Supporting Data Needs for NFPA Automatic Sprinkler Committees Research Project

Sprinkler Design Criteria for the Protection of Compact Mobile Shelving Systems

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ONE BATTERYMARCH PARK
QUINCY, MASSACHUSETTS, U.S.A. 02169
E-MAIL: Foundation@NFPA.org
WEB: www.nfpa.org/Foundation

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Sprinkler Design Criteria for the Protection of Compact Mobile Shelving Systems

Prepared by:

Garner A. Palenske, P.E.
Jonathan Perricone, E.I.T.
Schirmer Engineering Corp.

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FOREWORD

Compact mobile shelving systems are commonly found in healthcare, office, library, and numerous other occupancies. The advantage to the use of these systems is that aisles are eliminated, with the exception of one moveable aisle, in most cases saving up to 50% of floor area.

The 2002 edition (current) of NFPA 13 does not provide specific design criteria for compact storage arrangements. As a result, designing engineers are required to utilize protection criteria for either rack storage (storage depth 30 inches or deeper) or shelf storage (storage depth less than 30 inches), depending on the dimensions of the compact storage array. This is problematic because the fire protection design challenges presented by compact mobile shelving units are fundamentally different than those presented by stationary shelf and/or rack storage.

This report presents a review of available fire test data for these systems, identifies gaps, and makes recommendations for future testing to develop rational fire protection criteria for this storage system.

The Research Foundation expresses gratitude to the report authors Garner Palenske and Jonathan Perricone of Schirmer Engineering Corporation; Project Technical Panelists Kerry Bell, Edward Budnick, Christian Dubay, Morgan Hurley, Kenneth Linder, Joe Noble, John O'Neill and Rich Pehrson; and to the National Fire Protection Association for sponsoring the project.

The content, opinions and conclusions contained in this report are solely those of the authors.

Supporting Data Needs for NFPA Automatic Sprinkler Committees
Research Project

Technical Panel

Kerry Bell, Underwriters Laboratories Inc.

Edward Budnick, Hughes Associates, Inc.

Christian Dubay, NFPA

Morgan Hurley, Society of Fire Protection Engineers

Kenneth Linder, GE Insurance Solutions

Joe Noble, Clark County Fire Department

John O'Neill, The Protection Engineering Group, PC

Rich Pehrson, Futrell Fire Consult & Design, Inc.

Sponsor

National Fire Protection Association

SCHIRMER ENGINEERING
11770 Bernardo Plaza Court, Ste. 116
San Diego, CA 92128
Phone (858) 673-5845 Fax (858) 673-5849

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SPRINKLER DESIGN CRITERIA FOR THE PROTECTION OF COMPACT MOBILE SHELVING SYSTEMS

A REPORT SUPPORTING DATA NEEDS FOR NFPA AUTOMATIC SPRINKLER COMMITTEES

Prepared for:

Fire Protection Research Foundation

Prepared by:

Garner A. Palenske, P.E.
Jonathan Perricone, E.I.T.

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Schirmer Engineering Corporation
www.schirmereng.com

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INTRODUCTION

Compact mobile shelving is defined as, "*A system of record storage, usually a type of open-shelf file equipment, also known as track files, compaction files, or moveable files, in which sections or rows of shelves are manually or electrically moved on tracks to provide access aisles.*"[1] A typical configuration is shown in Figure 1.

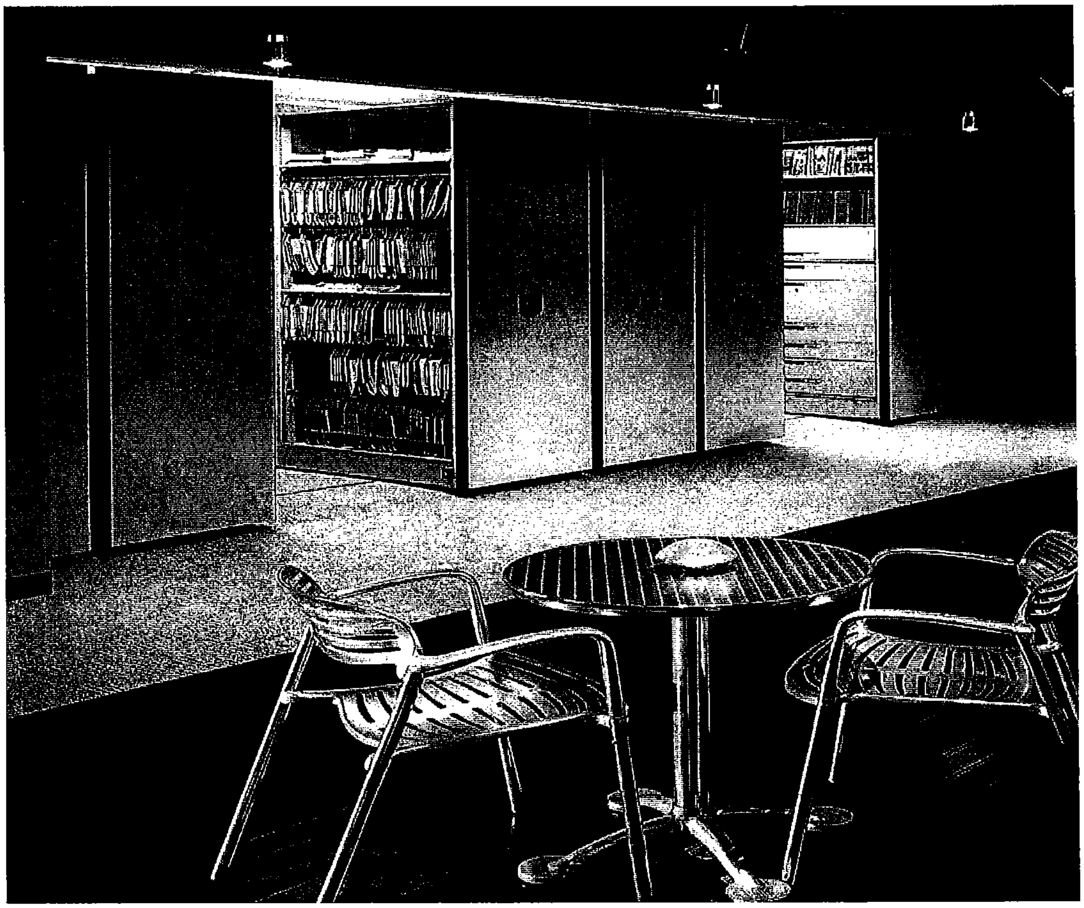

FIGURE 1: TYPICAL COMPACT MOBILE SHELVING SYSTEM

Compact mobile shelving systems are commonly found in healthcare, office, library, and numerous other occupancies. The advantage to the use of these systems is that aisles are eliminated, with the exception of one moveable aisle, in most cases saving up to 50% of floor area.

The systems are custom built to accommodate many different storage materials, including files, books, military equipment, and artwork. Manual and powered movement of the units is available.

Discussions with the industry indicates that approximately 80% of the systems are used in office type occupancies and cover a floor area of approximately 200 square feet. As the storage items are hand picked in most cases, storage height is normally 8 feet maximum. Shelves are

[1] National Fire Protection Standard 232, "Protection of Records."

generally 36 inches deep, tiers are 12 inches high. The construction of all systems reviewed was noncombustible (steel).

The 2002 edition (current) of NFPA 13 does not provide specific design criteria for compact storage arrangements. As a result, designing engineers are required to utilize protection criteria for either rack storage (storage depth 30 inches or deeper) or shelf storage (storage depth less than 30 inches), depending on the dimensions of the compact storage array. This is problematic because the fire protection design challenges presented by compact mobile shelving units are fundamentally different than those presented by stationary shelf and/or rack storage. In each of these applications, the configuration of the storage arrays obstructs the natural flow field of water from a ceiling level automatic sprinkler to the burning fuel below. The degree to which the water spray is obstructed is a function of the following problem specific parameters:

1. Location of the burning fuel with respect to the location of the nearest sprinklers.

2. Dimensions of the storage array with respect to the dimensions of the surrounding enclosure. This includes height of the array relative to the height of the room as well as clearance between the top of the array and the sprinklers above.

3. Size of flue spaces within the storage array (rack storage).

4. Characteristics of the natural (unobstructed) water flow field including flow streamlines and characteristic droplet momentum as determined by the design of the automatic sprinkler system.

The most significant difference between traditional rack or shelf storage and compact mobile shelving is the internal mobility of the storage array. The ability to save space by manipulating aisle widths adds a new unknown variable to the fire protection design problem. This new unknown creates a set of geometric permutations for the obstruction of overhead sprinkler sprays that is unique to the compact mobile shelving application. In addition, this mobility generates complexity for protection schemes traditionally used in rack storage applications such as in-rack sprinklers.

To address this issue, the NFPA 13 Discharge Committee authored a change to NFPA 13. This change added definitions of compact storage and provided design criteria for the protection of same.

The action of the committee was overturned at the Technical Committee Report Session of the June 2006 membership meeting. The membership requested the proposal be sent back to committee for further study. This action was supported by the Standards Council (July 26-28, 2006). See Appendix A for a copy of the proposed change and letter from the Standards Council.

LOSS HISTORY

To determine if compact storage does in fact present a fire protection exposure, available sources of applicable fire history were reviewed.

Data from the National Fire Incident Reporting System (NFIRS) Version 5.0 was reviewed. This data is presented in an analysis prepared by John R. Hall, Jr., Ph.D. of the National Fire Protection Association. Dr. Hall's paper, "*An Analysis of Automatic Sprinkler System Reliability Using Current Data*" was the primary source of data. Unfortunately, as confirmed by NFPA staff, statistics specific to compact storage are not available. For storage arrays in general, sprinklers are quite effective, controlling or extinguishing the fire 92% of the time when activated.

Discussions with the compact mobile shelving industry were also conducted to identify fire history. Specific loss history could not be identified.

Review of other fire protection standards, such as FM Global Loss Prevention Data Sheets, indicated no loss history specific to compact storage. Furthermore, substantial resources were not devoted to providing guidelines for the protection of compact storage.

RELEVANT STANDARDS/CODES

A review of relevant design standards applicable to the protection of compact mobile storage was conducted.

Section 2.2.4.3 of the Factory Mutual Global Data Sheet 8-9 "Storage of Class 1, 2, 3, 4 and Plastic Commodities" calls for protection "*...of rack storage in movable racks the same as multiple-row rack storage. Supply in-rack sprinklers via flexible in-rack sprinkler system connections, or other arrangements that provide sufficient water to the in-rack sprinklers.*" However, no specific design criteria are provided for compact storage with a depth of 30 inches or less as FM Global considers the position of the array to be always closed, thus resulting in depths which are 30 inches or greater.

National Fire Protection Association (NFPA) 232, "Standard for the Protection of Records" provides requirements for records protection equipment and facilities. Included in the scope of this standard are vaults, archives, file rooms, compartmented records centers, and record centers.

NFPA 232 requires both automatic sprinkler protection and smoke detection. (Sections 6.13.1 and 6.14.3 respectively). However, NFPA 232 does not provide the reader with specific design parameters, only that the system should comply with NFPA 13.

The NFPA Industrial Fire Hazards Handbook, 3rd Edition, discusses compact mobile storage in Chapter 57, "Records Storage." The requirements stated in this chapter are consistent with those of NFPA 232 (e.g. Automatic sprinklers and smoke detection). In addition, the author, Thomas Goonan, P.E., clarifies the intent of the protection scheme by stating, "*Although protection by sprinklers alone may permit fire involvement of the entire array, overhead sprinklers provide adequate protection for a building containing mobile shelving, and prevents fire from jumping to other arrays. In addition to sprinkler protection, a smoke detection system is suggested in mobile shelving areas not continuously occupied to provide a fire warning well in advance of sprinkler operations. Early warning smoke detectors may help limit the extent of fire damage in mobile shelving if skilled forces are quickly available during non-operating hours.*"

Review of this information clarifies the intent of providing fire protection for mobile compact storage. The focus of NFPA 232 is to provide property protection for records which are seen as vital and important in a business interruption sense, as well as historically significant or valuable. This is demonstrated by the section defining required levels of protection as well as risk tolerance.

In addition, the FM Global standards are purely based upon providing property protection. NFPA 13 does not specifically address compact mobile storage.

LITERATURE REVIEW

The objective of the following literature review is to analyze existing fire test data on the subject matter and evaluate the need for additional research. Toward that end, a literature search of fire testing data for compact storage was completed. The following fire tests were identified as relevant to the compact mobile shelving application:

- "*Fire Tests in Mobile Storage Systems for Archival Storage*" – Prepared for General Services Administration by FM Global – June 1978
- "*Archives II Mobile High Density Shelving Fire Protection System*" – Prepared for HOK/Ellerbe Becket by Underwriters Laboratories Inc. – November 1989
- "*Report of Fire Tests Mobile Compact Shelving Systems Archives II - Phase 2*" Prepared for HOK/Ellerbe Becket by Gage-Babcock & Associates, Inc. – May 1996.
- "*Design Criteria for Sprinklered Mobile Shelving Units for the National Library of Canada*" (Research Report No. 200) – Prepared for Public Works Canada by National Research Council of Canada – November 2005

Although fundamental differences in design variables are evident between each of these efforts, it is useful here to qualitatively summarize the parameters, findings and recommendations of each study.

FM Global 1978

The FM Global research effort included a total of three (3) full-scale fire tests involving compact mobile storage. The objective of the testing was to determine the adequacy of contemporary sprinkler design strategies for this type of storage. The specific strategy evaluated employed ½ inch orifice, high temperature sprinklers at uniform 10 foot spacing with a discharge density of 0.30 gpm/ft^2 over a design area of 1500 ft^2. This sprinkler system design can be considered characteristic of that found in warehouse type occupancies. The fuel consisted predominantly of paper files in storage boxes with the random addition of a relatively small percentage of plastic computer tapes. Measurements included gas temperatures at ceiling level, temperatures within the storage module, sequence and time of sprinkler operation, water flow to the sprinkler system and the extent of fire damage in the fuel array. Fire control was determined to be adequate if not more than 15 sprinklers operated, ceiling gas temperatures did not reach 1000°F for more than 5 minutes at any location, fire did not spread to any end of the array and if a cardboard radiation target exterior to the module did not ignite. All three tests were determined to have yielded successful fire control. The following findings by FM Global are highlighted:

1. A fire originating within the storage array is much more severe than one occurring at the open aisle face. In the former case, sprinkler operation was delayed by a factor of 3-5. Maximum ceiling temperatures increased by a factor of 2 and fire damage was greater.

2. The introduction of computer tapes improved sprinkler operation times within the closed array. However, ceiling temperatures increased greatly as did fire damage. Fire damage was evaluated as unacceptable.

3. The relatively low sprinkler to top of storage clearance of 20 inches was inconsistent with the sprinkler system design criteria. The low clearance is typical of an office occupancy, while the sprinkler system design is characteristic of a warehouse occupancy.

4. Fire severity was observed to be influenced by the packing density of fuel within an individual shelf. Researchers hypothesized that loosely packed shelves would yield increased ventilation thereby producing increased fire severity within the shelf and promoting spread to additional fuels.

Gage Babcock and Associates, Inc.(GBA) 1989

This test series was conducted to investigate methods to improve the fire protection of records within mobile compact shelving systems. The test report states that the extensive damage shown in previous testing (e.g. FM Global 1978) was unacceptable for the GSA's storage of archived material. The most significant differences from the FM Global 1978 test series were:

- Quick response sprinklers were used.
- The storage array included 4-5 inch spaces between units. These spaces were created by an electrically driven unit which opened the storage array upon smoke detection. This spacing was used in one of the two tests conducted.
- The ceiling above the test array was waffle slab construction intended to replicate the stack areas in Archives II. The waffle slab was constructed to simulate 7 inch wide by 20 inch deep concrete beams spaced longitudinally and transversely on 4 feet centers. The pockets formed by this structure were approximated 41 inches by 41 inches by 20 inches deep.
- For Test 2, a steel barrier was installed which effectively subdivided the shelving unit into two 18 inch deep units.
- The clearance from the sprinklers to the top of the storage array was 45 – 48 inches, an increase in clearance factor of 2.5 above the FM Global 1978 value.

Measurements included ceiling level gas temperatures above the point of ignition, gas temperatures near each sprinkler, gas temperatures within shelving units, gas temperatures at the ceiling 10 feet beyond the array, sequence and time of sprinkler operation and the extent of fire damage in the fuel array. Criteria for fire control were not specifically defined in the report. The following findings by Gage Babcock and Associates are highlighted:

1. The vertical barrier worked effectively to prevent horizontal fire spread throughout the test. Examination of the fire damage indicated no damage on the opposite side of the barrier, adjacent to the fire.

2. Multiple independent variables were changed thus complicating analysis of the results. For instance, in Test 1 the units were open with a 5 inch aisle; in Test 2 both the units were closed without the aisle, and the commodity was changed by increasing the amount of plastic computer tapes two fold.

3. The quick response sprinklers provided early intervention; however, any comparison to the FM Global 1978 test series is difficult as the sprinkler to array clearance was different. The ceiling was waffle type as opposed to smooth, and the fuel commodity in Test 2 contained significantly more plastic computer tapes.

4. Test 1, which utilized 5 inch aisles and quick response sprinklers, yielded successful results. The fire was controlled early with minimal product damage.

Gage Babcock & Associates Inc.(GBA) 1996

Phase 2 of the Archives II testing program was conducted with the goal of providing fire protection design requirements including criteria for sprinkler system design, shelving unit sizes and construction and storage commodities. Although this testing was conducted as a second phase addressing the Archives II building, a number of fundamental differences from the 1989 experimental setup were allowed. These fundamental differences included a clearance height from the top of the fuel to the sprinklers of 39 inches; a decrease of 14-20% from the values used in the 1989 testing. In addition, a shelf depth of 30 inches was used as opposed to the depths of 36 inches and 18 inches used in the first testing phase. This represents a 17-40% change in the aspect ratio, which subsequently led to significantly different fuel loading on each shelf. Measurements were taken in the same manner as the first phase of testing. Fire control was again not specifically defined in the report. However, the objective of the program was stated as to limit the fire spread to the center ranges and not involve outer ranges. The following findings by Gage Babcock and Associates are highlighted.

1. The ability to manipulate the configuration of the array for electric motor-driven units was recognized as a distinct advantage in providing fire protection for the storage arrangement. Quick response sprinklers were again used and in an effort to build upon the results of the 1989 tests, longitudinal flue spacing was set to 5 inches. This strategy contributed to early fire control and limited fire spread in a manner similar to the results of the first 1989 test.

2. A recommendation was made to manage the concentration of tape (plastics) storage within the general textual storage shelving as a means for reducing fire growth and spread.

3. The design density decrease to 0.20 gpm/ft^2 from 0.30 gpm/ft^2 used in the other tests is particularly significant. For this specific array control was achieved with the reduced density.

National Research Council of Canada (NRCC)– 2005

The objective of this study was to address fire protection design challenges specific to the National Archives/National Library of Canada building. As such, testing was not designed for comparison and validation of previous studies. Despite fundamental differences between the open and closed storage modules, many of the design criteria set by GBA were utilized in this effort. This included the use of continuous vertical fire barriers installed within the shelving units.

One of the major design challenges for the project focused on the issue of clearance between the top of the fuel package and the ceiling above. For this specific building only 7 inches were available. A design solution was sought which would allow minimal clearance and optimal document storage. Test 5 revealed that a decrease in clearance between the top of the fuel package and the ceiling to a value of 4 inches resulted in the inability of quick response sprinklers positioned at the ceiling to limit fire spread at a design density of 0.70 gpm/ft^2. Fire control was not achieved until the intervention of horizontal sidewall sprinklers. In addition, a concern regarding water damage due to sprinkler operation was raised. Test 1 with on-off sprinklers was intended to address this issue. Measurements included ceiling level gas temperatures, gas temperatures within the shelving units, sequence and time of sprinkler operation and the extent of fire damage in the fuel array. Criteria for fire control were not specifically defined in the report although it is evident that aisle jumping or damage at the extremities of the array was considered unacceptable. Several findings and recommendations were made as a result of the testing; however, it is critical to note that these recommendations are only applicable to open shelving units. Furthermore, it is vital to recognize that sprinkler types, locations and design densities were varied significantly between tests. Fire control was achieved with the use of in-flight adjustments to the sprinkler design densities in Test 4. Such adjustments are clearly not possible during an actual fire scenario, yet this test in part formed the basis for the following findings and recommendations by the testing authors:

1. Horizontal sidewall sprinklers were deemed essential for providing adequate fire control and were recommended to be installed at various locations including at staggered locations within the array.

2. The sidewall sprinkler design density of 0.70 gpm/ft^2 was recommended for five sprinklers over a single bay of compact shelves where each sprinkler was assumed to cover an area of 64 ft^2.

3. The ceiling level sprinklers were recommended to be designed at a minimum density of 0.30 gpm/ft^2 based on testing performed previously by GBA. Sprinkler coverage specifically in aisle spaces was deemed essential to fire control.

4. A minimum ceiling level clearance of 7 inches was recommended.

5. Custom designs were recommended for variations in shelving bay dimensions. Criteria for such designs included the arrangement of sprinklers to wet all storage surfaces.

6. A minimum 1 inch space between units was recommended in order to promote water access intermittently within the array from the ceiling level sprinklers.

7. Smoke control provisions were recommended but not explored in detail in the report.

DISCUSSION

Ideally, the results of the above tests could be used as a foundation for establishing design criteria for all compact mobile shelving applications. Such criteria would include parameters such as the height of the array, ceiling clearance above the fuel, width of aisles and design characteristics for automatic sprinkler response. However, the referenced literature contains a total of four research efforts with a cumulative total of twelve experiments. Seven of these tests deal exclusively with closed shelving arrays while the remaining five examine open arrays. Among the five experiments focusing on open arrays, only two resulted in fire control. The strategies employed to achieve this control appear to have been entirely dependent on the in-flight adjustment of the sprinkler design density in one test and the use of horizontal sidewall sprinklers in another. For the experiments focusing on closed arrays, only four tests utilized quick response sprinklers. Continuous sheet metal fire stops were utilized in only one of these four tests. Furthermore, the effect of the fire stops could not be reliably ascertained due to the manipulation of additional independent design variables. While it is clear that innovative design strategies have been implemented in past testing, it is problematic that these strategies have not been evaluated in accordance with the scientific method. The scientific method recognizes that dependent variables such as burning rate and gas temperatures depend on the design of independent variables such as fuel commodity and arrangement. In order to quantify this dependence it is necessary to compare all experiments to a control or baseline set of data. In the absence of such a baseline, design criteria for compact mobile shelving is without foundation.

In order to further illustrate this assertion, Appendix B presents a summary of the data gathered from the tests summarized above. The data shown illustrates a formidable obstacle to comparison of test results within each individual series as well as between separate test series. This obstacle is the consistent variation between tests of multiple design parameters influential to fire growth and development. The end result of such variations is a number of stand-alone test results, which are insufficient in providing conclusive evidence of the dependency of fire growth and development on any given independent design variable. For instance:

1. Fuel type, total loading and packing density were varied in each of the three FM Global tests. In addition to these variations, spacing within the shelving array was manipulated in each test, leading to characteristically different ventilation and internal radiation within the array. Therefore, although automatic sprinkler design criteria were held constant, variations in results can not be definitively attributed to any one of these influential categories.

2. Fuel type, total loading and packing density were varied in the two tests conducted by GBA (1989). In addition to these variations, further manipulations included the size of aisles, the number of shelving modules and the shelf depth. Certain aspects of each influential category were held constant between tests, but variations in results can not be definitively attributed to any one of these influences on the burning rate.

3. Sprinkler type, discharge density and spacing were varied in each of the five tests conducted by the National Research Council of Canada (NRCC). In addition to these variations, additional manipulations included the size of aisles. Furthermore, mechanical failures of the shelving arrangement during early stages of initial tests likely led to erroneous conclusions.

4. The array itself consisted of solid steel shelves, end panels and tops for both the FM Global and GBA test series, while the NRCC tests were conducted with open shelving arrays (i.e. no end panels, uprights or tops). This fundamental difference in the test array effected many influential fire growth parameters such as obstruction of the sprinkler spray, oxidizer access to the burning fuel and incident heat flux to adjacent fuels. This difference alone is enough to prevent meaningful comparison of results between the NRCC test series and its counterparts.

5. The aspect ratio of an individual rack or shelf may be defined as the ratio of length to depth. This ratio is important for determining the burning characteristics of fuel within the space. Shallow compartments provide minimal shielding of the burning fuel from a sprinkler spray above. Additionally, well ventilated shallow compartments typically yield flame extensions upward along the face of the unit. In contrast, deeper compartments provide increased shielding and consequently a higher degree of heat transfer internally within the module. Typically a depth of less than 30 inches is used as the value for defining a shallow compartment (shelf) and 30 inches or greater for a deep compartment (rack). Utilizing this definition, the data in Table 1 illustrates that all of the FM Global tests and all but one of the GBA tests were rack storage fires. Conversely, all of the NRCC tests were shelf storage fires.

6. Gas temperatures at the ceiling level were significantly different throughout the testing review. Ceiling gas temperatures were consistently significantly higher in the NRCC tests; however it is unclear whether this is due to the decreased clearance between the burning fuel and the ceiling, the lack of enclosed shelves or the performance of the automatic sprinkler system.

Suppression Theory

In general, the design objective for automatic sprinklers is to provide either fire control or fire suppression depending on the application. In either case, it is useful to present functional relationships between design variables. This gives context to the design challenge and lends organization to an otherwise haphazard search for design solutions. Perhaps the most notable piece of information that is characteristically absent in the existing literature is information regarding the burning rate of the fuel package. Currently, NFPA 13 includes such information by way of a relative comparison of the severity of the burning rate for different types of fuels. From a theoretical perspective, commodity classification could be presented in terms of a range of dimensionless burning rates known as B numbers. The B number is extensively used in combustion theory and may be thought of as the ratio of the energy needed to sustain combustion versus the collective influence of various forms of resistance[2]. For the evaporation of droplets within the flame and on the surface of the fuel, the burning rate of a given fuel may be characterized as shown in Equation 1.

$$B = \frac{Y_{O_2,\infty}\left(1 - X_r - X_{w,f}\right)\Delta h_c / r - c_p\left(T_v - T_\infty\right)}{L - \dfrac{\dot{q}''_{f,r} + \dot{q}''_e - \sigma\left(T_v^4 - T_\infty^4\right) - \dot{m}''_w L_w}{\dot{m}''_f}} \qquad (1)$$

Where:

$Y_{O_2,\infty}$ = ambient oxygen concentration (mass fraction)

X_r = fraction of total heat release radiated to surroundings

[2] Quintiere, J. Fundamentals of Fire Phenomena. John Wiley & Sons, Ltd. Chichester: 2006.

$X_{w,f}$ = fraction of water that reaches the flame and evaporates
Δh_c = heat of combustion
r = stoichiometric ratio of fuel and oxidizer mass
c_p = specific heat of fuel
T_v = temperature of vaporized fuel
T_∞ = ambient temperature
L = enthalpy of vaporization for fuel
$\dot{q}''_{f,r}$ = radiant heat flux from fuel
$\dot{q}''_e$ = external heat flux (if applicable)
σ = Boltzman constant
$\dot{m}''_w$ = mass flux of sprinkler water
L_w = enthalpy of vaporization for water
$\dot{m}''_f$ = mass burning rate of fuel

The presentation of Equation 1 is made to illustrate the long list of variables that characterize fire behavior in this application. Consider the shelf where ignition occurs and fire growth begins. Prior to the activation of automatic sprinklers, fire development is governed by the availability of heat, fuel and oxidizer. This is expressed in Equation 1 in terms of variables such as the stoichiometric ratio r, which is different for a shelf filled with boxes of paper documents as opposed to a certain percentage of plastic computer tapes. Consider fire spread to adjacent fuels and thermal feedback from the shelving unit of the closed array to the burning fuel surface. While the closed array provides thermal feedback to the fuel, it also shields the fuel from the mass flux of water being supplied from the automatic sprinklers overhead when activated. It is important to note that all of these mechanisms are characteristically different in the case of an open storage array.

Burning Rate Enhancements and Limitations

Fire growth within the storage module may be enhanced or limited by the combination of available heat, fuel and oxidizer. Obviously, fire growth may also be limited significantly by the delivery of water from automatic sprinklers. The geometry of the storage array plays a critical role in the shielding of both burning and potential fuels from each of these influences. The research efforts from FM Global, GBA and NRCC each specifically recognized the balance between the access of oxidizer and the access of sprinkler water to burning fuel within the array. Tests 1 and 3 of the FM Global series contain variations in both the fuel commodity and the ignition location; however, despite these multiple variations, there is evidence of an expected trend in the data. In Test 1, ignition occurs in a module whose front face is open to a wide aisle. This fire is ultimately controlled by 3 sprinklers activating at 17, 18 and 19 minutes, respectively. In Test 3, ignition occurs in module whose front face is open to a ½ inch wide longitudinal flue space. This fire is ultimately controlled by 4 sprinklers activating at 48, 78, 121 and 125 minutes respectively. The effect of changing the fuel commodity on fire growth is uncertain from these results; however, it is expected that the fire open to the aisle would have better access to ventilation thereby producing a more robust fire plume at a faster rate of development. Despite the strength of this plume, the relative decrease in shielding of the burning fuel allows the sprinkler spray to control the fire. In contrast, testing performed by GBA and NRCC underlined the importance of a minimum sprinkler clearance above the fuel and a minimum longitudinal flue space width in order for water to gain access to burning materials within the array.

The access of sprinkler water to a burning commodity within a storage array is an extraordinarily complex geometric exercise further complicated by the change in droplet momentum as a result of interaction with a dynamic fire plume. A far simpler limiting influence to address is the availability of oxidizer to the burning fuel. During the initial stages of fire development, the fire is confined to the shelf of origin. If the initially developing flame can be contained within the shelf of origin by passive barriers (i.e. steel uprights and horizontal shelving), then fire spread from the completely enclosed compartment will be governed by conduction through the steel boundaries. The localized compartment fire that results will attain a maximum burning rate dictated by the relative amounts of available fuel and oxidizer. Eventually, either the fuel or the oxidizer supply will be insufficient to sustain combustion.

RECOMMENDATIONS

Additional fire testing should be conducted due to the incohesive and incomplete nature of the existing test data. The test series should address the following issues:

1. The majority of the compact mobile shelving systems are relatively small in area (200 ft^2) and are found in light hazard occupancies. These buildings typically have low ceilings (8-10 feet). This scenario should be tested to determine the effectiveness of such a sprinkler system in controlling a fire within the storage systems. The sprinkler system should be designed in accordance with NFPA 13 for light hazard occupancies, including a density of 0.10 gpm / ft^2 using 165° rated, quick response pendant sprinklers spaced at a maximum of 225 ft^2 A major challenge will be developing a standard storage configuration due to the apparent customization of the systems.

2. The use of compartmentalization proved to be beneficial in reducing fire spread within the storage systems. This variable should be included in the test program. Should the light hazard sprinkler system fail to provide adequate protection, the next tests should include additional compartmentalization within the storage systems. Such additional compartmentalization should include quantification of the thermal resistance of these fire barriers.

3. The clearance between the top of storage and the sprinklers is a major concern as storage height is commonly maximized under these low ceilings. The first tests should be run with the standard 18 inch clearance to develop baseline data. Reduction in this clearance should then be tested. If unsatisfactory performance of the sprinklers is observed due to obstruction at low clearances, side wall type sprinklers should be tested.

4. The variability of the commodity stored within the storage systems is problematic. Commodity can vary from Class I to plastic commodities, although the majority of the commodity best fits the definition of Class III. Two sets of commodity based design criteria should be developed, one for Class III and below, and one for Class IV and plastics.

5. Providing aisle or flue spaces greatly improved the ability of the sprinklers to reach the fire. Further study and testing regarding the practicality of providing same, as well as testing to determine specific dimensions, should be conducted.

CONCLUSION

Existing data regarding the performance of compact mobile storage systems in fire situations is incohesive and insufficient to serve as a foundation for generalized fire protection design guidelines. Additional testing is necessary to develop standard criteria for the protection of these systems.

Prepared by:

SCHIRMER ENGINEERING CORPORATION

Garner A. Palenske, P.E.
Vice President/Regional Engineering Manager

GAP:nz

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RESULTS OF INDUSTRY MEETING

On December 13, 2006, an industry meeting was held in Rosemont, Illinois to review the information and data included within this report. A presentation was made by Garner Palenske summarizing key sources from the literature review and the findings of the analysis detailed in this report.

The attendees of the industry meeting suggested the following direction should be taken for future work:

1. The majority (80%) of the facilities utilizing compact mobile storage systems are offices, hospitals and other light hazard occupancies. These occupancies should be targeted first for fire testing or other research. Next in priority should be mercantile occupancies.

2. Prior to conducting fire testing, pass/fail criteria should be developed. The potential slow burning nature of a fire within a compact mobile shelving system makes development of this criteria particularly challenging.

3. Although many of these systems are installed with clearances from sprinkler to top of storage less than 18 inches, first tests should be run with complying clearances.

APPENDIX A
STANDARD COUNCIL ACTION

BALLOT RESULTS: Affirmative: 29
BALLOT NOT RETURNED: 1 AMAR

13-6 Log #497 AUT-SSI **Final Action: Reject**
(1.1)

SUBMITTER: Denyse Dubrucq, AirWars Defense
RECOMMENDATION: Revise as follows:

Covers minimum requirements for the design and installation of automatic sprinkler systems and of exposure protection sprinkler systems including the character and adequacy of water supplies to sprinkler systems and Liquid Nitrogen supplies to Liquid Nitrogen sprinkler systems.

SUBSTANTIATION: An alternative to water fire suppression, Liquid Nitrogen fire control method, may best suit some facilities. Reasons why liquid nitrogen provides a good alternative method of fire control include firstly, the gaseous Nitrogen displaces the air containing Oxygen suffocating fire; and secondly, the initial low temperature and the energy consumed by evaporation cools down the burn to prevent melting and ignition of noxious materials.

The structure after the fire will not have sustained water damage to the structure or furnishings making cleanup afterward limited to eliminating smoke damage during the period of the burn. Nitrogen atmosphere does not pollute during fire fighting and does not react with plastics or other interior components, thus not producing noxious gases.

These systems take into account the breathing arrest of people and animals and include in the equipment breathing masks to resuscitate anyone caught in the fire mitigation process. Also emergency personnel at the facility and the fire and police departments will be instructed in new procedures used in Liquid Nitrogen fire fighting.

Additionally, Liquid Nitrogen systems can overcome hostage situations. Nitrogen rents assailants and hostages unconscious so assailants can be handcuffed and all can be resuscitated without loss of life or bodily damage.

COMMITTEE MEETING ACTION: Reject
COMMITTEE STATEMENT: See Committee Statement for Proposal 13-5 (Log #824).
NUMBER ELIGIBLE TO VOTE: 30
BALLOT RESULTS: Affirmative: 29
BALLOT NOT RETURNED: 1 AMAR

13-7 Log #CP2 AUT-SSI **Final Action: Accept**
(Chapter 2, Annex E)

SUBMITTER: Technical Committee on Sprinkler System Installation Criteria
RECOMMENDATION: Add the appropriate section numbers where the listed documents are referenced with the chapters of NFPA 13.
SUBSTANTIATION: Supports the usability of the documents so that the user can quickly establish where mandatory references are applicable.
COMMITTEE MEETING ACTION: Accept
NUMBER ELIGIBLE TO VOTE: 30
BALLOT RESULTS: Affirmative: 29
BALLOT NOT RETURNED: 1 AMAR

13-8 Log #CP328 AUT-SSD **Final Action: Accept**
(Chapter 3, and 12.2.2.4)

SUBMITTER: Technical Committee on Sprinkler System Discharge Criteria
RECOMMENDATION: Add definition of "Compact Shelf Storage" to read:

Compact Shelf Storage. Storage on solid shelves not exceeding 36 inches in total depth, arranged as part of a compact storage module, with no more than 30 inches between shelves vertically, and with no internal vertical flue spaces other than those between individual shelving sections.

Add definition of "compact storage module" from NFPA 909:

Compact Storage Module. An assembly of shelving sections mounted on carriages with the arrangement of carriages on tracks so as to provide one moving aisle serving multiple carriages between fixed end ranges.

Move existing material from 12.2.2.4 into a subsection 12.2.2.4.1 entitled "Storage with Intermediate Walkways"

Renumber current 12.2.2.4 as 12.2.2.4.1 entitled "Storage with Walkways", and add new Section 12.2.2.4.2 entitled "Compact Shelf Storage"

12.2.2.4.2.1 Compact shelf storage shall be protected using quick response sprinklers within a wet pipe, non interlock preaction system or single interlock preaction system.

12.2.2.4.2.2 Spacing of pendent or upright sprinklers shall be limited to maximum 10 ft on centers.

12.2.2.4.2.3 Where less than 18 in. clearance can be maintained between sprinkler deflectors and the top of storage, horizontal sidewall sprinklers shall be installed with minimum 6 in. clearance between the sprinkler deflectors and top of storage.

12.2.2.4.2.4 Where sidewall sprinklers are utilized, they shall be quick response horizontal sprinklers placed such that sprinkler discharge is parallel to the movable aisle within the compact storage. Sidewall sprinklers shall be limited to a maximum distance along the wall (S) of 10 ft and maximum room width (L) of 12 ft, except that opposite rows of sidewall sprinklers shall be permitted for widths of up to 20 ft where sprinklers are staggered. Sidewall sprinklers shall operate at a minimum discharge pressure of 30 psi.

12.2.2.4.2.5 Where spacers are used to create a minimum flue space of 3 in. between shelving sections, the sprinkler system shall meet a design point of 0.3 gpm/sq. ft. over 1500 sq. ft. for protection of compact shelf storage up to 8 ft in height.

12.2.2.4.2.6 For compact shelf storage without minimum 3 in. flue spaces between shelving units, the sprinkler system shall meet a design point of 0.3 gpm/sq. ft. over 2500 sq. ft. for protection of compact shelf storage up to 8 ft in height.

SUBSTANTIATION: There is a need to address the protection of this specialized storage arrangement within NFPA 13. The definition of "compact storage modules" is extracted from NFPA 909.

The sprinkler protection criteria for compact/movable shelf storage is based on tests conducted in 1978 by Factory Mutual for the General Services Administration, tests conducted in 1989 at Underwriters Laboratories for HOK Architects Joint Venture and Gage-Babcock Associates, and tests conducted in 1991 at the National Research Council of Canada for the National Archives and Library of Canada. Testing of sprinkler protection for compact shelf storage has demonstrated the need to maximize water spray coverage and minimize the possibility of the spray from one sprinkler delaying the discharge of other sprinklers in the area.

COMMITTEE MEETING ACTION: Accept
NUMBER ELIGIBLE TO VOTE: 27
BALLOT RESULTS: Affirmative: 24 Negative: 1
BALLOT NOT RETURNED: 2 BLUMENTHAL, MULTER
EXPLANATION OF NEGATIVE:

PEHRSON: The proposed protection scheme is an amalgamation of a number of different tests done for specific storage and building arrangements. There is no assurance that this protection will work as intended when looking in more detail at the actual tests:

- Successful fire control required all storage to be in Hollinger boxes and is not included in the criteria - tests without were not acceptable (as determined by the test sponsor).
- 4 in.to 5 in. spacers were used during the tests, not 2 in.
- Successful fire tests required different combinations of horizontal and vertical dividers that are not included in the criteria.
- The referenced fire tests were for specific shelf configurations (styles). No work was done to verify if the shelf configurations represent the wide range of styles in actual use or if the ignition locations represented the worst case.
- Open newspapers, even with very high sprinkler densities, were not controlled, yet this is a common configuration for libraries.
- The proposed sprinkler densities were shown in the FM tests to be unable to protected mixed media (paper with a small amount of plastic).
- The horizontal sidewall configurations showed mixed performance for one storage height/ceiling clearance test arrangement, yet are incorporated in the criteria for general use.

COMMENT ON AFFIRMATIVE

KEEPING: Some items that were deemed to be pertinent in the reports concerning the tests for the National Library of Canada do not appear to have been addressed. For example, the mobile shelving units had to be fitted with spacers to create 1 in. wide flue spaces, the systems had to be capable of providing a minimum density of 0.70 gpm/sq.ft. with five sidewall sprinklers flowing and the operating pressures were based on 1/2 in. orifice sprinklers. (which were probably the only quick response types that were available at that time). I believe that such matters still need to be incorporated and that some further development of this proposal will be necessary.

13-9 Log #21 AUT-SSI **Final Action: Reject**
(3.3 Attic)

SUBMITTER: Peter T. Schwab, Wayne Automatic Fire Sprinklers, Inc
RECOMMENDATION: Add text to read as follows:

Attic. A normally uninhabited but typically accessible, generally enclosed but ventilated, weather-protected, unfinished space located at or near the top of a building, immediately below a roof and above the ceiling of generally inhabitable space or spaces.

SUBSTANTIATION: There is currently no formal definition for an attic in NFPA 13.
COMMITTEE MEETING ACTION: Reject
COMMITTEE STATEMENT: No technical justification offered to warrant specifically defining the concept of an attic. Current intent of the standard is clear, using the general dictionary meaning for the term.

Additionally, a committee proposal has been developed to address the use of the term attic in Chapter 8, where the more appropriate reference is to a combustible concealed space. See Proposal 13-222 (Log #CP8).

NUMBER ELIGIBLE TO VOTE: 30
BALLOT RESULTS: Affirmative: 29
BALLOT NOT RETURNED: 1 AMAR

SC #06-7-2-a
D#06-05

NFPA

Casey C. Grant, P.E.
Secretary, Standards Council

29 August 2006

To: Interested Parties

Subject:

Standards Council Decision (Final):	**D#06-05**
Standards Council Agenda Item:	**SC#06-7-2-a**
Date of Decision:	28 July 2006
NFPA 13, *Standard for the Installation of Sprinkler Systems* (2007 edition)	

Dear Interested Parties:

At its meeting of 26-28 July 2006, the Standards Council considered an appeal on the above referenced matter. The Short Decision was transmitted on 31 July 2006.

Attached is the final decision of the Standards Council on this matter.

Sincerely,

Casey C. Grant, P.E.
Secretary, NFPA Standards Council

c: K. Almand, D. Berry, M. Brodoff, S. Desrocher, C. Dubay, L. Nisbet
Members, TCC on Automatic Sprinkler Systems (AUT-AAC)
Members, TC on Sprinkler System Discharge Criteria (AUT-SSD)
Members, TC on Sprinkler System Installation Criteria (AUT-SSI)
Members, NFPA Standards Council (AAD-AAA)
Individuals Providing Appeal Commentary

Standards Council Decision (Final):	**D#06-05**
Standards Council Agenda Item:	**SC#06-7-2-a**
Date of Decision:	28 July 2006
NFPA 13, *Standard for the Installation of Sprinkler Systems* (2007 edition)	

At its meeting of 26-28 July 2006, the Standards Council considered appeals on the proposed 2007 edition of NFPA 13, *Standard for the Installation of Sprinkler Systems*, requesting the Council to overturn the Association action of Returning a Portion of a Report in the form of Proposal 13-8 and Comments 13-48a & 13-1f through 13-48. These Proposals and Comments, as accepted by Technical Committee on Sprinkler System Discharge Criteria (the Technical Committee), propose new sprinkler protection criteria for compact mobile shelving (the compact shelving protection criteria).

The background of this issue is as follows. The new compact shelving protection criteria were first proposed in this revision cycle of NFPA 13 by Proposal 13-8 which was accepted by the Technical Committee. This Proposal inserted a new section 12.2.2.4.2 addressing compact shelf storage protection and additionally added new definitions of Compact Shelf Storage and Compact Storage Module to Chapter 3. Subsequently, Comment 13-48a, also accepted by the Technical Committee, further modified these new proposed protection criteria (the other related comments were all acted on by the Technical Committee through reference to its action on Comment 13-48a). Others, however, who opposed the new protection criteria made an amending motion at the Technical Committee Report Session of the June 2006 Association membership meeting to return Proposal 13-8 and related Comments, and this motion was successful. Under NFPA rules, the successful return motion meant that the new edition of NFPA 13 would not include the new compact shelving protection criteria. Representatives of the American Fire Sprinkler Association and the National Fire Sprinkler Association, thereafter, appealed to the Council requesting that the Council reject the result of the Technical Session vote and include the compact shelving protection criteria in the new edition of NFPA 13.

On an appeal, the Standards Council accords great respect and deference to the NFPA codes and standards development process. In conducting its review, the Council will overturn the result recommended through that process, only where a clear and substantial basis for doing so is demonstrated. The Council has reviewed the entire record concerning this matter and has considered all of the arguments raised in these appeals. In the view of the Council, this appeal does not present any clear and substantial basis on which to overturn the results recommended by the NFPA codes and standards development process. Accordingly, the Council has voted to deny these appeals and uphold the return to committee of the proposed compact shelving protection criteria. The effect of this action is that the 2007 edition of NFPA 13 will not include Proposal 13-8 and Comments 13-48a & 13-1f through 13-48.

Without attempting to review each argument that the Council has considered and rejected, the Council wishes to comment on two matters. First, the Council notes that in these appeals there has been an allegation that the Technical Committee Report Session was improperly "packed" by the opponents of the new compact mobile shelving provisions at issue here. Activities aimed at bringing out the vote at an NFPA membership meeting are not, however, improper provided that all NFPA members who attend and vote are properly credentialed in accordance with NFPA rules and that the vote is not in contravention of the general principles of fairness set forth in the NFPA Guide for Conduct of Participants in the NFPA Codes and Standards Development Process.

In particular, that Guide requires participants not to "urge, arrange, or otherwise facilitate the participation of persons with no interest [in the purposes of NFPA] for the purpose of affecting the outcome of a vote on an issue at a Technical Session." No evidence has been offered indicating that any activities aimed at bringing out the vote were in contravention of these guidelines or were in any other respect improper and, accordingly, the Council has rejected the "packing" allegation.

Second, the Council also notes that, both in their arguments to the membership at the Technical Session and in their presentation to the Standards Council on appeal, representatives of the compact shelving industry criticized the testing on which the proposed compact shelving protection criteria were based, and they indicated that, while testing was needed, the testing that was available was inadequate and not representative of the real-world range of uses of compact shelving. They expressed a strong commitment to see that the necessary testing to support the development of reasonable and technically substantiated protection criteria for compact shelving. The Council has been informed that there is a new project addressing compact mobile shelving systems that was recently initiated with the Fire Protection Research Foundation. The Council urges the industry to meet that commitment toward further testing and hopes that the Research Foundation can play a useful role in facilitating that effort as appropriate.

Council members Bell and Isman recused themselves from deliberations and vote on this issue.

APPENDIX B

FIRE TEST DATA SUMMARY

SUMMARY OF COMPACT STORAGE TEST DATA FOR THE FIRE PROTECTION RESEARCH FOUNDATION

TEST SERIES	COMMODITY	ARRAY DETAILS	SHELF LENGTH / DEPTH	FUEL CLEARANCE TO SPRINKLERS/ ARRAY HEIGHT	SEPARATION BETWEEN UNITS	AS DESIGN (GPM/SQFT)	SPRINKLER TYPE	IGNITION LOCATION	SPRINKLER RESPONSE	FIRE SPREAD	MAXIMUM CEILING LEVEL GAS TEMPERATURES
FM-78-1	Paper files in archival boxes, fully stocked	Solid steel shelves, end panels and tops. 36 inches in depth, vertical steel barriers at 42 inches in the transverse direction, tier 12 inches high	$\frac{42\ in}{36\ in}=1.17$	$\frac{20\ in}{7.75\ ft}=0.22$	½ inch with 1 central aisle 27.5 inches wide	0.30	Pendant, ½ inch, 280°F, SR, 10 ft x 10 ft spacing.	Centered below four sprinklers near the center of storage module, at the front edge of the shelf at the 27.5 inch aisle.	3 sprinklers operated @ 17, 18 and 19 minutes. fire controlled	fire controlled	400 °F
FM-78-2	Same, except some shelves empty	Solid steel shelves, end panels and tops. 36 inches in depth, vertical steel barriers at 42 inches in the transverse direction, tier 12 inches high.	$\frac{42\ in}{36\ in}=1.17$	$\frac{20\ in}{7.75\ ft}=0.22$	½ inch with 1 central aisle 27.5 inches wide	0.30	Pendant, ½ inch, 280°F, SR, 10 ft x 10 ft spacing.	Same, except the units were closed.	4 sprinklers operated @ approx 90 minutes. fire controlled	fire controlled	800 °F
FM-78-3	Paper files in archival boxes with some computer tapes on plastic reels in polystyrene canisters in fiberboard boxes.	Solid steel shelves, end panels and tops. 36 inches in depth, vertical steel barriers at 42 inches in the transverse direction, tier 12 inches high.	$\frac{42\ in}{36\ in}=1.17$	$\frac{20\ in}{7.75\ ft}=0.22$	½ inch with 1 aisle at end row 27.5 inches wide	0.30	Pendant, ½ inch, 280°F, SR, 10 ft x 10 ft spacing.	Same, except the units were closed.	4 sprinklers operated @ 48, 78,121 and 125 minutes. fire controlled, but extent of fire damage unacceptable	fire controlled, but extent of fire damage unacceptable	1200 °F
GBA-89-1	Paper files in boxes and plastic computer tapes	Solid steel shelves, end panels and tops. 36 inches in depth, vertical steel barriers at 42 inches in the transverse direction, tier 12 inches high	$\frac{42\ in}{36\ in}=1.17$	$\frac{(45.5\rightarrow 48.75)\ in}{7.833\ ft}=0.48\rightarrow 0.52$	5 inches throughout	0.30	Waffle ceiling assembly. Upright, ½ inch, 165°F, QR RTI = 50 fts ½, 10 ft x 10 ft spacing	Near the center of the storage module, at the front edge of the shelf at the 5 inch aisle. Between sprinklers.	3 sprinklers operated @ 1.5, 2.8 and 3.6 minutes. fire controlled	fire controlled	1000 °F
GBA-89-2	Double the amount of plastic computer tapes	Solid steel shelves, end panels and tops. 36 inches in depth, vertical steel barriers at 42 inches in the transverse direction, tier 12 inches high. Additional steel vertical barrier, provided to subdivide the shelf depth from 36 inches to 18 inches	$\frac{42\ in}{18\ in}=2.33$	$\frac{(45.5\rightarrow 48.75)\ in}{7.833\ ft}=0.48\rightarrow 0.52$	1-2 inches throughout	0.30	Waffle ceiling assembly. Upright, ½ inch, 165°F, QR RTI = 50 fts ½ 10 ft x 10 ft spacing	Same, except the units were closed. Aisle was 1-2 inches. Ignition between sprinklers.	2 sprinklers operated @ 12 and 60 minutes. fire controlled	fire controlled	1300 °F
GBA-96-1	Boxes 50-75% full of textual files. Plastic computer tapes scattered throughout storage array makes up 8% of total fuel stored. Several shelving units were completely filled with computer tapes.	Solid steel shelves, end panels and tops. Four-post units 30 inches in depth, vertical steel barriers at 42 inches in the transverse direction, tier 12 inches high. Uniform 5 inch space between each range.	$\frac{42\ in}{30\ in}=1.4$	$\frac{39\ in}{8.58\ ft}=0.38$	5 inches throughout	0.30	Waffle ceiling assembly. Upright, ½ inch, 165°F, QR, RTI = 50fts$^{1/2}$, 10 ft x 10 ft spacing	Centered below four sprinklers. Near the center of the storage module at the front edge of the shelf at the 5 inch waffle.	2 sprinklers at 4 minutes 39 seconds, third at 9 minutes 30 seconds and fourth at 39 minutes.	With the exception of the fire intensity created by the contrated tape storage, the fire was controlled.	826 °F
GBA-96-2	Same as Test 1 except plastic tapes made up 5% of total fuel stored and were distributed throughout the storage.	Solid steel shelves, end panels and tops. Four-post units 30 inches in depth, vertical steel barriers at 42 inches in the transverse direction, tier 12 inches high. Uniform 5 inch space between each range.	$\frac{42\ in}{30\ in}=1.4$	$\frac{39\ in}{8.58\ ft}=0.38$	5 inches throughout	0.20	Waffle ceiling assembly. Upright, ½ inch, 165°F, QR, RTI = 50fts$^{1/2}$, 10 ft x 10 ft spacing	Centered below four sprinklers. Near the center of the storage module at the front edge of the shelf at the 5 inch waffle.	2 sprinklers at 3 minutes 35 seconds, third at 5 minutes 35 seconds, fourth at 6 minutes 17 seconds.	fire controlled	1422 °F

Test series ID = Agency – Year – Test Number
FM = Factory Mutual
GBA = Gage Babcock & Associates
NRCC = National Research Council of Canada

11770 Bernardo Plaza Court, Ste. 116
San Diego, CA 92128
Phone (858) 673-5845 Fax (858) 673-5849

TEST SERIES	COMMODITY	ARRAY DETAILS	SHELF LENGTH / DEPTH	FUEL CLEARANCE TO SPRINKLERS/ ARRAY HEIGHT	SEPARATION BETWEEN UNITS	AS DESIGN (GPM/SQFT)	SPRINKLER TYPE	IGNITION LOCATION	SPRINKLER RESPONSE	FIRE SPREAD	MAXIMUM CEILING LEVEL GAS TEMPERATURES
NRCC-05-1	Paper files in storage boxes with two rows of newspaper storage.	Open shelves without end panels or tops. 6 tiers, 10 inches tall, 30 inches deep, with steel barrier to subdivide the shelf depth to 15 inches. Not typical of mobile compact storage.	$\frac{32\ in}{15\ in} = 2.13$	$\frac{7.8\ in}{7.89\ ft} = 0.08$	None	On/off, 0.46	On/off pendent sprinklers spaced at 50 sq.ft.	Unit closed, no aisle	Uncontrolled, test terminated	Uncontrolled, test terminated	1100 °F sustained with 4 sprinklers operating
NRCC-05-2	Paper files in storage boxes with two rows of newspaper storage.	Open shelves without end panels or tops. 6 tiers, 10 inches tall, 30 inches deep, with steel barrier to subdivide the shelf depth to 15 inches. Not typical of mobile compact storage.	$\frac{32\ in}{15\ in} = 2.13$	$\frac{7.8\ in}{7.89\ ft} = 0.08$	None	0.46	Pendant, QR RTI undetermined	Unit closed, no aisle	Uncontrolled, shelf failure, test terminated	Uncontrolled, shelf failure, test terminated	1650 °F sustained prior to shelf failure and termination of test
NRCC-05-3	Paper files in storage boxes with two rows of newspaper storage.	Open shelves without end panels or tops. 6 tiers, 10 inches tall, 30 inches deep, with steel barrier to subdivide the shelf depth to 15 inches. Not typical of mobile compact storage.	$\frac{32\ in}{15\ in} = 2.13$	$\frac{7.8\ in}{7.89\ ft} = 0.08$	1 inch	0.70	QR pendant and horizontal sidewall, with sidewall sprinklers 4 inches from the ceiling.	Unit closed, no aisle	Fire extinguished	Fire extinguished	Ambient to 1650 °F and back to ambient in 1 minute.
NRCC-05-4	Paper files in storage boxes with two rows of newspaper storage.	Open shelves without end panels or tops. 6 tiers, 10 inches tall, 30 inches deep, with steel barrier to subdivide the shelf depth to 15 inches. Not typical of mobile compact storage.	$\frac{32\ in}{15\ in} = 2.13$	$\frac{7.8\ in}{7.89\ ft} = 0.08$	1 inch	0.50, then 0.60 at 25 minutes	QR pendant and horizontal sidewall, with sidewall sprinklers 4 inches from the ceiling.	Unit closed, no aisle	Uncontrolled, then extinguished when higher density was applied	Uncontrolled, then extinguished when higher density was applied	Not reported.
NRCC-05-5	Paper files in storage boxes with two rows of newspaper storage.	Open shelves without end panels or tops. 6 tiers, 10 inches tall, 30 inches deep, with steel barrier to subdivide the shelf depth to 15 inches. Not typical of mobile compact storage.	$\frac{32\ in}{15\ in} = 2.13$	$\frac{2.0\ inches}{7.89\ ft} = 0.02$	1 inch	0.70	QR pendant and sidewall, with sidewall sprinklers 2 inches from the ceiling.	Unit closed, no aisle	Delayed control	Delayed control	1300 °F and climbing until increased sprinkler density suppresses fire.

Test series ID = Agency – Year – Test Number
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