PROTECTING LIBRARIES AND MUSEUMS FROM FIRE

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The problem of designing fire protection for a library or a museum almost always is resolved in the choice between manual fire suppression and automatic fire suppression, primarily automatic sprinkler systems.

INTRODUCTION

Librarians and curators have found fire protection of valued collections a fire-versus-water dilemma. They have traditionally come to fear water more than fire. Automatic sprinkler systems, a standard form of fire protection in textile mills since about 1880, did not begin to find acceptance by the library community until nearly 100 years later. Some librarians still do not want them, and among museums there is still resistance to them. But actual experience with fire disasters in cultural properties and historic buildings has convinced us that automatic sprinklers are indeed the best solution.

FIRE TESTS OF BOOKSTACKS

Fire protection doctrine for libraries has been developed in two ways: (a) By laboratory testing; (b) By fire disaster experience. Following two devastating library fires in 1950, insurance companies began to bring pressure to bear on important libraries to improve their fire protection. The New York City Public Library contracted with Factory Mutual Insurance Companies to conduct fire tests in their Norwood, Massachusetts laboratory. The tests would determine whether or not the conventional open arrangement of book stacks was dangerous as a fire risk, and also, whether or not automatic sprinklers would be a suitable system of fire protection. [1] Two tests were made, using an assembly of four tiers of open shelves, 9 meters high and loaded with books, closely resembling the open stacks in the New York Public Library. The first test showed that sprinklers were indeed effective in extinguishing a fire in bookshelves. A fire was started in a book cart directly adjacent to and touching the lowest tier. At 3 minutes, 25 seconds, the books in the first tier began to burn. At 3 minutes, 43 seconds, a sprinkler head opened on the next tier above, discharging water at 71.9 liters per minute. After another 4 minutes, 38 seconds, the fire was declared under control, 10 seconds after a second sprinkler head had opened. Total water discharged was 350 liters.

In the second test, as in the first, the four tiers were arranged vertically and a fire was lit at the base. There were no sprinklers this time. The fire progressed steadily upward; in 9 minutes it was burning in the fourth tier, 7.3 meters above the floor. Firemen then used a 380 mm hose line discharging 56.8 liters per minute for 10 minutes, 23 seconds, then a 630 mm hose discharging 1003 liters per minute for 10 minutes, 40 seconds. At that point the fire was considered under control, although it smoldered for hours.

LIBRARIANS WERE SKEPTICAL

The engineers who conducted the tests were satisfied with the results; clearly, books on the shelves would burn readily and sprinklers would put out the fire. Unfortunately, however, a number of prominent librarians who witnessed the tests were not convinced. They prevailed upon the American Library Association to set up a Library Technical Project to study the problem further, obtaining a grant of $50,000 to pay for studies by a recognized fire protection firm. There was also an advisory committee for the project, six leaders in the library field.

The final report of this study was published in 1963. [2] In many ways it was a good guide to various aspects of construction and other forms of protection for libraries. But it was somewhat am-
biguous on automatic sprinkler fire protection. True, sprinklers were recognized as "ideal", and as "complete protection on a 24-hour basis". But "they might pour out water after the fire was extinguished; someone might shut down the system too soon; and the fire might rekindle". There were passages describing the nearly perfect performance of sprinklers controlling 96.2% of fires in protected premises, and with 71% of the fires controlled with one, two, three or four sprinklers.

The advice this book gave librarians was equivocal. A library of generally sound construction need not install sprinklers, they said, "which might only be introducing an additional hazard". It was as though the fire expert were catering to the librarian's fear of water. Sprinklers were clearly indicated if your library was of wood frame construction, or underground, or more than five miles from a fire station. It is unlikely that libraries were influenced by this report to install sprinklers.

FIRE DISASTERS

More important than fire testing in the development of fire for libraries and museums has been actual fire experience. [3] Libraries in North America had suffered fire disasters even in colonial times. Harvard College lost its library to fire in 1764. The Library of Congress burned three times before 1852. The very large New York State Library burned in 1911 and more than one million items were lost. In England the Free Library of Birmingham was lost in 1879, when set afire by the torch of a workman.

Two significant incendiary fires occurred in Michigan in 1950-51 both set by employees. The Library of Government at the University of Michigan burned in June, 1950, with a loss of $637,000. Only a few months later, in February, 1951, the State Library of Michigan at Lansing was heavily damaged in a fire that burned for five days in a fire-resistive structure. The loss was $2,850,000, and two floors of the building were removed, so severe was the destruction.

THE PHILADELPHIA EXPERIENCE

The fire that seemed to influence library fire protection design more than any other was that of the Klein Law Library at Temple University, July 25, 1972. This fire occurred in the center of Philadelphia in midday. The city fire department surrounded the building with 27 vehicles and pumped water into the building at the rate of 41,639 liters per minutes for 91 minutes. Collections in the main floor were fire- and smoke damaged, and rare books in the basement were under water for four days before being removed for drying.

Very heavy losses were paid by insurors. Following this disaster they would look at a large library as a risk requiring automatic protection systems, and certain libraries would require automatic suppression, primarily sprinkler systems. Soon after the Philadelphia fire the main library at the University of Maryland would install sprinklers, and in the 1970's the main library at the Berkeley campus of the University of California would install sprinklers and a variety of other protection systems. There were similar projects in many other places.

OPEN STYLE BOOK STACKS

The Philadelphia library collections were almost entirely on two levels, in the main reading room and the basement. A more hazardous construction was that of libraries built almost everywhere between 1860 and 1950. This was the era of the monumental library, a design attributed to Henri Labrouste in the building of the Bibliothèque National in Paris, 1858-1868. [4] It included a closed book stack, a free-standing framework of cast iron columns and wrought iron beams, "a gigantic rack to house 900,000 volumes". This design appealed to both architects and librarians, and it was replicated in many libraries built during the 100 years following.

In this familiar design (Fig 1) the framework carrying the books has little support, or none, from the building structure. It stands by itself. It does not have solid floors, but tiers of shelving with open slots and open stairways; these provide for movement of air through the stacks, inhibiting mold and facilitating convection heating. In a fire, however, they carry heat and smoke upward, while water from firefighting pours downward through the same openings into
books which may have been undamaged by fire. It is truly a "built to burn" design.

LOS ANGELES CENTRAL LIBRARY
This open construction, unfortunately was the design of the Los Angeles Central Library, which suffered a major fire disaster April 29, 1986. As in the Philadelphia fire, a mighty fire department responded quickly with almost unlimited resources in manpower and equipment. But this time it was not until seven and one-half hours later that the fire was declared extinguished. More than 350,000 books and other items were utterly destroyed. Another 700,000 were wet, and were placed in cold storage warehouses until they could be freeze dried, 30 months later. In this fire the only reason the entire stacks structure did not collapse was that the fire had been set near the top, at the fifth tier of the seven-tier stacks. The seventh tier did, in fact, collapse into the sixth and fifth tiers in one area. The immediate estimate of loss was $23,000,000. The arsonist was never identified. Another incendiary fire occurred five months later in the same library, and caused $2,000,000 damage to the music collections.

MISCONCEPTIONS ABOUT SPRINKLERS
The April, 1986 fire proved beyond a doubt that automatic sprinklers are essential in such an open design. The chief officer of the Los Angeles City Fire Department, Donald Manning, said "If the building had been sprinklered we might have had a few hundred books damaged; we might have had a few thousand dollars damage"; but why had the library not installed sprinklers years earlier when the fire inspectors repeatedly recommended them? Public officials were quoted in the press with statements that showed alarming misconceptions about the function of a sprinkler system. One said "The standard back then (1966) was not to put sprinklers in libraries because... if alarms go off by mistake, you are going to lose great parts of your collections". Another said "There are more false alarms than fires, and the sprinklers would be activated during false alarms".

COMPARTMENTATION
The plan subdividing a building both horizontally and vertically with fire resistive construction, called compartmentation, is possible for libraries and museums, but it is seldom achieved. As early as 1879 it was first on the list of requirements for the ideal library when W.F. Poole addressed the American Library Association... "so that if a fire starts, it shall be confined to the compartment in which it originates, and the rest of the library be saved". A test made at Cornell University in 1960 showed that containment of a library fire would be possible with solid floors and fire resistive construction. But how often do we see such a building? More often the choice is an atrium. One building where compartmentation is a primary fire protection element is the British Record Office at Kew. Another is the James Madison Building of the Library of Congress in Washington, D.C. Each level is cut off from the others by enclosed stairways, and the very large areas on all levels are subdivided into smaller areas. One argument against total reliance on compartmentation for fire protection is that it is very difficult to achieve from day to day. To the extent that it succeeds, the fire risk is certainly reduced. But a fire protection engineer would probably not give it much value except as an extra bonus in
a sprinklered design.

DETECTION OR SUPPRESSION?
When the time comes for a decision on fire protection for any library or museum it is likely that there will be opposition to sprinkler protection because it introduces another water system into the building, increasing the possibility of a water incident when there is no fire. A smoke detection system is attractive by comparison because it does not involve water, at least until the fire brigade arrives. Yet insurance industry records show that the likelihood of unwanted water from a sprinkler malfunction is less than one in one million. Smoke detection systems have the virtue of sounding an alarm, sometimes before fire breaks out. A local alarm will alert any staff member who may be on the premises, and may result in prompt action with an extinguisher to put out a fire. A central station alarm should bring the fire brigade to the building. But actual experience of detection systems without the support of suppression systems has been highlighted with some spectacular failures. These occur not from defective equipment as much as from errors of installers, mechanics, and others. Example: an alarm brought the fire brigade to a Canadian university campus at night, but they had to go from building to building before they found the fire in the library; a mechanic had failed to wire the connection to the annunciator panel. Also in Canada, a university's fire alarm circuits were being tested during the night; the signal from a detector was considered a test signal. The fire was a multi-million dollar loss, and included a considerable part of the engineering library. In still another university library, a $340,000 fire brought to light the fact that the contractor who installed the fire detection system had somehow left the reference room out of the system, and this is where the fire occurred. These are only three of the many incidents that demonstrate this critical difference between automatic detection and automatic suppression.

MANUAL FIRE SUPPRESSION
When we discuss the action of automatic detection systems we are discussing manual fire-fighting, the time-honored, traditional attack on a fire, occasionally by someone close to the fire and able to attack it with a portable appliance, but usually by a company of trained and capable fire-fighters. In the Los Angeles fire, the finest of fire service organizations attacked the fire with more than 300 men and 60 vehicles, and required more than seven hours to extinguish it. How did this happen, in daylight, and in the middle of a great city? When an arsonist set a fire in the fifth level of the book stacks, smoke detectors set off bells and lit up the annunciator panel at the guard station. The guard called the fire department immediately, even before the central station completed their notice to the fire department. The firemen arrived within five minutes. There was some delay in locating the fire. For one reason or another, it was almost fifteen minutes before water was thrown on the fire, and by this time it had spread laterally and involved the sixth and seventh tiers. The effect of such a delay is portrayed in Rex Wilson’s chart (Fig 2) in the rapidly diminishing probability of successful manual extinguishment of a fire as it expands. [7] In this fire the expansion was not just horizontal but vertical, through the porous construction and the open stairways. More than 300 firemen labored through a long day to control this fire. It was a sorry day for the theory that detection systems can protect as well as automatic suppression systems. We are reminded of Chief Don Manning’s post-mortem statement on this terrible fire, that if the library had been sprinkler-protected, the loss would have been a few hundred books... a few thousand dollars damage.

WATER DAMAGE
In news accounts of fires it is not unusual to read or hear that “the fire damage was inconsequential, but water damage from sprinkler action amounted to $10,000.” What we are not told is that fire damage without sprinkler action would likely have been $100,000 or more. There is an opportunity in this situation for a statement by the fire officer to the reporter, that the sprinkler system saved the building, and without it the fire would have been a difficult and dangerous one for the brigade. Library and museum managers sometimes fail to consider the
actual history of water damage apart from fires or fire-fighting. Water incidents in libraries outnumber fires. They include broken water and steam pipes, construction operations, condensation, seepage, storm-driven rains, leaking roofs, and flooding from one source or another. [8] There are excellent water detection systems available which not only detect unwanted water in a building, but tell just where it is.

INCENDIARISM

An important consideration in designing fire protection for libraries is this: Most library fires are incendiary. We have had fires from contractor operations, heating systems, electrical faults, and lightning, and these make up about 20-25% of fires in libraries. Almost all the rest are set fires “deliberate ignition by person or persons unknown”.

Placing burning materials through the book return has been by far the most prolific origin of arson fires in North American libraries. This is the device, also called the book drop, through which books and other materials borrowed from the library are returned after

hours. In western Canada a bomb made from gasoline and gunpowder was placed in the book drop to burn out a suburban library. In California young boys dropped a single paper match inside, and a $375,000 fire resulted. In New York City (Brooklyn), someone poured 19 liters of gasoline through the book drop and set it ablaze. Preventing the book drop fire is not difficult. Many libraries have placed collection boxes outside the library. Others have an enclosed area, a closet to confine any fire in the receiving space, and others have this area under a sprinkler head.

WHO ARE THE ARSONISTS?

The book drop arsonists who have been identified have been young males, probably acting on impulse to impress others. A fire bomb was placed in an occupied reading room of the main library at Berkeley (University of California) in 1970: it is presumed to have been the work of a political activist; there were many arson incidents in colleges in that period. Other fires have been set in libraries by employees, like the janitor in a Maryland university library who wanted to be recognized as a hero helping others get out of a burning building. Finally, there are the vandals and thieves who break in at night looking for something to steal, then set a fire, or many fires, as they leave.

VANDALISM

Protection against vandalism has become an important part of fire protection. Incendiary fires are often related to senseless acts of persons who break in at night, or who have some compulsion to destroy cultural property, such as books in libraries and works of art in museums. The need for strengthening or eliminating book returns in libraries is a part of this. So is the strengthening of doors and windows, especially at the rear of a building, or on sides not visible from the street. Installation of alarm systems against intrusion is routine in museums and in most libraries.

The great fire in the Los Angeles Central Library in April, 1986 was set in the stacks by an unknown arsonist while there were 400 people in the building. Numerous people had access to the stacks, including
employees of contractors who were replacing doors as part of a fire protection improvement project. This suggests the need for internal security measures, such as keeping the stacks closed against casual patrons, and accessible only to staff persons and carefully screened researchers. Closed circuit television is now widely used in museums and libraries to survey remote areas inside and outside the building. This was one of the systems provided in the new Goldwyn Memorial Library in Hollywood, California, rebuilt following the destructive arson fire of 1982.

NEW SYSTEMS

Several refinements in the hardware of fire protection systems recent years should be useful in planning for new buildings and the improvement of existing buildings. One of these is the use of plastic pipe and fittings for automatic sprinkler systems. Plastic pipe has certain advantages over traditional materials. It is now approved in the U.S. for exposed piping in horizontal runs below flat, horizontal ceilings, provided that quick response heads are used, and deflectors are placed 2.5 cm to 20.3 cm from the ceiling. Plastic pipe has survived bursting pressure tests over 6.89 MPa and temperatures over 871°C in laboratory tests. Two materials are used. Polybutylene burns readily when dry, but not as used in a wet pipe system, and it does not burn when frozen. CPVC, post-chlorinated polyvinyl chloride, does not burn readily when dry, but requires a charge with an anti-freeze solution in cold climates; and there are a number of such installations. But plastic pipe would probably not be approved for retrofitting a bookstack structure of the open type unless floors of fire resistive materials were part of the plan. However, plastic pipe and fittings are light in weight, flexible, have good hydraulic characteristics and can be assembled with hand tools.

Fast response heads in automatic sprinkler systems were first developed as a life safety device for patient rooms in hospitals. They should find acceptance in libraries and museums, in that such a head will open early on a small fire and use a minimum of water. Another item with special promise for libraries and museums is the on-off or stop-and-go sprinkler head. One now on the market uses both a fusible component and a snap-disc control it opens early over a fire, then shuts off the flow of water when the temperature falls to 35°C. The water flow alarm to a central station has by this time signaled the fire service, but if the fire rekindles, the sprinkler head will open again to place water on the fire. Libraries have found it possible to use a mix of technologies in one building, for example, standard heads on a wet pipe system over shop and dead storage areas, on-and-off heads over other places with higher values.

COMPACT STORAGE

Modern design in larger libraries frequently involves compact storage (or mobile storage) for expanding collections, in which book shelves are mounted on wheels, so that a single aisle space is enough for several mobile shelf units. This has the effect of approximately doubling the fire loading. Fire tests were made to determine the special needs of this design in terms of fire protection. [9] Sprinkler protection was considered absolutely essential, with perforations in any metal above the bookshelves to vent heat and smoke, and to let water through into any fire. Mobile shelving is in general use in public libraries and university libraries. The University of Illinois installed 88.56 km of such shelving in 1983. The Library of Congress probably has the largest of such installations, in law and music collections in basement levels. The law library has 108.5 km of bookshelves. The music library has 18.35 km of shelves supporting boxes of sheet music and manuscripts. Storage space is increased 90 percent in the change from conventional shelving. Floor loading capacity in this mobile storage is 1238 kg/m². Compact or mobile storage units are mostly of two types, hand-cranked and motor driven, but some units can be moved by hand without mechanical assistance. Experience to date indicates that the hand-cranked type requires little maintenance. The motor driven installations have a higher degree of fire hazard, in that every unit has its own electric motor, each a potential fire source as it deteriorates with age. Any compact storage installation becomes a site for a “burrowing” fire, deep-seated and not well suited to
Halon 1301 protection. Since basement and sub-basement levels are logical sites for these extra-heavy loads, the fire protection plan might well include extinguishment with high-expansion foam, reinforced with automatic sprinklers.

**DISASTER PREPAREDNESS**

Closely related to fire protection and water damage protection is the matter of disaster preparedness. The unfortunate experience of fire and water disasters is most useful. Every library and museum should have its own manual of emergency action to be taken, based on the history of these disasters. For both libraries and museums, the restoration of materials wet during a fire or water emergency is a matter of great concern. Wet materials which cannot be immediately placed in an approved drying process need to be put into a freezer and blast-frozen to −35°C to stabilize water damage and inhibit mold. The actual drying process can be undertaken at a later time.

It is good for librarians and curators to recognize that wet materials can be restored in modern drying processes, also that water damage due to manual firefighting is liable to be many times greater than any that would be created in extinguishment of fire with automatic sprinklers. Vacuum freeze-drying of wet books and artifacts has advanced greatly since it was first used in Denmark in 1968. Early in 1989, the largest book drying project ever attempted was completed in California. This was the drying of 586,000 books water damaged in the fires of 1986 in the Los Angeles Central Library. These were held in cold storage for 30 months, and were dried in the five months from September, 1988 to January 1989. In the late 1980's the vacuum chamber sublimation process has been refined with several innovations which have reduced the time required for drying by half, and have obtained better results than earlier methods. [10]

**AUTOMATIC SUPPRESSION WITHOUT WATER**

Automatic suppression systems are, of course, not limited to water. The British records Office in Kew protects one area in a basement level with a high-expansion foam system. It is likely that some rooms in libraries and museums are equipped with Carbon Dioxide total flooding systems, although we do not accept these in spaces which are workplaces, because of the danger of sudden asphyxiation.

In recent years rare books, special collections, and works of art have been protected with total flooding systems using Halon 1301 (BrCF3) Bromotrifluoromethane. It is popular with librarians and curators because of its potential for instantaneous extinguishment of fire, the total absence of residues, and its low toxicity. It is essential in extinguishing a fire to maintain a 5% mix of Halon in air for as long as 10 minutes, and this requirement demands careful engineering of the protected spaces. In some places in important libraries and museums Halon systems are being reinforced with automatic sprinklers, so that if the Halon protection should fail for any reason, water will follow to put out a fire.

The use of Halon 1301 is now in jeopardy, in view of its alleged threat to the upper atmosphere as an ozone depleter. Limitations on production have been imposed. But suppliers are prepared to provide the gas for some time, and manufacturers are busy in research to develop new ozone-benign materials to take its place. A combination of Halon 1301 and Halon 1211 in portable fire extinguishers has proved highly effective, and because of the unusual properties of Halons is well suited to libraries and museums.

**MUSEUM PROTECTION**

Museums have been reluctant to provide automatic sprinkler protection against fire. Curators seem to reason that a skilled fire brigade can put out a fire without getting water on anything not burning. When the Museum of Modern art burned in Rio de Janeiro in 1978, 950 works of art were destroyed including paintings by Miró, Picasso, VanGogh, and other masters. A director of the museum observed that it would take $7,500,000 to restore the concrete and glass building, "including the installation of an adequate sprinkler system". In the same year a spectacular incendiary fire destroyed the San Diego Aerospace Museum and Library. It was rebuilt with sprinkler protection. The prejudice against sprinklers dissipates in the smoke of fire disasters in unpro-
ected buildings.

A number of fire protection systems and construction features were built into the James Madison Memorial Building of the Library of Congress as it was completed in 1979. Compartmentation and complete automatic suppression systems are the basic guarantees of the building's capability for protecting the collections. Smoke extraction is a feature of the HVAC (Heating, Ventilating, and Air Conditioning) systems. A public address system reaches all areas to carry emergency instructions. The highest valued collections have Halon 1301 total flooding systems, but these are being reinforced with on-off sprinklers as second line of defense. The two older buildings of the library have since been retrofitted with sprinklers and modern smoke systems.

Many of the features of the Library of Congress fire systems are also in place in such modern Canadian libraries as those of Metropolitan Toronto and Hamilton, Ontario, and two large libraries in Riyadh, Saudi Arabia. The most impressive combination of fire protection systems may be that of the new British Library in London. Here the planners have had to solve complex problems of drainage, smoke venting and suppression systems. Halon systems were approved, but not without the support of automatic sprinkler protection for the same spaces. Extreme precautions were taken to isolate water mains and other possible sources of water; very deep basement construction required superior protection against flooding. Completion of this great library is expected in 1993.

**NEW LIBRARIES**

U.S. cities and universities are routinely building fire protection into their new libraries. Complete suppression systems are part of the protection in such libraries as those of Portland, Maine; Dallas and Houston, Texas; Atlanta, Georgia; Hollywood, California; Broward County at Fort Lauderdale, Florida; and Law Libraries at Stanford University and University of California at Berkeley, also the new Engineering Library at Berkeley. There are many others, including smaller community libraries like Gaithersburg and Cockeysville in Maryland, Pohick Regional in Burke, Virginia; Fremont, California; Ketchum, Idaho and St. Charles, Missouri.

Museums seem to have trailed somewhat behind libraries in making the decision for 24-hour protection through automatic suppression, although they are completely convinced of the merits of other forms of protection. Some curators have held to a policy of not loaning works of art to any museum protected with automatic sprinklers. On the other hand, many important museums are well protected. These include the fourteen national museums under the management of the Smithsonian Institution, including the spectacular Air and Space Museum. Others are the J. Paul Getty Museum at Malibu, California; the very large Henry Ford Museum at Greenfield, Michigan; and two classic automobile museums, the Behring Museum at Blackhawk, California; and the Auburn-Cord-Duesenberg Museum at Auburn, Indiana.

It is sometimes said that the cost of an automatic sprinkler system in a new building is about the same as the cost of wall-to-wall carpeting. This may not be an accurate comparison. However, it is no exaggeration to say that the cost of such a system in a library or museum is less than one per cent (or two percent) of the values the system will protect from fire. Reliance on automatic detection systems supported by manual suppression may be purchased for less, but the value of the protection depends very directly on its performance in the fire emergency, and the success of the fire-fighters responding. The strongest proponents of automatic suppression systems for protecting our cultural resources include fire service officers who have had to battle very difficult and destructive fires in libraries, museums, and historic buildings.

The conclusion must be drawn from a study of library and museum fires occurring over the last 40 years that the most reliable and effective fire protection for these places is automatic suppression, on guard day and night. Automatic sprinkler systems have proved their worth in thousands of fires. Automatic detection systems are valuable in several important ways. But manual suppression without the support of sprinkler systems cannot promise protection, even with the great resources and skills of the
finest firefighting forces. Surely our priceless and irreplaceable works of art and books deserve the most reliable protection we can find.

REFERENCES: