

The Impact of Portable Fire Extinguisher Agents on Cultural Resource Materials

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FIRE PROTECTION
RESEARCH FOUNDATION
Research in support of the NFPA mission



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30 YEARS OF FIRE ENGINEERING LEADERSHIP

Role of Portable Extinguishers in Cultural Resource Protection

- Limit damage to irreplaceable objects and structures
- There is usually a trained staff
- Which agent/unit is best?
 - Fire performance
 - Collateral damage
 - Cost

Cultural Resource Collections

- Museums
 - Art galleries
 - Natural history
 - Antiquities and new technologies
- Libraries
- Historic structures

Project Objectives

- Quantify Impact of Discharging Agent on Materials
- Provide Data to NFPA 909 and 914 for Extinguisher Selection

Phase I

- Literature Review
- Prototype Test Specifications



- Proposed Phase II Validation Tests

Extinguishers of Interest

- Water (mist)
- ABC Dry Chemical
- Clean Agent Halocarbon
- CO₂

Early Stage Fire Scenarios – Fire Loss

- Data
 - NFPA /NFIRS
 - NFPA 909
 - UK
- Loss
 - Major incidents
 - Arson and electrical
 - Involvement of ordinary combustibles

Causes of Structure Fires in Museums or Art Galleries 1980–1997

Annual Averages [Ahrens, 1999]

Cause	Fires	Direct Property Damage
Electrical distribution	22 (24.5%)	\$560,000 (27.4%)
Incendiary or suspicious	17 (18.6%)	\$530,000 (26.0%)
Other equipment	10 (10.9%)	\$261,000 (12.8%)
Open flame, ember or torch	8 (9.1%)	\$41,000 (2.0%)
Heating equipment	7 (8.0%)	\$528,000 (25.8%)
Smoking materials	7 (7.5%)	\$13,000 (0.7%)
Cooking equipment	6 (7.2%)	\$26,000 (1.3%)
Exposure (to other hostile fire)	4 (4.4%)	\$55,000 (2.7%)
Natural causes	4 (4.0%)	\$22,000 (1.1%)
Appliance, tool or air conditioning	3 (3.6%)	\$2,000 (0.1%)
Other heat, flame or spark	1 (1.4%)	\$3,000 (0.2%)
Child playing	1 (0.8%)	\$0* (0.0%)
Total	89 (100.0%)	NR**(100.0%)

Early Stage Fire Scenarios – Fire Hazard Analysis

Peak Fire Size (kW)	Growth Rate ()	Steady Burning Duration (min)	Total Burning Duration (min)	Representative Fuel Loading
200	Medium	2–3	7	Small miscellaneous combustibles, small garbage can, small artwork display
500	Medium	5	12	Small miscellaneous combustibles, several trash bags, small artwork display.
3,000	Fast	20	30	Medium room fire, moderate combustibles, large display, multiple furnishings.
5,000	Fast	25	>30	Large room fire, moderate combustibles, large display, multiple furnishings.
15,000	Fast	>30	>30	Large gallery/period-room, storage room, or open office fire, full-room fire involvement.

Early Stage Fire Scenarios – Test Scenarios

- Norwegian Tests
 - Wood stacks ignited by kerosene
- UL 711
 - 1:A - 350kW
 - 2:A - 780kW

Materials of Interest

- Architecture;
- Ethnographic collections;
- Glass and Ceramics;
- Leather and related materials;
- Metals;
- Modern Materials and Contemporary Art;
- Natural history collections;
- Paintings;
- Paper and graphic documents (including books);
- Photographic materials;
- Textiles and fabrics;
- Wood and furniture; and
- Miscellaneous materials related to protective materials and materials used for stabilization and restoration of collections and artifacts.

Neat Agent Characteristics

- Mechanical Damage from Agent Discharge?
- ABC Dry Chemicals
 - Slightly acidic, mildly corrosive, hygroscopic
- Clean Agents
 - Limited data
- Water Mist
 - Blotchiness, corrosion, stiffening of leather, buckling of fibers
- CO₂
 - Thermal shock

Fire Effects on Collection Materials

- Wood – discoloration and bubbling of paint layer occurred; discoloration of tempera by soot;
- Iron – darkening of metal and dark surface corrosion;
- Oil paintings – canvas was deformed; darkening of the paint layer and discolorization; layers were found to bubble and/or crack;
- Leather – severe deformation and scorching;
- Wool – severe shrinkage; scorching occurred and the wool became crispy;
- Cotton – scorching and darkening/discolorization occurred;
- Linen – severe darkening occurred; there was color change; and
- Cardboard – darkening and deformation of edges occurred; there was no pH change

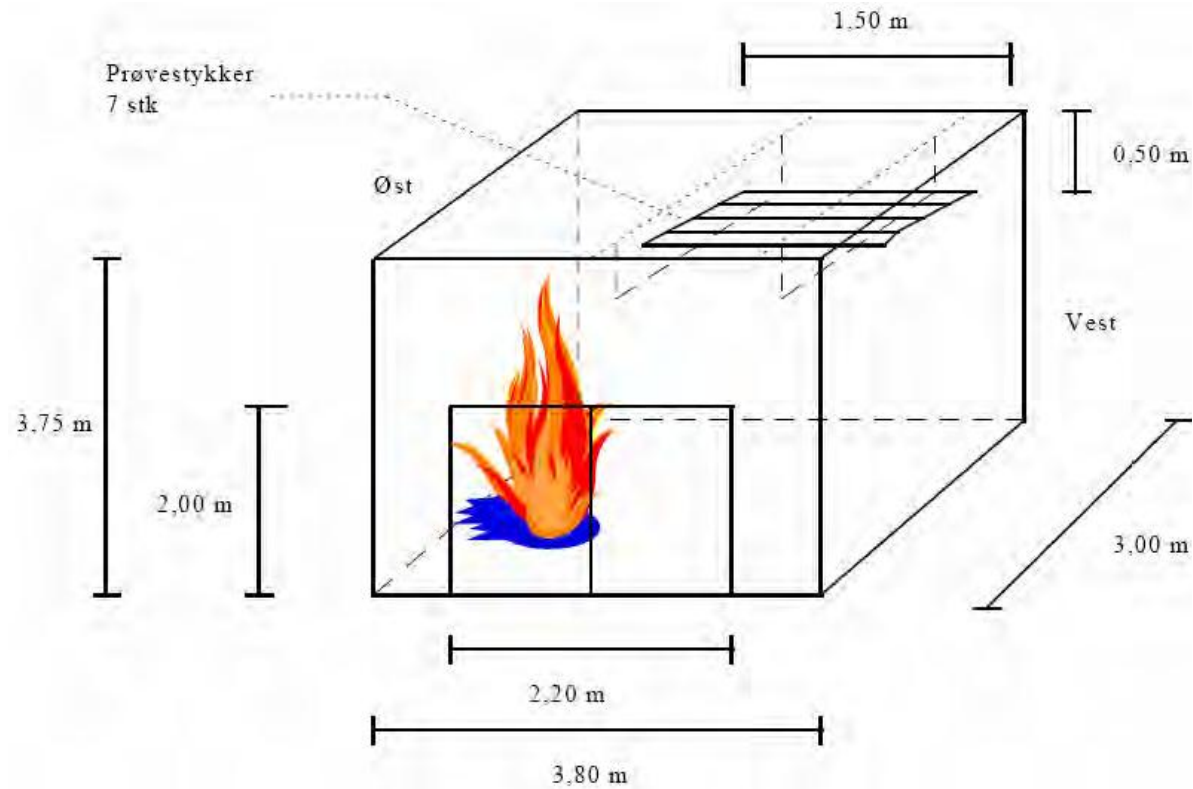
Combined Fire and Extinguishing Effects

- ABC Dry Chemical
 - TDPs – sulfur dioxide, oxides of phosphorous
 - Surface coating
- Clean Agents
 - HF, COF₂, small amounts of HCl
- CO₂
- Water Mist

Contaminant Dispersion and Concentration Modeling

- Considered
 - Building air flow models, CONTAMW
 - CFD – FDS, FLUENT, STAR-CD
 - Mathematical models
 - Hybrid approaches e.g., CONTAM w/CFD
- Conclusions
 - No single analytical tool available
 - Local effects – focus on testing

Test Methods



General fire test set-up used during Norwegian COWI portable extinguisher tests [Jensen 2006]

Measurement Techniques

- Agent concentration
 - FTIR
- Thermal decomposition products
 - Wipe samples analyzed using ion specific electrode technique
- Humidity and temperature
 - RH, thermocouples
- Physical impact
 - Force – pressure transducers

Proposed Test Protocols

- Physical impact tests
 - Surrogate materials
 - Comparative measures
- Enclosure tests
 - Representative real materials
 - Direct and indirect exposures
 - Neat agent and fire exposure tests
 - Human operator
 - Fire tests – limit thermal exposure

Extinguishers to be Evaluated

- ABC Dry Chemical (monoammonium phosphate)
 - > 85% MAP
 - < 85% MAP
- IG-001 (CO₂ – carbon dioxide)
- HCFC Blend B (Halotron I)
- HFC-236fa (FE-36)
- Water Mist

Materials to be Evaluated

Materials from the Norwegian (COWI) Tests:

- Wood – painted
- Iron
- Oil painting
- Leather
- Textiles – wool, cotton, linen
- Cardboard

Additional materials:

- Stone/Marble
- Fur/hair
- Glass/ceramic
- CDs/DVDs
- Paper/books
- Water color & acrylic paintings
- Photos/negatives
- Bone/ivory
- Other metals (brass, bronze, Cu, Al, steel)
- Artifacts displayed in an enclosure (box) –TBT

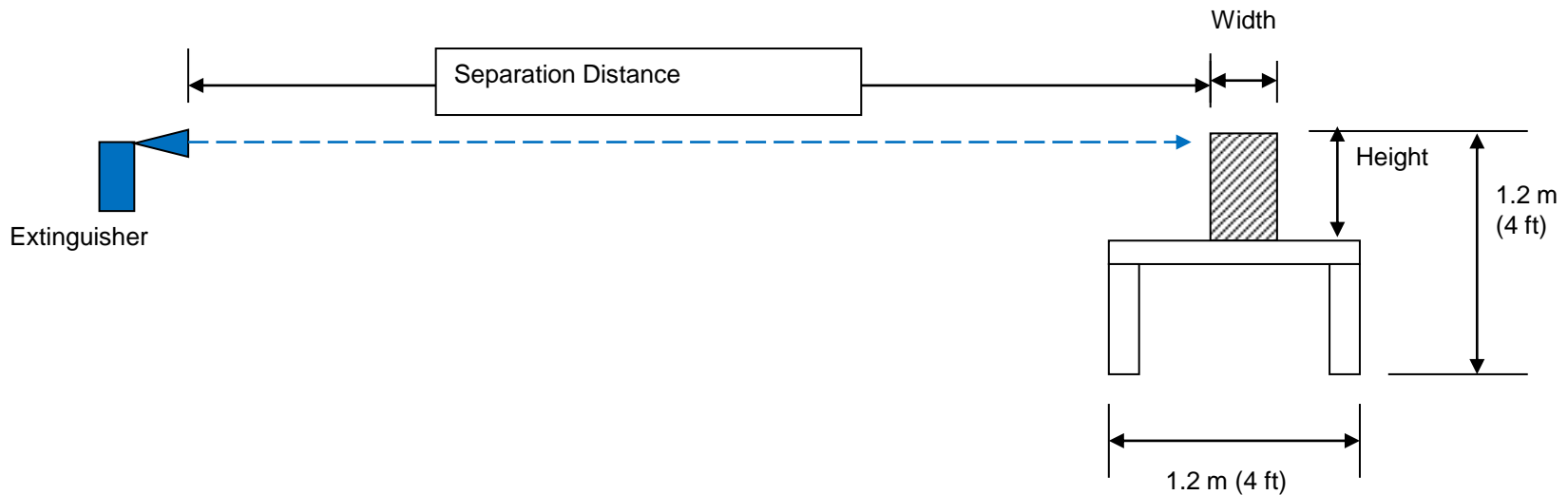
Physical Impact Tests



Test Materials: Plastic film, paper, canvas, metal foil

Analysis: Check for tears, cracks, distortions

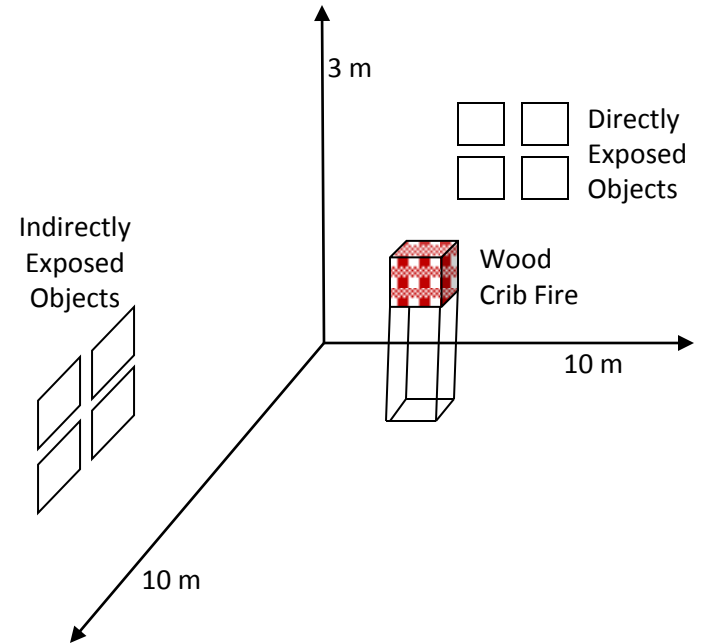
Physical Impact Tests



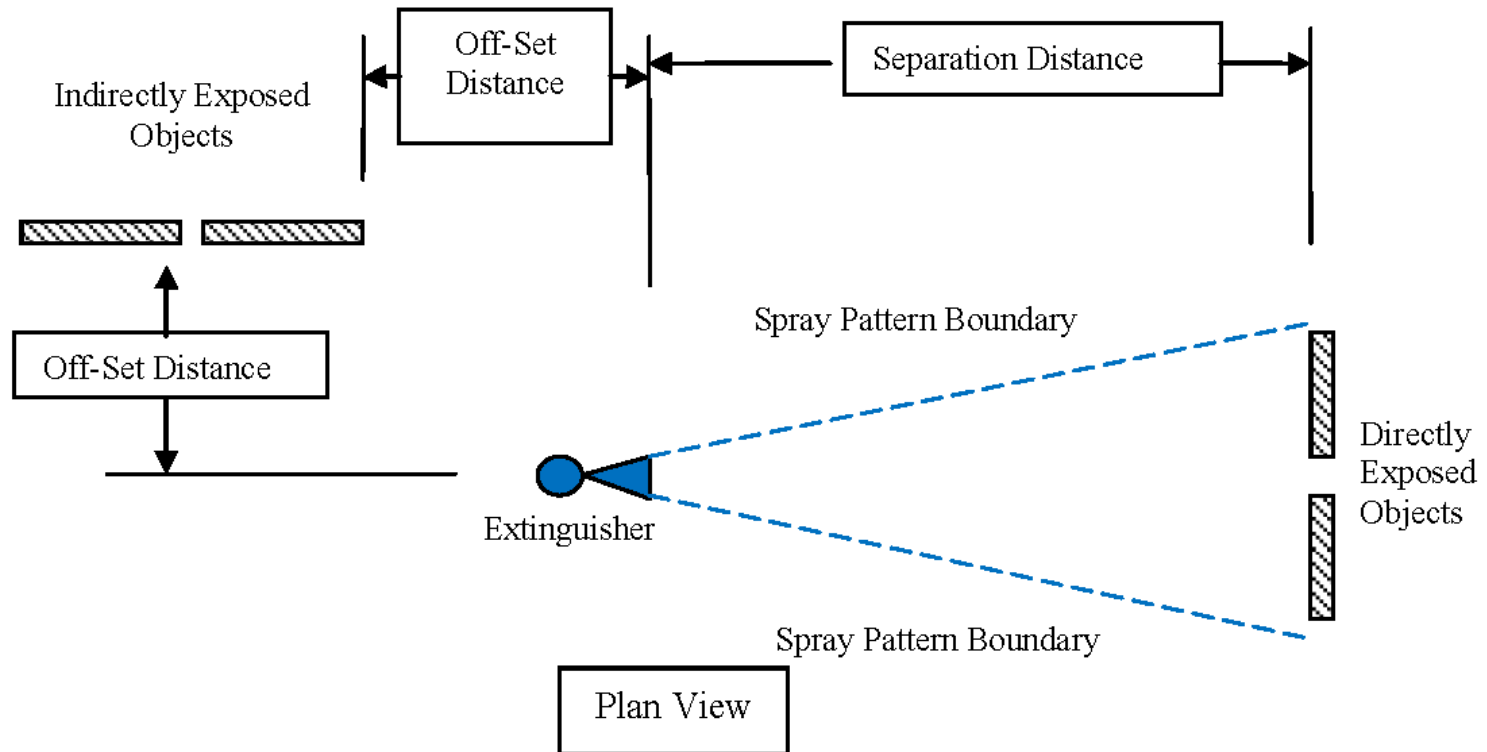
Test Objects: Wood blocks with varying dimensions
Analysis: Check for toppling or displacement

Exposure Test Set Up

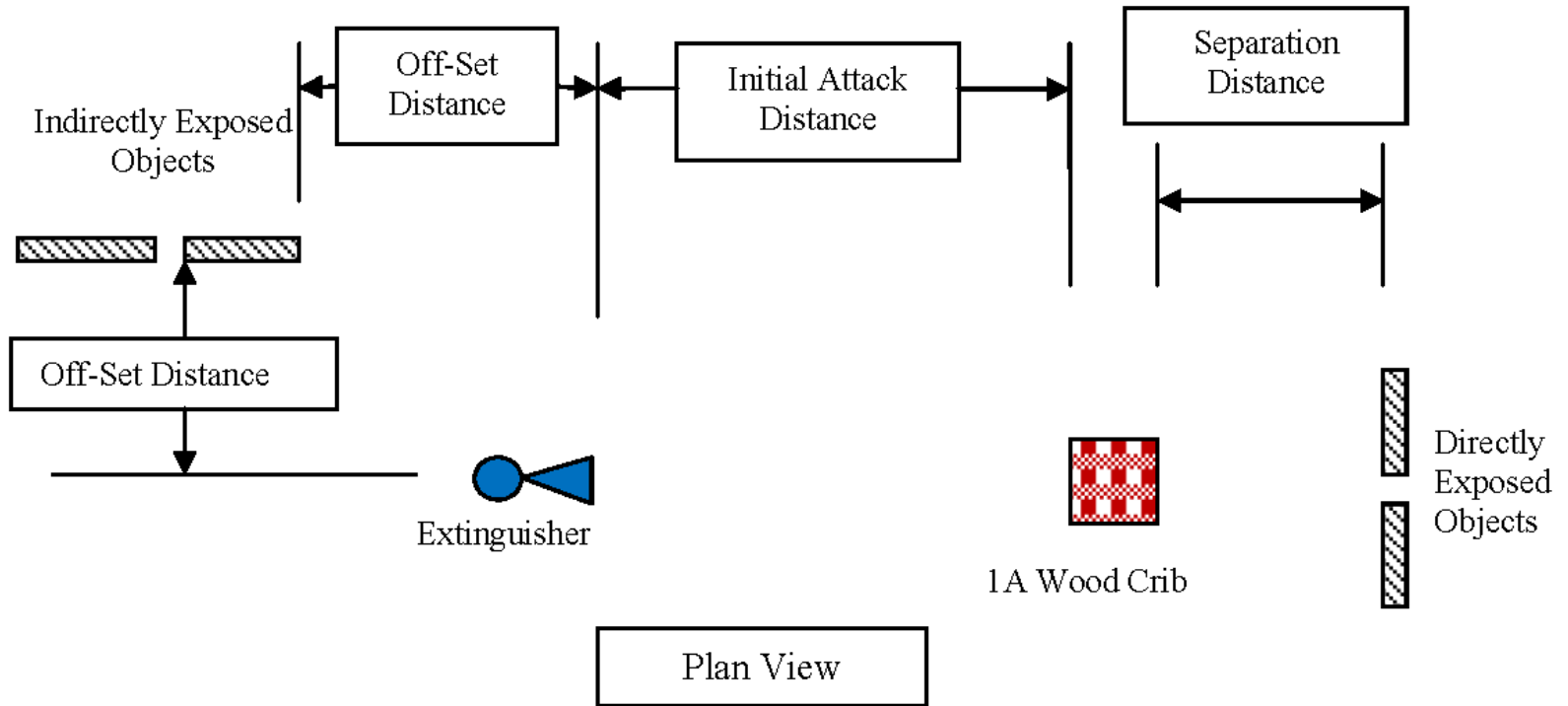
- Fire exposure tests
 - 350 kW (modified 1:A crib)
- Compartment characteristics
 - $\leq 1.2 \text{ kW/m}^3$
 - 300 - 350 kW fire
 - $h \geq 3 \text{ m}$
 - $l \text{ or } w \geq 6.1 \text{ m}$
- Instrumentation to condition and monitor space
 - $T = 70 \pm 4 \text{ F}$
 - $\text{RH} = 65 \pm 7\%$
 - Agent concentration – FTIR
 - Wipe samples – Ion specific electrode
 - Fluoride, chloride, pH
 - No active ventilation



Non-Fire Exposure Tests



Fire Exposure Tests



Conservator Assessment

Most materials - Soot deposition, deformation, expansion, contraction, scorching, charring, staining

- **Paper**
 - Embrittlement
 - Staining
 - Distortion
 - Breakage (from weak, wet paper)
 - Solubilizing of sizes/coating
 - Feathering, sinking, or removing of media
 - Charring
 - Cockling
 - Scorching
 - Desiccation
- **Paint/finishes**
 - Cracking
 - Shrinking
 - Oil/water gilding (covering/cracking)
 - Curling
 - Loosening/peeling
 - Solubilizing
- **Skin/leather**
 - Becoming translucent
 - Sensitivity to expansion and shrinking
 - Gelatinization
 - Desiccation
 - Swelling
 - Stiffening
 - Blackening
- **Photographs/films**
 - Shrinkage
- **Wood**
 - Blooming (whitening)
 - Cracking/splitting
- **Hard materials (including metal and stone)**
 - Fissures
 - Cracks
 - Discoloration
 - Crazeing
- **Metals**
 - Surface corrosion
 - Darkening
 - Tarnishing
- **Textiles**
 - Changes in color
 - Shrinkage
 - Discoloration
 - Blotchiness

Summary

- Test Protocols Developed and Ready for Validation Testing
- Tabulated Known Effects of Ambient Conditions, Fire, and Agents on Collection Materials

Technical Panel

Bogdan Dlugogorski, *University of Newcastle*
Deborah Freeland, *Arthur J. Gallagher & Company*
Cindy Greczek, *Colonial Williamsburg Foundation*
Michael Kilby, *Smithsonian Institution*
Nancy Lev-Alexander, *U.S. Library of Congress*

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FPRF

Kathleen Almand

The report can be found on the FPRF website

<http://www.nfpa.org/categoryList.asp?categoryID=260&URL=Research/Fire%20Protection%20Research%20Foundation/Reports%20and%20proceedings>

Questions or Comments

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