Sprinkler Protection for Multiple-Row Rack Storage Systems – Phase 1

Background
Historically, NFPA 13, Standard for the Installation of Sprinkler Systems, has defined high-piled storage racks, where solid shelves larger than 20 ft² (1.9 m²) have been installed, as solid shelf racks. In addition, when pallet loads stored within open racks are not provided with minimum 6 in (150 mm) wide flues on all four sides of the load, the storage arrangement is also defined as solid shelf racking. Because of the shielding effect created by racks that qualify as solid shelf, in-rack sprinkler protection is required at every tier level. For several cycles prior to 2022 Edition, NFPA 13 has permitted multiple-row racks that are provided with minimum 6 in (150 mm) wide transverse flue spaces a maximum of every 5 ft (1.5 m) horizontally, but void of longitudinal flue spaces, to qualify as open racking. In addition, the required ceiling-level sprinkler designs for multiple-row racks is generally based on the full-scale fire test results obtained using double-row racks. However, in the 2022 Edition of NFPA 13, the definition of open racking for multiple-row racks was changed and required either (1) minimum 6 in (150 mm) flue spaces around each pallet load within the multiple-row rack, or (2) the multiple-row rack to be provided with minimum 6 in (150 mm) wide transverse flue spaces no more than 5 ft (1.5 m) apart and the rack depth limited to a maximum of 20 ft (6.1 m) as defined by minimum 3-½ ft (1.1 m) wide aisles.

The Committee used the results from a full-scale fire test conducted in March 1971, on behalf of the Rack Storage Fire Protection Committee, to establish these parameters. The multiple-row rack depth for this test was based on two double-row racks placed back-to-back replicating the storage arrangement at the time for multiple-row racks, and results applied to storage up to 16 ft (4.9 m) deep. Multiple-row racks commonly found in today’s warehouses come in many shapes and sizes, most of which are deeper than 20 ft (6.1 m) and do not qualify as open racking. As a result, the requirements of NFPA 13 would mandate the installation of in-rack sprinklers at every tier level for these types of storage racks. Many stakeholders have found this requirement to be very onerous to comply with. As a result, there is a need to determine what defines open racking for multiple-row racks, if the ceiling-level sprinkler designs for them can be those indicated for double-row racks, and the level of in-rack sprinkler protection needed when multiple-row racks qualify as solid shelf racking.

Racks commonly used today: While there is a wide range of rack storage systems that are currently used in warehouses, the rack storage protection guidance in NFPA 13 was developed around the definitions of open racking. As shown in Figure 1 (left), traditional open racking includes longitudinal and transverse flues nominally 6 in. (150 mm) wide occurring no more than 5 ft (1.5 m) on centers. In this view, transverse flues are in the up/down direction and longitudinal flues are in the left/right direction. Aisles between the rows of storage that are less than 3-½ ft (1.1 m) are effectively considered flues.
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Figure 1: Plan view of row layout for single to multiple-row rack storage (left) and example of a rack system with multiple rows without transverse flues

Beyond the storage of palletized commodities, active warehouses now handle goods at the carton or piece level. This has introduced several storage configurations that deviate from traditional open racking configurations either due to the flue widths, flue spacing, or row depth. Figure 1 present examples of common storage configurations:

A) Single-row racks storage individual cartons or bin boxes

B) Multiple-row racks with only transverse flues (often referred to as flow racks)

C) Multiple-row racks with only longitudinal flues (narrow aisles)

Figure 2: Plan view of storage configurations that deviate from traditional open-frame configurations

For single row rack systems, cartons are typically placed and picked using wire-guided forklifts operating in very narrow aisles. As shown in Figure 3, transverse flues are often limited to around 3 in (75 mm) at the rack uprights. Any other transverse flues midway between the rack uprights may be significantly misaligned. The typical objective is to maximize storage density (left image) and may contain design features to maintain longitudinal flues, at least for the lowest cartons in each storage tier (center image). Though, storage of bin boxes (right image) often only includes transverse flues at the rack uprights.
Figure 3: Examples of single-row rack storage of cartons (left), optional longitudinal flue spacing (middle) and storage of bin boxes (right).

As shown in Figure 4, some racking systems are designed for products to be stored very deep by omitting the use of longitudinal flues. Transverse flues are often maintained either by the rack uprights for pallet load storage or have unaligned flues in between the uprights for smaller products. Depending on the storage technology, robotic systems may be responsible for cartons fed into the back of the rack and flow down-slope on rollers to the front of the rack where picking occurs. Other technologies are also available.

Figure 4: Example of rack system that only incorporates transverse flues for storage

Another variation of multiple-row racks occurs when the aisles separating the individual rows is less than 3-½ ft (1.1 m) wide and are therefore considered flues. These configurations can be achieved with single-row or double-row (Figure 5) and may or may not have aligned transverse flue depending on the how the products are stored.
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Figure 5: Example of rack storage with narrow aisles with double-row storage

Fire Protection Guidance: Guidance for the protection of multiple-row rack storage configurations is available in NFPA 13 [1], Standard for the Installation of Sprinkler Systems, and FM Global Property Loss Prevention Data Sheet 8-9 [2]. Storage of Class 1, 2, 3, 4 and Plastic Commodities. However, many questions have been raised regarding the application of the existing standards to the increasing options in multiple-row rack storage configurations. Some of the questions raised by the NFPA 13 committee, as well as other stakeholders are:

- What is the minimum flue/aisle size and spacing needed to stop horizontal fire spread for the different storage configurations?
- How to identify storage configurations where in-rack sprinkler protection is needed, versus when ceiling-only sprinkler protection is adequate? This includes when storage heights are exceeded, flue spacing does not meet minimum requirements, and storage depths are exceeded.
- What other potential mitigation options could be applied (e.g., aisles/aisle width, vertical barriers, leaving pallet positions open to simulate an aisle/break in the storage, etc.)?
- What tools/resources can be provided to inform fire service response to a fire in a multiple-row rack storage warehouse? How does the fire service get access to the storage?
- Clarify the definition of net flue spacing established in Data Sheet 8-9 versus nominal flue spacing established in NFPA 13.

Research Goal
The overall goal of this research program is to develop guidance on sprinkler protection for multiple-row racks including determining a scientifically based definition of open racking for multiple-row racks as well as developing guidance on appropriate sprinkler protection and/or other mitigation options (e.g., aisle spacing, vertical barriers) for multiple-row racks that do not meet the definition of open racking. There will be an emphasis on identifying storage configurations where results from large-scale fire tests with double-row racks can be applied to multiple-row racks. This project is a Phase 1 that involves a literature review, gap analysis, and development of a research plan to work toward the overall goal.

1 National Fire Protection Association, Standard for the Installation of Sprinkler Systems, 2010
2 FM Global Property Loss Prevention Data Sheets, Storage of 1, 2, 3, 4 and Plastic Commodities, Interim Revision, October 2020
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Research sponsored by

Property Insurance Research Group (PIRG):
- AIG
- CNA Insurance
- FM Global
- The Hartford
- Travelers Insurance
- Verisk
- Zurich Insurance Group

Project Tasks

This research project, with technical oversight from the project technical panel, will involve the below three tasks identified as Literature Review and Gap Analysis, Test Plan, and Final Report. Implementation of the test plan will be addressed as a follow-up project (Phase 2).

Task 1: Literature review and gap analysis

1. Regulatory Requirements. Review and document the evolution of the requirements in NFPA 13 for solid shelf criteria and how they were developed. Conduct a literature review to study the existing guidance for multiple-row racks, solid-shelf storage, and requirements for in-rack sprinklers.
2. Past Fire Test Data. Identify, clarify, and review any past fire tests in the literature that are relevant to multiple-row rack storage, such as in the following applications:
   a. Horizontal Racks
   b. Pitched Flow Through (Gravity Fed) Racks
   c. Solid shelves
   d. Double-row racks without transverse flues (e.g. drive-in, flow-thru, and push-back)
   e. Automated, or robotic storage, technologies that are being applied to multiple-row rack storage configurations.
3. Develop definitions for storage arrangements that could be classified as open racking for multiple-row racks.
4. Identify knowledge gaps regarding the fire behavior and sprinkler protection of multiple-row racks.
5. Document the findings from Task 1 in an interim report and review with the panel.

Task 2: Test plan

Develop a prioritized plan for full-scale fire testing to inform sprinkler protection guidance for storage with multiple-row racks that will be implemented in a future phase. The goal of the testing will be to develop protection recommendations for storage in multiple-row racks. Opportunities to expand the experimental results through targeted modeling should be considered. Full-scale fire testing should address configurations involving narrow aisle (single, double and multiple), with and without transverse flues and flow through racks.

Review the test plan with the panel and address feedback as needed.
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Task 3: Final Report
Develop a final summary report that contains the results from Task 1 and Task 2 to provide the basis for completing the experimental plan for sprinkler protection of multiple-row rack storage.

Deliverables
- Interim report
- Draft final report
- Final report
- At least one presentation to the relevant NFPA 13 technical committees, or similar

Schedule and Implementation
This research project is led by the Fire Protection Research Foundation and will be conducted in accordance with the “Research Foundation Policies for the Conduct of Research Projects”. The project will be guided by a Project Technical Panel who will provide input to the project, recommend contractor selection, review periodic reports of progress and research results, and review the final project report. At a minimum, three Panel meetings will be held: project kick-off, review of interim report, and review of draft final report. The Foundation will provide documentation of all Panel meetings.

Intellectual Property
The Research Foundation will retain rights to all project deliverables including, the project report, which will be published on the Foundation website. The project deliverables may also include data collected over the course of the project.

Schedule and Costs
This is a fixed price project in the amount of $30,000. All indirect and travel costs incurred are intended to be included within this fixed price. The Foundation does not have a limit on indirect costs, but the total proposal cannot exceed this fixed price. Proposals for this project shall include a breakdown of costs by task.

The proposed schedule is provided in the table below. Suggested modifications to the proposed schedule can be provided with substantiation.

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<th>Tasks</th>
<th>Deliverable Timeline</th>
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<td>Selection of Contractor</td>
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<td>16 June 2023</td>
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<td>Interim Report</td>
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How to Respond
Letter proposals shall be submitted electronically to Amanda Kimball, Executive Director, of the Foundation, at akimball@nfpa.org no later than 5:00 pm Eastern time 5 June 2023. For additional details see the “Research Foundation Policies for the Conduct of Research Projects”, the Foundation Operating Principles, and “Research Project Guidelines for Contractors” on the Foundation website at: https://www.nfpa.org/foundation.
Each proposal shall include a description of the following weighted evaluation criteria: problem understanding (30%), technical merit (include scope and approach) (30%), and prior relevant experience and personnel expertise (30%). An additional criterion, current level of active foundation engagement, will be considered as the remaining 10% weighted evaluation criteria. For more information on the criteria, please refer to the “Research Foundation Policies for the Conduct of Research Projects.”

Please note, the body of the research proposal submittals shall not exceed six pages in length, including a short bio of the proposed personnel and not including the cover page. Any additional relevant information (e.g., Project participants’ CVs or resumes, letters of support, detailed description of past relevant experience, detailed description of RFP-Respondent’s organizational facilities, competencies, other capabilities, and references) not covered in the body of the proposal should be appended to the proposal, with a maximum combined page limit of 12 pages, including the body of the proposal and appendices.

Additionally, all bidders must submit a completed disclosure statement with the proposal (this does not count towards the page limit). This form can be downloaded here.

Note: This project will proceed only on the basis of receipt of a proposal deemed acceptable to the Foundation and the project sponsor(s). Information on the Foundation’s policies for the conduct of research can be found on our website. Services received are subject to our standard contractual terms.