Special Challenges – Fire and Fire Suppression

Warnings regarding the use of space not originally designed for the storage of archival and library materials

by Tom Goonan
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Introduction

From a fire protection standpoint, there is little difference between archives and short-term records. A piece of paper burns the same, creates as many calories and does as much damage whether it is a page from the Federal Register or the signature of Chief Sitting Bull. Tests cited in this talk were mostly of fires in records boxes intercepted on their way to the incinerator. A fire progressing up the sides of hollinger boxes might vary a few seconds from a fire traversing records cartons, but the main variable would likely be the moisture content of the container.

Extinguishing a records fire is essentially the exercise of applying the wet stuff to the hot stuff. Water extinguishers, hose streams and sprinklers are the applicators most used, and most successful. Automatic sprinklers are successful whether or not there is anyone around. Gas extinguishers can be successfully used on incipient fires, but with limited expectations. I will discuss these systems later.

An **ideal** archive facility is a collection of one-story sprinklered buildings, adequately separated. A **practical** archive facility is a sprinklered one-story building block divided into modules by fire walls with protected openings, each having an outside wall or roof which can fail or be demolished in case of a runaway fire within a module. Where massive venting cannot be achieved, a high-expansion foam system may be the only practical backup to provide. I will return to these themes.

Fires in Records

In standard records center fire tests, sprinklers were standard spray type, 280EF, 10' x 10' spacing. The sprinkler nearest the fire was centered over the shelving, which was the most obstructed position. No sprinklers were located over the aisle. In this test, 50 cartons of records were destroyed; ceiling temperature exceeded 1000EF for seven minutes, which might have been bad news in a building with bar joist roof support. (The roof could sag and break the sprinkler lines.) In a later test, using large drop sprinklers, ceiling temperature was limited to less than 1000EF, but loss of records was three times as great.

Tradeoffs like these require attention to detail and an understanding of your problems. Spray developed by the standard spray sprinklers in the first test exhibits much greater penetration and control; the shelving greatly limits the ability of large drops to extinguish fire under the shelves.

At that time a number of records centers had roofs supported by unprotected bar joists which were vulnerable to temperatures above 1200EF. (Some of these buildings are still with us.) Applying effective fireproofing to bar joists is expensive and very messy; therefore providing large-drop sprinklers, although less efficient at extinguishing fires, provided safety against roof collapse and destruction of the sprinkler piping. Buildings adapted for records center usage may exhibit the same deficiencies today, and require the same "fix".

Sprinkler Design

A variety of so-called "large orifice" sprinklers are available today which exhibit "large drop" behavior. They are approved for use in high-piled general storage up to forty feet high. No data exists for their use in high shelving. There is no evidence that they would have any effect below the top level of catwalks, unless means are provided to retain records on their storage shelf during a fire to prevent exfoliation into the aisle. There may well be a combination of ceiling sprinklers and under-catwalk sprinklers that will provide safe storage in sky-high records centers, but it hasn't yet been announced. That day will probably arrive as soon as major companies fund full-scale testing of promising technology. However, when that day eventually arrives, I would say that the last place for storing archives would be in a fifty-foot stack.

It is entirely possible, however, that the solution to the fifty-foot record storage problem will suggest safer ways to protect archival storage. Keep tuned.

Subdivide the Collection

A basic tenet in fire protection is to limit the percentage at risk. A standard records storage module is 40,000 square feet, up to 250,000 cubic feet of records per module. Additional records require additional modules. Modules are required to be separated from one another by 4-hour fire walls with protected openings (and 4-hour floors in multi-story buildings). As long as the primary protection (sprinklers) does its job, fire walls are redundant. Failure of primary protection gives the fire separations a nearly impossible task: Seven-foot high storage provides about 70 pounds per square foot of fuel; 15-foot-high storage , about 150 pounds a square foot. Fire duration at 2000EF or more is estimated at 1 hour per 10 lb/square foot; for seven-foot-high storage (say, compaction files) provide a seven-hour fire; 15-foot high storage-open rack, provides a 15-hour fire.

To save the building (other than the module) in uncontrollable fire, the fire department (or nature) must provide massive venting such as roof collapse or removal of an outside wall to dump heat and smoke to the atmosphere and permit hose streams from the outside to cool the fire and relieve the fire stress on the wall separations. This is impossible in multi-story buildings except for the top floor (like the MPRC fire in St. Louis) or a ground floor wall that

can be destroyed (as in the Chicago records center fire) Just forget basement or mine storage.

The NARA Fire Module

The NARA records module, 40,000 square feet in area and about 22 feet high, is probably a direct descendent of the GSA general warehousing module, which, in turn is descended from the US Corps of Engineers warehouse module for the US Army (and Navy and Air Force, by default). It seems to be a practical size; not too much to lose in a fire disaster and not too expensive to build; a good, all-around size for general storage use. The size has been re-evaluated at long intervals, without many changes. NARA, where possible, uses 20 to 25,000 square foot modules for archives storage. The preferred defined storage module for records centers today is something like 240,000 or 250,000 cubic feet of records, without defining dimensions. Archives, to the extent practical, are limited to 7 or 8-foot high shelving; some are track files and some fixed open shelves.

Shelving for open-shelf storage is closely controlled; 30" wide, 14 feet high, double row back-to -back, with a 30" aisle for records storage. Where archives are stored on fixed open shelves, the arrangement is mostly on single 30" shelf with an aisle on both sides. Sprinkler spacing has been defined as 10' x 10', 0.30 gallons per minute per cubic foot, using standard or large-drop sprinklers rated at 165EF to 286EF, normal or quick response.

Fire Resistivity

Prescribed fire walls between storage modules is 4-hour rating with protected openings. Other walls probably have the same rating requirement; however, note should be taken of the need for roof or wall venting in the event of uncontrolled fire. A frangible wall which could be massively breached with equipment available to the local fire department should be considered in future building designs. Frangible roof design is also an attractive option; one which could withstand a substantial fire exposure (over 1500EF) for a period of 30-90 minutes before failure.

Protected Openings

Wall openings between storage modules should be avoided unless totally unavoidable. Unavoidable openings should be provided with 2-hour rated self-closing fire doors on each side of the wall. Service corridor openings also require 2-hour self-closing or automatic-closing protection on one side of the wall; that provides 4-hour separation between storage modules.

Mobile Compact Shelving Systems

I surely hope that you don't mind me calling these things track files. Most track files are 7 or 8 feet high. Height and length have practical limits related to strength, stability and accessibility. Current standards do not prohibit 14' high track files, but they would be scary to me, from a toppling standpoint. Arrays have a practical track length of 25'. Sprinkler standards (such as they are) are the same as for open shelf filing. Fire characteristics are not

the same. Records boxes facing the open aisle would produce the same kind of fire as open shelving the same height. Without internal dividers, and in the absence of fire department intervention, a fire would slowly burrow through the entire array, even though the aisle fire would be controlled. With adequate overhead sprinklers, a professional fire department should be able to control and overhaul the fire in short order, due to its slow-moving characteristics. Also due to its slow-moving characteristics, a fire in track files that originates away from the aisle will produce smoke long before a sprinkler operates. This interval might be 45 minutes to an hour. For this reason, ceiling mounted smoke detectors are an important addition in records stored in track files. Records stored on fixed open shelving produce fires which quickly proceed to the point where sprinklers operate and give an alarm. In this situation, smoke detectors do not produce any useful lead time and are not an economical use of funds.

High-Expansion Foam

High-expansion foam can provide some credible assurance of controlling a fire that might be escaping sprinkler control. Limited testing demonstrates that hi-ex foam has the ability to overcome a well-established fire. Like gas extinguishment, to do its job hi-ex foam must fill the entire fire compartment to totally submerge the fire, and continue refilling at a rate adequate to totally replace the foam broken down by the fire.

If provided to justify the use of mines and multistory buildings for records centers, hi-ex foam should be required to demonstrate the ability to overcome a fire spreading beyond sprinkler control in a 250,000 cubic foot records module.

Hi-ex foam can be used as a backup for sprinkler failure only if adequate reliability factors are built into design of the system. Inadequate water supply is identified as causing about 8% of sprinkler failures; such a failing would also cause a hi-ex system failure. Closed valves, which is identified as causing 30% of sprinkler failures in the attached chart on Unsatisfactory Sprinkler Performance below is a symptom of poor maintenance, which could affect a hi-ex system in a number of ways - water valves, foam valves, air fans, directional dampers - all sorts of failure modes affect foam systems. Whether to rely on sprinkler waterflow alarm for activating the hi-ex system, or providing an entire separate heat-detection system is a design decision. A smoke detection system designed to activate hi-ex foam seems to be much too reactive.

Gas Extinguishment

Gas systems have very little inherent safety. To extinguish a fire, everything has to work perfectly. A whole separate detection system- (often two systems, both of which have to activate) -has to detect the fire, report it to a central station and activate the system. The system has to sound warnings, start the timer (for escape time), turn off vent fans, close dampers, close doors (and possibly windows), fire the squibs that open the gas valves, open and shut various directional valves (if the gas protects several independent rooms). And if someone hits the abort button because he thinks it might be a false alarm, forget the whole

thing. If the fire is within design limitations, not deep seated, all doors and dampers seat properly, the gas has not leaked away since the last inspection, and the gas resupply is not awaiting refill by requisition, the gas will extinguish the fire as if by magic.

Multi-Story Buildings

No traditional fire resistive building will survive a module burnout (7 to 15 hour fire); an exception was the top floor MPRC fire. Modules are inaccessible from the outside; an exception was the ground floor - Chicago Records Center fire, where the building was saved when the exterior wall was removed to vent heat and smoke to the sky and make the fire accessible to hose streams. Existing multistory buildings may be candidates for hi-ex foam backup (single system for multiple modules).

Cavern Storage

Caverns selected for records storage are clean and dry, with essentially no air movement. They are prized as low-maintenance facilities with no heating or air-conditioning required. Lighting is limited to task lighting and safety lighting; therefore, no UV exposure. A minimal water supply is maintained for comfort of a small staff; doesn't necessarily meet the substantial sprinkler system and fire hose requirement. The location is probably remote, reducing security requirements and simplifying visitor control.

Where is the snake in our paradise?

A sprinkler-controlled fire requires:

Overhaul and extinguishment by the fire department; smoke removal by the fire department and the small environmental system; data recovery by the staff and outside auxiliaries.

A fire beyond control with sprinklers:

The fire walls should contain the fire in the module of origin for four hours; however, before the fire spreads throughout the module of origin, smoke and heat will migrate, filling the cavern, making it dangerous and eventually impossible to remain. Without means to dump smoke and heat to the atmosphere, the fire will continue to grow until it involves all the cavern contents. The cavern may be inaccessible for months. Nothing will remain to salvage.

Caverns are usually remote from the services of a large, well-organized fire department. This may be a superfluous problem, because there is no safe place to base a fire department inside a cavern. There is little a fire department can do outside a cavern. Caverns are usually remote from a substantial water service. A credible private water service would consist of a sizable (250,000 to 1,000,000 gallon) ground tank and two or more fire pumps (1000 to 1500 gpm). Without the possibility of massive smoke and heat venting, a hi-ex foam system might be designed to provide adequate backup fire extinguishment.

Let us review:

Caverns have no outside venting capacity. Module burnout must vent massive quantities of heat and smoke directly to the outside to avoid a total cavern burnout. Venting into cavern does not permit manual fire fighting. A cavern would be inaccessible for months after a burnout. Hi-ex foam is a candidate for limiting a fire to a module, given sprinkler failure. There is no possibility of venting a module fire outside. There is no natural drainage. Failure of sprinklers to control a fire for any reason would result in quick abandonment and total burnout of the entire cavern contents unless hi-ex foam provides adequate backup.

Basement Storage

Basements have all of the downside features of caverns, with two exceptions. They are not necessarily remote. They might be served by superior fire departments. The fire department can operate to some extent from the outside, with limited inside travel. Otherwise, basements are very difficult to ventilate in a fire, and are mostly inaccessible to firefighters.

Failure to control a fire in a basement will almost certainly result in the loss of the building and all the contents.

Cold Storage

Fortunately for the human race, cold fuel will produce hot fires. Unfortunately for the archivist, the same rule applies when the fuel is called archives or records. In my early days as a factory fire insurance inspector, managers of cold-storage warehouses nursed a belief (or hope) that their products were somehow "fireproof" because they were stored at zero Fahrenheit, or fifty below. Match ignition of paper (to their chagrin) demonstrated no observable difference at seventy above or fifty below.

Sprinkler protection in cold storage requires careful design of dry pipe sprinkler systems or anti-freeze systems. Maintenance retesting of such systems requires even more care.

Library Materials

Archival materials, which may include boxed books, are generally stored in hollinger boxes, although they may also be in records boxes; both stored on open shelves.

Library materials in the form of books are generally stored on open library shelving in the form of bookstacks. Modern stacks are generally 6 to 8' high library shelves, nearly ceiling high in buildings built for library stacks. Shelves are erected on a flat slab concrete floor, floors connected by enclosed stairways with self-closing fire doors. Bookstacks are currently sprinklered, with sprinklers running in the aisles. Most of the battles over providing sprinklers to protect books took place in the 70's. Large library fires such as the huge Los Angeles Public Library fire convinced even the die-hards.

The basic model for library bookstacks was developed for the Library of Congress in the 1880's. They filled the courtyard with cast iron bookstacks that were interconnected about every eight feet vertically with metal struts. Walkways were attached to the interconnecting struts, and the stacks supported the roof. Slots at the walkway allowed air to rise from the

basement for heating (and fire, if that happened). A few years ago the LOC stacks were sprinklered, greatly reducing a large threat to the nation's heritage.

I worked on a restoration of the Furness Library at the University of Pennsylvania, Philadelphia, (ca 1890) designed on the same model by the same architect, Furness. The restoration job won a national award and several state awards for the architect, Robert Venturi of Venturi Scott Brown and Associates, from the American Institute of Architects and others. An interesting side note: the Furness stack walkways were clear glass slabs about 1" thick.

Fire Experience

The Military Personnel Records Center Fire

The MPRC fire in Overland, MO was not the ultimate records center fire - not even close - not even for that building. The MPRC fire was limited because it occurred on the top floor. Had it occurred on a lower floor, the building windows would have permitted it to spread to upper floors. The floors above the out-of-control fire would have been too much at hazard for firefighters to occupy, to prevent flames outside the windows from igniting paper stacks inside the windows. Later in the fire, the flooring directly above the fire would actually become too hot to stand on. The atmosphere would be too hot to endure, and the floor would begin to fail and sag, precipitating imminent total collapse of the building. Descending floor and heavy stacks of paper impose impact loading on the floors below. Partial or total building collapse breaks the building apart and spreads the fire to all floors, at which time the loss of the building and all the contents is assured. This description was taken from a report that I wrote about the MPRC building 6 months before the actual fire. The fire that subsequently occurred in July 1973, was on the top floor, and relatively easy to prevent descending. While the entire top floor was destroyed, it was fortunately never a serious threat to the rest of the building. The attached chart on the Extent of Fire at the Military Personnel Records Center was part of my report.

Chicago Records Storage Facility Fire*

On Tuesday October 29, 1996, a still alarm was sounded for a fire in an automatic sprinkler protected records archive building shortly before 2 p.m. Before the fire was declared under control nearly ten hours later, it had reached the fourth alarm level with a commitment of 17 engines, 9 trucks and tower ladders, a squad and several additional special pieces of equipment. The last fire company left the scene about 5 p.m. on November 7, 1996 and a full box alarm assignment was involved in overhaul operations for over 24 hours after the fire. Damage consisted of the total loss of thousands of record storage boxes and their contents, water and smoke damage to thousands of other boxes, the loss of steel storage racks and structural damage to the fire area and adjacent fire divisions. The value of the lost records and the cost to restore salvageable records was still being determined at the time this investigation was conducted. The loss of the racks and storage boxes themselves is estimated at over $3 million. The structural damage and replacement of the destroyed front wall has

been estimated at over $2 million. Early assessments of the total dollar loss have been set at over $50 million.

Aggressive fire department interior and exterior operations contained the fire to the 35,000 square feet compartment of origin. The fire area contained storage of cardboard boxed records in approximately 28 feet high metal racks with solid shelves. Automatic sprinklers were provided at the ceiling level only and may have been shut off in the immediate area of fire origin. Flames were first observed near the ceiling level above one of the storage racks. After discovering the fire, employees may have delayed in immediately notifying the fire department while they attempted to extinguish the fire. The cause of this fire was still being investigated but it is believed to be electrical in nature.

The successful control of this fire can be attributed to the performance of the fire separation walls supported by a large fire suppression force. Effective pre-incident planning and standard operating procedures also contributed. Companies supported the automatic sprinkler systems at Siamese connections and attended to openings in the fire separation walls. The availability of a good water supply to support the numerous hand lines and master streams, as well as the automatic sprinkler systems was important to the overall tactical plan.

** I was surprised that the fire investigator did not cite removal of an outside wall as a key element in saving the facility. The double effect of dumping heat and smoke and direct application of hose lines to the fire were to my mind the saving of the facility.

Iron Mountain fire - South Brunswick, New Jersey*

After the fire in Chicago, serious fires occurred in four other records storage facilities. Two of these fires also resulted in the total loss of contents, even though both buildings were protected by automatic sprinkler systems. In addition to the loss of the contents, both of these buildings were destroyed.

Three of the fires, all determined to be the result of arson, occurred between March 10 and March 19, 1997 in two adjacent records storage buildings in South Brunswick, New Jersey. Both buildings were operated by the same company and were part of 117 record storage sites operated countrywide. One building with its contents was totally destroyed. The first two fires occurred on March 10 and 17, 1997 in the same building, which contained an estimated 250,000 record storage boxes. Both of these fires were controlled by the automatic sprinkler systems and fire department operations. The automatic sprinkler protection included a strong hydraulically calculated overhead system and in-rack sprinklers. Boxes were stored on steel shelves and racks in a similar configuration to that used in Chicago. The exact storage height was not available. The Monmouth Junction Fire Department was still on the scene of the March 17, 1997 fire when the third fire occurred.

The March 19, 1997 fire was reported at 10:20 a.m. in a building located around the corner from the one above. The building, constructed of concrete walls and metal roof, contained an estimated 850,000 records storage boxes. Storage was on steel shelves and racks with

intermediate catwalk levels. The exact storage height was not available. Automatic sprinklers were installed at the ceiling and in the racks following the same design which controlled the previous fires.

Flames penetrated the roof of the building by early afternoon in the third fire and reached 100 feet in the air by 8 p.m. that night. There are reports that all of the automatic sprinkler systems were shut down to allow fire firefighters to access the building late in the morning. Either the systems could not be turned back on or the fire opened too many heads and the water supply could not support all of the open sprinklers. There are reports of drafting operations from nearby ponds at the height of the fire to bolster weakening water levels. Parts of the concrete walls collapsed in the afternoon and the roof collapsed by evening.

Fire department interruption of the automatic sprinkler system must always expect that the system will have to be quickly turned back on again. Typically, if large amounts of cold white smoke are being generated, the fire is being controlled by the sprinklers but it is by no means extinguished. There is still a large amount of heat being generated which is being absorbed by the sprinkler discharge as the water turns from liquid to steam. It is not advisable to turn off the sprinklers under such conditions. Alternately, large amounts of black or dark smoke strongly suggest that sprinklers are not controlling the fire and a major fire is developing. Under these circumstances the Fire Department should prepare for the fire to spread to fire walls or throughout the structure. If the sprinkler water supply is interrupted to allow firefighters into the building or as a means to improve visibility, then the seat of the fire should be reached by crews within minutes to complete extinguishment. Any delay in advancing into the structure can result in the fire overwhelming the system. An increase in air temperature or a change from white smoke to dark smoke after the interruption of sprinklers is a strong indication that the sprinklers should be turned back on immediately and without delay. Otherwise the Incident Commander should expect the fire to overwhelm the sprinkler system with the probable result that structural failure of non-fire resistance rated elements will occur soon.

A firefighter or officer in full turn out gear, air pack and with a radio must be in constant attendance at closed automatic sprinkler control valves. If the position becomes untenable, then every effort should be made to reopen the valves unless there is strong and reliable indications that the sprinkler system has been damaged due to a collapse.

In the Chicago records center fire, the Chicago Fire Department kept the automatic sprinkler system operating for days. The sprinklers were still discharging water as outside contractors were overhauling and removing the building's contents with heavy equipment. Their tactics and support of the sprinkler system are good examples for other fire departments to study.

West Pittston, Pennsylvania, Records Center Fire*

The fourth records center fire occurred on May 5, 1997 in West Pittston, Pennsylvania, located between Scranton and Wilkes-Barre. The center was a single story, 44 feet tall, noncombustible building with a ground floor area of about 78,000 square feet. The original

section was built in 1995; an addition was completed approximately six months before the fire. The center was protected throughout by a ceiling level only dry pipe automatic sprinkler system. No sprinkler design information was available although the system was judged to be inadequate for the occupancy by the insurance carrier.

Record storage boxes were arranged on solid metal shelves in double and single row metal racks to a height of 42 feet. Intermediate level grated metal walkways were provided to access the boxes. The arrangement was similar to the rear section of the Chicago Records Center building. The company operated nine other records storage buildings throughout four states.

The cause of the fire has not been determined although one theory involves a failure in a lighting fixture that ignited the boxes. The fire was not controlled by the ceiling only automatic sprinklers and spread throughout the structure resulting in a total loss.

*Directly quoted from "Sprinklered Records Storage Facility, Chicago, Illinois, October 29, 1996; Federal Emergency Management Agency, United States Fire Administration"; available at http://www.usfa.fema.gov/ No author named. This is included to give archivists a feel for uncontrolled records fires. Color photos are included in the on-line report.

** Speaker's comments on this fire report.

Related News from the NFPA Front

On the second of March 1999, after 10 years as chairman of the National Fire protection Association Committee on the Protection of Records, I passed the gavel to Steve Hannestadt, Chief of Security for the National Archives. The committee publishes two documents, NFPA No. 232, Protection of Records and NFPA No. 232A, Guide for Fire Protection for Archives and Records Centers. The NFPA 232 Guide, developed in the 70's is basically a statement of the National Archives fire protection standard.

Getting off to a running start, the Committee, under Chairman Hannestadt produced a draft of a new document combining NFPA 232, which covered records collections from safes and file cabinets up to oversize file rooms, with 232A into a single document using code language (mandatory requirements in jurisdictions enforcing this code). The new NFPA 232 will be up for adoption in the fall of 2000.

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Tom Goonan Associates is an independent fire protection engineering, building code, and fire code consultancy. Tom Goonan's firm has participated in the design, construction and/or protection of hotels, shopping centers, business buildings, and historic restorations.