and Statistical Overview

Automatic Sprinkler System Status	Number of Fires
Not Installed	14
Overpowered by Fire	7
System Shut Off Before Fire	2
Not in Area of Fire Origin	3
Damaged by Explosion	1
Unknown	1
Total	**28**

Status of automatic suppression systems in 1987 large loss fires (NFPA Journal, 1988)



Perspectives and Statistical Overview

Automatic Detection System Status	Number of Fires
Not Installed	19
Functioned as Designed	4
Not in Area of Fire Origin	1
Installation Incomplete	1
Unknown	3
Total	**28**

Status of automatic detection systems in 1987 large loss fires (NFPA Journal, 1988)

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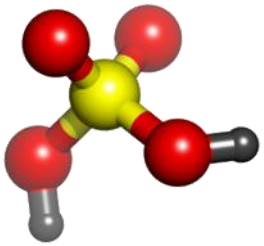

Facility Siting and Location

- Safe separation distances
  - Flame radiation
  - Toxic and/or flammable vapor clouds
  - Blast waves
- Water supply access and reliability
  - Susceptibility to drought
  - Robust supply of water

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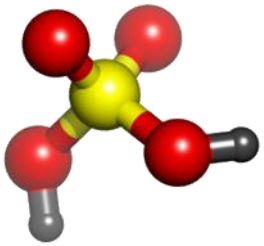
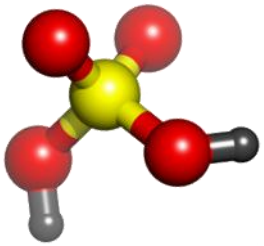


Facility Siting and Location

- Safe egress, rescue, and manual fire fighting
  - Egress to adjacent protected building or designated area
  - Distance from fire department
  - Site accessibility
- Hazard segregation and isolation
  - Grouping similar hazardous chemicals
  - Isolating and protection special or targeted dual use chemicals
  - Isolation and elimination of ignition sources



Facility Siting and Location

Miscellaneous considerations

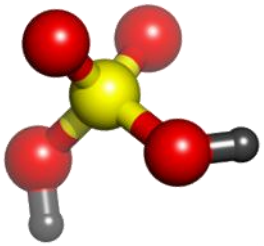
- Environmental (e.g., flooding, drought)
- Naturally occurring hazards (e.g., earthquake)
- Water run-off with the possibility of contamination
  - Waterways such as rivers, lakes, ponds
  - Underground aquifer
  - Food supplies

Facility Siting Incident

- Sandoz Basel Fire, 1986 in Switzerland
- Textile and agrochemical manufacturing facility
- Structural steel framed building that was 90m long, 50m wide with two 12m high peaks. 12cm brick wall in the middle to create two separate buildings

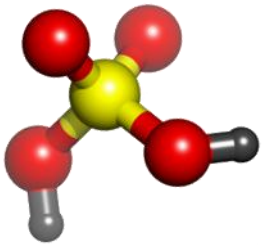
http://www.swissinfo.ch/eng

http://www.novaquatis.eawag.ch/media/2006/20061101/index_EN



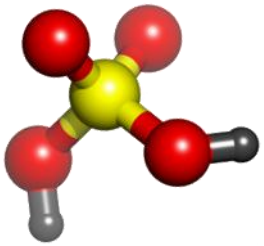
Facility Siting Incident

- Original use was for machinery storage, converted over to flammable liquids storage
  - Explosion-proof electrical fixtures
  - Sealed sewer drains
  - Installed three water curtains to be operated by plant fire brigade
- No automatic sprinklers or smoke detectors
- Chemicals stored in plastic bags, plastic and steel drums
- Materials stacked to maximum height of 8m



Facility Siting Incident

- Storage at the time of incident
  - 859 metric tons of organophosphate insecticide
  - 12 metric tons of a phenyl-urea derivative used for weed control
  - 73 metric tons of di-nitrocresol derivative herbicide
  - 26 metric tons of fungicide
  - 11 metric tons of water soluble organic mercury compounds
  - 5.6 metric tons of misc. agrochemicals
  - 364 metric tons of various formulating agents
- Most have flash points of 30°C and higher



Facility Siting Incident

- Incident occurred on October 31, 1986
- Key points to the incident
  - Palletized chemicals were plastic shrink wrapped and then finished by using a blow torch
  - Plastic wrap could ignite if exposed for sufficient duration
  - Chemicals in the warehouse (e.g., Prussian Blue dye) could burn flamelessly, smokelessly, and slowly thus eluding early detection by workers
  - No automatic suppression or smoke detection

Facility Siting Incident

- Initial fire responders determined that fire spread was too rapid to control
  - Fire foam was used, but proved to be ineffective
  - Responders directed to cool surrounding buildings
  - Limited success as steel drums were propelled from the building of fire origin to adjacent structures
- Water was applied at 30 cubic meters per minute
- Containment basins filled quickly and toxic chemicals flowed into the Rhine River

http://www.rockwool.com

http://www.swissinfo.ch/eng

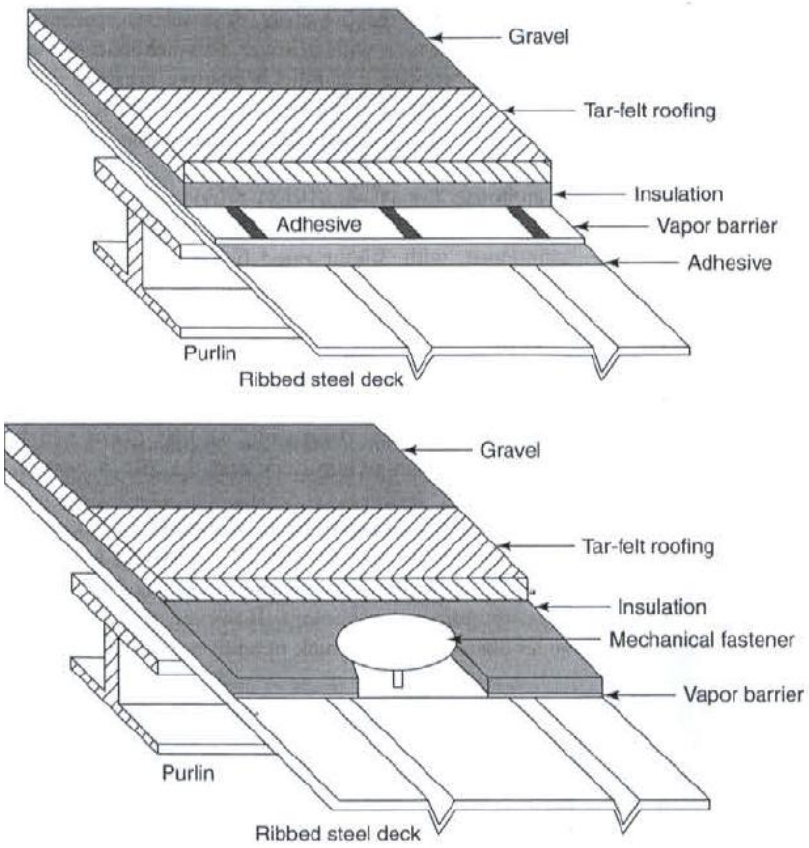
Facility Siting Incident

- Extensive environmental impacts
  - Most fish were killed by mercury poisoning in a 250km section of the Rhine downstream of Basel
  - Subsoil water levels had to be pumped away to preserve the municipal underground water supply
  - Wind carried the smoke produced by the fire over residential communities causing eye and respiratory issues
- Extensive financial impacts
  - $60M US in settle charges
  - Figure does NOT include environmental clean-up and restoration efforts

http://www.novaquatis.eawag.ch/media/2006/20061101/index_EN

Construction Considerations

- Fire resistant construction
  - Fire walls – hour rating
  - Fire doors – prevents smoke form passing under
  - Roofing – connecting areas, fastened to fire walls
- Smoke control
  - Isolation
  - Ventilation
- Fire suppression systems
  - Not only water but could include foams, dry chemical, carbon dioxide, halon, etc.



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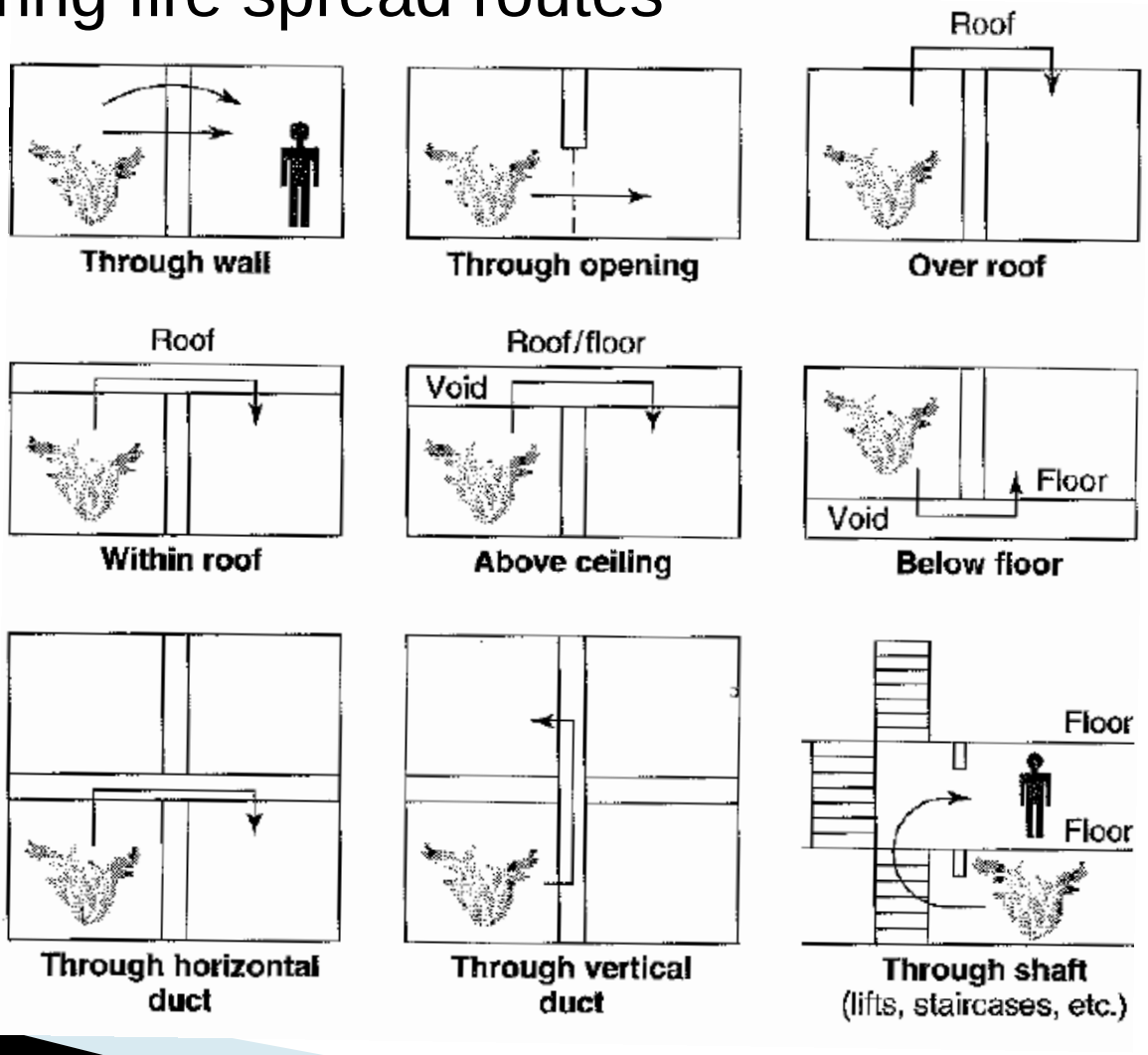
Robert G. Zalosh

Construction Considerations

Frequency occurring fire spread routes

= Fire

= Fire route



ISO TC 92, SC4 Fire Safety Engineering

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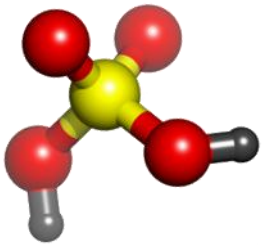
Construction Considerations

- Structural and thermal properties of construction material
- Fire resistance analytical calculations
- Fire resistance testing for listing
- Fire wall design and loss experience
- Insulated metal deck roofing
- Water spray protection of structural steel
- Protective insulation materials on structural steel

Protective spray insulation material for structural steel

www.barrierst.com



Storage of Flammable Chemicals

- Chemical properties must be considered
  - Flash point
  - Auto-ignition temperatures
  - Extinguishability
- Storage tanks
  - Capacity
  - Tank spacing
  - Emergency ventilation
  - Fire suppression
  - General designs should be approved to meet specifications (such as FM Global – Factory Mutual)

FM APPROVED

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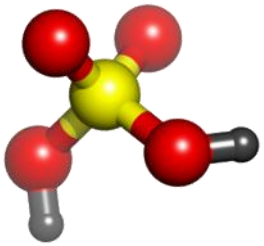
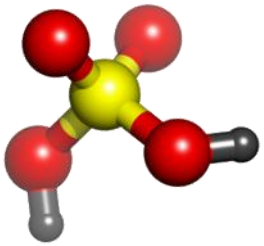
Ignition Sources

- Sparks produced during welding or maintenance
  - General Motors Livonia Fire, 1953
  - 6 fatalities, $35M US property loss
- Discarded cigarette
  - Ford Cologne Fire, 1977
  - $100M US property loss
- Open flame
  - Sandoz Basel Fire, 1986
  - $60M US property loss,
  - Thousands experienced health issues
- Electrical arc in wiring
  - Hinsdale Telephone Office Fire, 1988
  - Between $40 – 60M US property loss



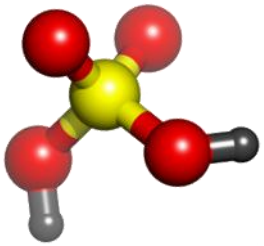
Security Considerations

- Access of fire fighting personnel into secured areas
- Cable fire affecting security system reliability
  - Effects pumps, lights, cameras, security gates, etc.
- Occupant load of security personnel in spaces with insufficient exits
- Fire as a means of distraction
  - Pulls resources away



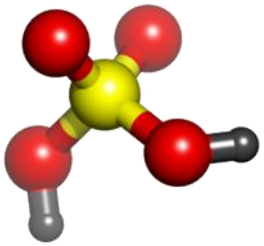
Lessons Learned

- Need for fire walls and other passive barriers
- Need for roof deck fire spread tests
- Need to regularly test sprinkler water flow rates and to fixed known impairments
- Need for fire resistant electrical cables
- Need for containment of contaminated water run-off



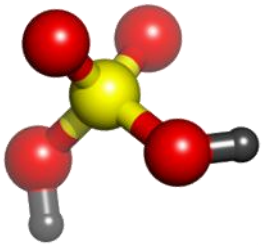
Lessons Learned

- Need to upgrade warehouse sprinkler protection to accommodate storage of more combustible commodities
- Need for smoke control in facilities with equipment vulnerable to damage from smoke and corrosive combustion products
- Need for adequate emergency egress provisions for large number of workers
- Need for improved protection of flammable liquid warehouse



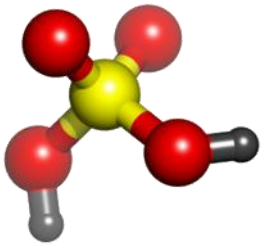
Areas Needing Improvement

- Need for automatic detection and suppression systems in areas containing large quantities of electrical equipment and cables
- Need for adequate emergency egress provisions for large numbers of workers
- Effective sprinkler protection for flammable liquids in plastic containers



Areas Needing Improvement

- Need for compartmentation via reliable fire walls and doors in large manufacturing facilities
- Need to restrict storage of special hazard commodities in general purpose warehouses
- Problems caused by residue of flammable liquids on building walls, ceilings, and floors



Summary of Key Points

- Broad overview of industrial fire protection
- Engineering based methodology to identify potential fire hazards
- Context of historic fires
- Security considerations which may be compromised by fire or explosion

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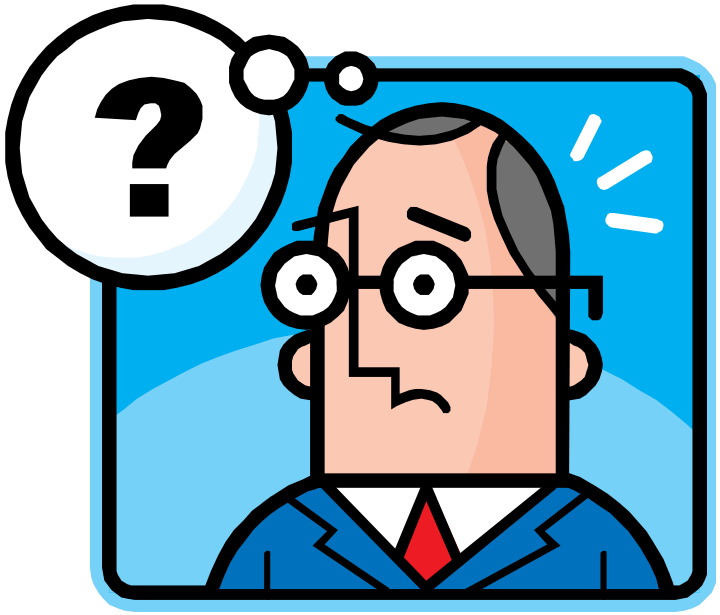
Questions?



Eric D. Branson
edbrans@sandia.gov

Jason W. Brown
jbrown2@sandia.gov

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References and Additional Sources

- *Industrial Fire Protection*, Robert Zalosh
- *SFPE Handbook of Fire Protection Engineering*
- *Fire Dynamics*, Dougal Drysdale
- *Principles of Smoke Management*, John Klote and James Milke
- *Ignition Handbook*, Vytenis Babrauskas