



THE FIRE PROTECTION RESEARCH FOUNDATION

FIRE EXTINGUISHING AGENTS AND CULTURAL RESOURCE COLLECTIONS

1.0 ASSESSMENT OF NEED

Portable fire extinguishers and their associated fire extinguishing agents play an important role in reducing the impact of fire within museum and library collections (Wilson, 1991; Wilson, 2004). A fire which can be extinguished in its incipient stage will not grow to threaten adjacent materials. A range of extinguisher agents are commonly used in museums and libraries including water, clean gaseous agents, dry chemical, and foam. Their effectiveness in combating fires has been studied and is well-understood; their effects on collections materials with which they come into contact has not been verified. Contact with collection materials can occur by overspray during firefighting efforts. There are reports of situations where the discharge of an extinguisher and its subsequent mitigation has caused more damage and off-line time than the incipient fire incident (IPG, 2000). Contact between extinguishing agents and collections materials may also be the result of vandalism or accidental discharge. In one incident in England a malicious discharge of a single 5kg powder and two 9 liter water extinguishers caused over £320,000 in damages (Kidd, 2011).

To fully evaluate the appropriateness of selecting and using an extinguisher in a cultural heritage environment, its effectiveness at extinguishing a fire should be compared to the potential for damage to collection materials from the agent and its thermal decomposition products and the degree to which the agents can be removed from collections materials after exposure. While conservators are well versed in the effects of moisture and water on collections, little data is available on the effects of short or long term exposure to non-water based extinguishing agents.

To date only one study, commissioned by the Norwegian Archive Library and Museum Authority (ABM) and Rijksantikvaren, the Norwegian Directorate for Cultural Heritage (RNDCH), has examined the effects of extinguishing agents on cultural property, (IPG 2000; Jensen, 2006). It was limited in its scope and while it provides some useful information, its results are not reproducible as information on the material of the test enclosure, the mechanical ventilation in the test enclosure, the fuel package and the attempts to control temperature were not published. Additionally it failed to establish a systematic method for assessing results and did not take cleaning into account. In 2009, recognizing the need for further investigation, the National Fire Protection Association (NFPA) Technical Committee on Cultural Resources

submitted a project proposal to the Fire Protection Research Foundation (the research arm of NFPA) to develop test specifications and procedures for measuring the impact of portable fire extinguisher agents on cultural resource collections. The Fire Protection Research Foundation commissioned a scoping report from Hughes Associates, Inc, a leader in fire protection engineering. The report (see supplementary materials) included a literature review and established the theoretical parameters testing the impact of extinguishing ~~materials~~ agents on collections materials. The report was vetted by a technical panel consisting of conservators, fire protection engineers and extinguisher manufacturers. Due to costs, no actual testing was carried out at the time.

The project currently under consideration seeks to conduct the fire-testing and materials assessment. The results will be of tremendous use to museums and libraries both nationally and internationally, allowing them to better match their fire ~~prevention~~ protection needs to their preservation mission.

2.0 IMPACT

Curators, conservators and museum managers currently do not know how to assess the impact of extinguishing agents on artifacts. There is little data in the literature, and a standardized assessment methodology has not been established. This project is intended to quantify the impact of discharging portable fire extinguisher agents on cultural resource materials, and establish a scientific method for this assessment. The research will also validate and refine a test protocol which can be used by other organizations to continue to assess various materials and add to the database of known extinguisher effects. A cost-effective, repeatable test method will be established to allow comparison of test data between users.

It is intended that the results will provide the cultural resource community with guidance on extinguisher selection. This information will be proposed for adoption by the National Fire Protection Association (NFPA), the world's leading advocate of fire ~~prevention~~ protection and an authoritative source on public fire safety. NFPA publishes two consensus standards, *Code for the Protection of Cultural Resource Properties – Museums, Libraries and Places of Worship* (NFPA 909, ~~2005~~2010), and the *Code for Fire Protection of Historic Structures* (NFPA 914, 2007). These documents are widely used by the cultural resource community throughout the world as a reference for fire safe practices. Incorporating the results in these standards will assure worldwide recognition and use of the data and guidance.

3.0 PROJECT DESIGN AND EVALUATION PLAN

The Fire Protection Research Foundation (FPRF), an independent nonprofit associated with NFPA, sponsored a project which established a plan for this proposed effort. The preliminary work included a comprehensive literature review, the development of prototype test specifications, and procedures to test the effects of extinguishers [Scheffey and Forssell, 2010]. This follow-on effort proposes to carry out the recommendations in the prototype specifications by conducting extinguisher ~~impact~~ tests on actual cultural resource materials. The data, along with a validated test procedure, would be created for use by the cultural resource community at large. The approach proposed includes:

- Carefully controlled experimentation by world recognized conservators and fire scientists;
- Ongoing peer review of the project by leading authorities; and,
- Widespread dissemination of the data and guidance to the cultural resource community via the leading international fire safety advocate.

3.1 Project Management

The project will be a partnership between the Colonial Williamsburg Foundation (CWF), Hughes Associates, Inc (HAI) and the Fire Protection Research Foundation (FPRF). Colonial Williamsburg will lead the project and supply both management and conservation expertise. HAI will provide the fire science expertise and will conduct all the exposure tests detailed below. FPRF will disseminate the information and convene an independent technical review committee to assure that the methodology and results are technically valid. This partnership builds on a long history of collaboration between the three institutions both with regard to this project and broader issues of fire safety in cultural heritage organizations.

3.2 Technical Approach

3.2.1 Summary of Work to Date

In the planning phase, a detailed review of portable fire extinguishers was performed. The characteristics of extinguishing agents, multi-purpose (ABC) dry chemical, carbon dioxide, clean agent halocarbon, and water mist extinguishers were documented along with collection material characteristics. While the effect of water/moisture on materials is well known, the effects of other agents have not been well characterized.

In order to establish a fire protocol, early stage fire scenarios were assessed. A fire loss review of museums, libraries, and other heritage and cultural buildings revealed that fires are most likely to involve ordinary, solid combustibles. A fire size on the order of 350 kW using a standardized wood crib was selected as a representative fire threat.

Test and measurement techniques were identified. Tradeoffs were analyzed in terms of a detailed, scientific approach compared to ad hoc discharge tests. A middle ground was adopted, with the goal to provide a cost-effective, repeatable test method using actual collection materials. Three basic tests were recommended, including non-fire exposure tests, fire exposure tests, and physical impact tests. A prototype test specification was developed based on material and agent variables. Anticipated agent effects were considered in specifying the test set up, procedures, and instrumentation. This research project will adopt the recommendations from this prior effort.

3.2.2 Sample Materials and Extinguishing Agents to be assessed

3.2.2.1 Sample Materials

A review of a number of collections in museums both nationally and internationally suggests that the materials most likely to be on open display are metals, stone, ceramic, wood (typically as frames, furniture or sculpture) , painting and textiles (typically in the form of curtains, bedhangings or upholstery). Typically works of art on paper, costumes, and more exotic

materials such as silver, horn, and feathers are protected either by glazing or vitrines. While some luxury materials such as tortoiseshell and ivory, may be present as inlay in furniture or as small artifacts in period rooms (particularly in European collections), it was felt that the difficulty and expense of acquiring adequately sized samples overshadowed their prevalence.

Based on this assessment, the following materials were chosen for assessment: iron, copper, aluminum, leather (vegetable tanned), unpainted wood (either yellow pine or poplar to simulate the secondary wood often found in furniture), varnished wood, oil painting on canvas, acrylic painting on canvas, stone (sandstone/limestone), stone (marble), stone (granite), low fired ceramic (terracotta), and high fired ceramic (stoneware or porcelain).

No textile samples were selected for testing at this juncture because it was felt strongly by both the team and a number of external textile conservators who were consulted that there are too many factors to consider. Variables such as fiber, mordant, nap, dye and weave make it difficult to choose one or two samples whose behavior can represent the material class in a meaningful manner. A more meaningful study of the exposure of textiles to portable fire extinguishers can and should be made once the protocol is tested and standardized. Storage materials (such as acid free card and tyvec) were also excluded because the permeability of the material to the extinguishing agent was more of a factor than its cleanability. Most museums are more likely to replace contaminated storage materials than to take on the expense of cleaning them.

The samples will be 4 inches by 4 inches in size and will be mounted on non-acid cardboard target arrays measuring 22 inches by 22 inches. Two sets of samples will be mounted to each target array—one towards the interior and the second along the exterior—to ensure that results are not skewed by the samples placement on the board. Due to the problems inherent with acquiring nearly 50 samples of the requisite size of any of these materials that have also been aged in an identical manner, modern samples will be prepared by the project staff.

Control samples of the materials that are exposed during the fire and non-fire exposure tests will be prepared. They will be conditioned similarly to the exposed samples. These samples will be bagged and packaged for examination with the exposed samples.

3.2.2.2 Fire Extinguishers and Agents

Portable extinguishers will be used including those applicable for use in a museum/cultural heritage type application. The ~~units~~ agents identified include (in order of testing priority): ABC Dry Chemical (monoammonium phosphate); Water Mist; Clean agent (HCFC Blend B (Halotron I); potentially Novec); ABC and water; Foam (AFFF or non-fluorosurfactants foam); and, IG-001 (CO₂ – carbon dioxide).

These extinguishers are typically classified by Underwriters Laboratories as to their size and effectiveness on various fires. They will have a minimum UL 711 1A or 2A rating [Underwriters Laboratories, 2005] for use on incipient, ordinary combustible fires.

3.3 Proposed Test Methodology

3.3.1 Test Enclosure

An important test parameter is the fire size to room volume ratio. Keeping this ratio low is consistent with the typical application of portable extinguishers, i.e., small fires in large spaces. Scenarios involving larger ratios are typically dealt with by fixed suppression systems, i.e., sprinklers, or left for the local fire department. Portable extinguishers also are not meant to develop a uniform agent concentration or application density throughout the enclosure, but are meant to develop a high concentration or application density locally at the fire, with lower concentrations elsewhere in the space. A room/enclosure will be used which exhibits these aspects. The room will be conditioned similar to that in a typical museum space [Erhardt et al., 2007].

3.4 Agent-Only Exposure Tests

Non-fire exposure tests will evaluate the effects of portable extinguisher agent spray on representative materials both within and outside of the extinguisher spray pattern. The objective is to evaluate the effects of the neat agents on representative materials under normal environmental conditions. During these tests, the portable extinguishers will be discharged directly onto the representative materials from a distance representing the nominal effective range of the extinguisher. A second set of representative materials will be indirectly exposed, mounted outside of the extinguisher spray pattern to assess the effects incidental exposure from overspray. The controlling parameters are illustrated in Figure 1.

Each target array will hold 26 samples. Given the 13 sample materials identified, each target array will have two of each sample, one located directly within the extinguisher spray pattern and one on the periphery. This is predicated on the spray pattern being wide enough to cover the target array. Some fire training of this approach is anticipated during scoping tests.

Two sets of representative material/object mounts will be used. They will be mounted on the back wall of the enclosure or on a vertical stand. The direct exposure target will be in front of the extinguisher discharge. Indirectly exposed objects will be mounted on the side wall of the enclosure or on a stand. The temperature and relative humidity will be monitored outside of extinguisher spray. Temperature will also be monitored at the face of the directly exposed materials.

One test for each agent will be conducted, so there will be a total of two direct and two indirect samples of each material to investigate for effects. A total of 6 exposure tests are anticipated, with 312 total samples exposed.

3.4.1 Fire Tests

The objective of the fire exposure tests is to evaluate the effects of the combination of the agents, decomposition products and fire effluent on representative materials while the extinguisher is utilized to extinguish a fire involving Class A (solid) materials. The effects of a fire alone on the representative materials by itself will not be evaluated in this test program, since there is data available on this [Roberts et al., undated]. The portable extinguisher will be

used to extinguish a wood crib fire with the representative materials mounted downstream of the wood crib. A second set of representative materials would be located outside of the direct discharge to assess the effects of a reduced exposure. The arrangement is illustrated in Figure 2.

The magnitude of the Class A fire will be well below the limits of a 2-A rated extinguisher. When a test is performed, it is desirable to have a fire which is easily suppressed by the extinguisher. This eliminates the variable of whether or not the fire is extinguished. A Class A wood crib fire on the order of 200–500 kW will be used. The total burn duration will be 1–3 minutes. Scoping tests of this procedure will be needed to fine tune this scenario.

The exposure arrays will be the same as in the non-fire exposure tests. Three hundred and twelve samples will be exposed. The total number of exposure samples in the fire and non-fire tests is 624.

3.4.2 Post Exposure Assessment

After each test, the exposed samples from both arrays will be removed from the enclosure and weighed. The samples will then be visually examined for any sign of damage due to the exposure. This examination will include checks for tears, cracks, distortions, residue, and discolorations. The samples will then be placed in a conditioned space (same temperature and RH) and allowed to acclimatize for up to 24 hours.

The exposed samples will be divided into four quadrants and cleaned and assessed for damage or change at the following post-test intervals:

- Within one week of the 24 hour acclimatization period; this scenario is designed to simulate the conditions in a larger institution that might have a team of conservators on staff. These samples will be reassessed after six months and then again after twelve months.
- Another set of boards will be stored, and cleaned at 6 months; this scenario is designed to simulate conditions in a smaller institution where it may be necessary to seek funding or expertise prior to mitigation. These samples will be reassessed six months after cleaning and then again after twelve months.

The cleaning techniques to be used will consist of swabbing with deionized water; removal with a soft brush vacuuming and the use of a soot eraser. Each technique will be conducted in one of the four quadrants of the sample.

Assessments will include identification of planar distortions, adhesion of soot or other by products (agents can be carriers of combustion products), accretions, acid effects including corrosion and embrittlement, stains, and discoloration. Photographic documentation will be made during the examinations. (See supplemental materials for a sample assessment sheet).