Site-Specific Decision Trees for Handling Unstable Materials – Evonik, Inc.

Project #2

Juliet Freed, Lan Tong

Professors: Dr. William Clark, Michelle Chutka, Dr. Ray Mentzer

Mentor: McKenzie Temme

CHE 59700 Summer Capstone Project

Davidson School of Chemical Engineering

Semester Manuscript

8/4/2025

Table of Contents

List of Figures

List of Tables

Introduction

Evonik Tippecanoe Laboratories has identified potential growth opportunities for the existing hazardous material framework pertaining to oxidizer and organic peroxide classification and storage, which is the basis for the Site-Specific Decision Trees for Handling Unstable Materials project. Evonik Tippecanoe Laboratories is a contract manufacturing organization (CMO), meaning it operates as a third-party active pharmaceutical ingredient (API) manufacturer. Evonik's business model involves receiving and reviewing contracts from customers, then agreeing to manufacture the products after verifying that the project is feasible regarding onsite capabilities and timeframe. When Evonik receives a customer project proposal, all current work on the project by the customer is often benchtop or lab-scale research, meaning that Evonik personnel need to review the research and make changes for scale-up where necessary. It is common for lab-scale research to include high-energy, thermally unstable, and/or explosive oxidizers that may be too hazardous for high quantity use during scale-up. Evonik process safety employees must review customer proposals for details like these and be able to assess feasibility quickly and efficiently, usually with only a few days between receiving the proposal and making a go/no-go decision on moving forward with the project.

Oxidizers and organic peroxides are inherently more dangerous than traditional combustibles due to their ability to lower the flashpoints and ignition temperatures of combustible material and increase the overall explosive potential of a reaction.[1] The varied requirements for stable storage of oxidizers and organic peroxides can become complicated and create opportunities for small mistakes or oversights in evaluating proper storage conditions. In these instances, severe explosions and intense fire outbreaks can occur entirely due to improper or compromised storage. Although Evonik does not expect to have any extremely hazardous

materials onsite, it is still critical to have a complete understanding of safe storage codes, as low-reactivity hazardous materials can cause serious harm. Fires and explosions, even due to lower hazard oxidizers, happen quite commonly at industrial sites in the United States. They can result in injuries, environmental harm, economic loss, and damage to the company or brand reputation. Refer to Appendix G for a detailed report of oxidizer and organic peroxide-related incidents at US industrial sites in recent years.

At present, Evonik does not have a standard program framework for quick classification of oxidizers or organic peroxides. As a result, any project requiring the storage and handling of these compounds must be reviewed on a case-by-case basis and researched and classified separately every time by the process safety team. This process is very involved and time-consuming, as it requires significant research of the National Fire Protection Association (NFPA) Hazardous Materials Code standards to ensure that all storage conditions are appropriately tailored to the physical state, concentration, and quantity of the material. The goal of this project is to review and interpret NFPA codes, focusing on classifying organic peroxides and oxidizers commonly used in API production, and creating a set of optimized tables and decision trees for storage and handling protocols. The capstone team employed Microsoft software tools and various NFPA standard codes in a collaborative environment to develop all project resources. Successful creation and implementation of oxidizer and organic peroxide storage decision tools will streamline communication, finalize decisions for customer proposals, and verify that Evonik can safely manufacture per contractual agreements. This work is essential for the speed and adaptability of Evonik employees responsible for making decisions on customer proposals that involve multiple types of hazardous materials. It will also assist the process safety team in verifying continued understanding and commitment to safe storage processes.

Literature Review

The 2025 NFPA Hazardous Materials Code was primarily used for this project. Other hazardous material codes and classifications exist and are widely used in industry, such as the International Fire Code (IFC) or the Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) Standards, which also apply to hazardous material storage practices. However, the NFPA Hazardous Material Code was adopted by Evonik as the company's predominant hazardous material code source. Therefore, codes or standards from outside organizations were out of the scope of this project. Although using NFPA codes is not required in the state of Indiana, Evonik Tippecanoe Laboratories chooses to use NFPA because it is universally adopted in other Evonik locations where it is required under state law. From Evonik's Environmental, Social, Health, and Safety (ESHS) perspective, it is crucial to comprehensively cover all locations and ensure that every site is following the best practices globally, with no site being more lenient with codes than another site. Specifically, the NFPA 400 Code was used, which details hazardous material storage requirements in industrial and commercial settings, and was the most heavily used resource for this project. The NFPA has over 300 standard books, with each NFPA number code corresponding to different topics in fire safety, hazardous material safe practices, and building construction. As the NFPA codes are interconnected with one another, several other NFPA documents were also referenced for this project, including the NFPA 13, 110, 780, and 5000, amongst others. These codes were consulted primarily because of references made to them in the NFPA 400 codes on topics including sprinkler systems, electrical systems, emergency standby power systems, and explosion protection.

While the primary focus of the capstone project was creating the oxidizer and organic peroxide storage tools, an additional side project involved capstone team members searching literature for any research involving clearly defined, commonly used oxidizers under NFPA standards. Since Evonik manually verifies NFPA standard classification of oxidizers for each project, they would like access to research that provides a quick reference for this verification. The goal of this side project was to identify and compile literature that may be suitable for use as a reference for future Evonik projects. To begin the project, the capstone group met with Purdue University Libraries resources and searched relevant databases. The full literature search was conducted using a series of databases available through the Purdue University Libraries system, including CHEMLIBnetBASE, Knovel, Reaxys, SciFinder-n, and Web of Science, as well as using Google Scholar. Search terms were created based on a list of Evonik's known oxidizers of interest, chemical CAS numbers, NFPA regulations, and related hazardous material keywords to identify any relevant technical papers, material safety data sheets, chemical reaction data, technical engineering handbooks, and material property data. Chemical engineering department faculty and industry process safety experts were consulted for advice related to the search as well. Although the comprehensive search strategy included several databases and involvement from subject matter experts, the results did not yield many directly applicable documents on oxidizers or organic peroxides with established NFPA classifications outside of what the NFPA 400 Appendix already provides. This outcome was not unusual and somewhat expected, as previous Evonik Tippecanoe Laboratories employees have conducted a similar search using Evonik resources and have met the same challenges. Despite the limited results, the comprehensive search methodology and list of search terms were compiled into a report to

provide a baseline and to streamline efforts for any potential future work on this subject. The full report is available through the embedded link in Appendix F.

Data and Results

Throughout the summer semester, the capstone team created and refined a collection of optimized, structured resources for classifying oxidizers and organic peroxides based on their corresponding NFPA class-based protocols. The NFPA defines an oxidizer as "Any solid or liquid material that readily yields oxygen or other oxidizing gas or that readily reacts to promote or initiate combustion of the combustible materials and that can, under some circumstances, undergo a vigorous self-sustained decomposition due to contamination or heat exposure."[2] NFPA standards organize oxidizers into four different classes, separated by their ability to react and ease of combustion within their environment, with Class 1 being the least reactive and Class 4 being the most reactive. While not currently in regular use, Class 1 and 2 oxidizers are expected to be most frequently used at Evonik's Tippecanoe campus for future projects, with Class 3 oxidizers to be less frequently used. Class 4 oxidizers are not expected to be used at Evonik's Tippecanoe campus because of their high hazard level and related safety risks. As such, the decision trees will exclude Class 4 oxidizers but include the other three classes. The four classes of oxidizers are illustrated in Figure 1, along with their common applications in pharmaceutical contexts.

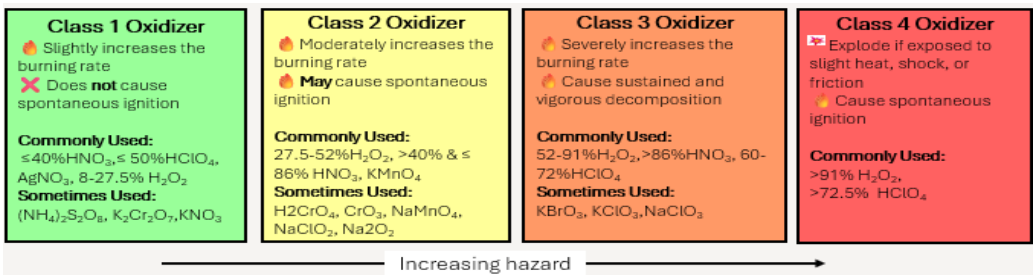


Figure 1. Classification of Oxidizers (1-4) and their Examples in Pharmaceuticals[3]

The NFPA defines an organic peroxide as "any organic compound that has a double oxygen (-O-O-) peroxy group in its chemical structure."[2] In simple terms, all organic peroxides are oxidizers, but not all oxidizers are organic peroxides. NFPA standards organized organic peroxides into six classes based on their reactivity: Class I, IIA, IIB, III, IV, and V. Inverse to the NFPA's classifications of oxidizers, Class V is the least reactive and Class I is the most reactive of the organic peroxides. Class I organic peroxides are classified by their fast-burning rate and high reactivity. Class II organic peroxides are split into groups IIA and IIB because of their larger range in burning rates, with Class IIA having a faster, more severe burning rate than Class IIB. The higher organic peroxide classes are characterized by increasingly less sensitivity to fire, heat, and shock. They are generally less reactive, with Class IV and V organic peroxides burning with equal or less intensity than traditional combustibles. Due to difficulties transporting highly reactive peroxides and their uncommon use in the pharmaceutical API manufacturing industry, Class I organic peroxides are not planned to be used in Evonik Tippecanoe's future work and are out of the scope of this project. The six classes of organic peroxides are illustrated in Figure 2, along with their common applications in pharmaceutical contexts.

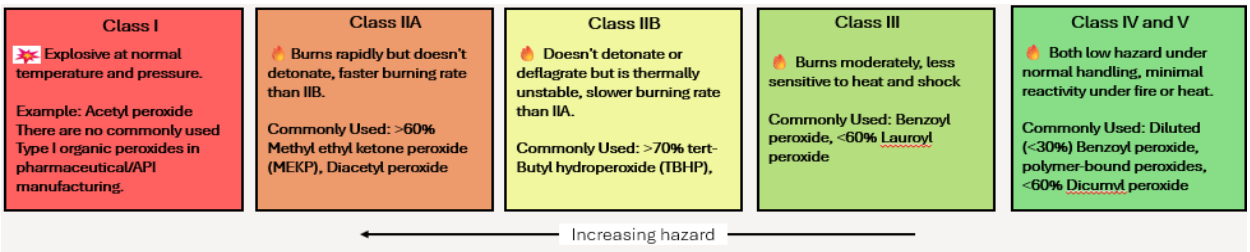


Figure 2. Classification of Organic Peroxides (Class I-V) and Their Examples in Pharmaceuticals[4–6]

The process of building out the decision trees was completed by generating drafts for each of the different classes, starting with classes that are expected to be more commonly used. Drafts were refined through input from project mentor McKenzie Temme, as well as through

input from impacted Evonik personnel during an onsite visit that included Q&A sessions with Evonik's onsite Fire Department team staff and Capital Project Engineering Manager. From these Q&A sessions and weekly project meetings, the capstone team was able to gain insight into the main questions that arise during a project proposal evaluation period. These questions include understanding how to quickly classify chemical compounds and what feasible storage solutions exist for the compounds based on NFPA recommendations. The first step in evaluating a project proposal is to verify whether a less reactive and more easily manageable substitute for any hazardous substance used in the project process is available. Assuming no substitutes exist for the project, the next step is to classify the oxidizer or organic peroxide and confirm that it is within the classes deemed acceptable for use onsite at Evonik Tippecanoe Laboratories. Acceptable use includes any of the above classes approved onsite, assuming they are transportable hazardous materials or materials that are not deemed too dangerous to ship safely through traditional transportation methods.[7] From here, considering different storage options for the oxidizer or organic peroxide is the next step, which is where the NFPA guidelines build out into more detailed, case-specific recommendations. While general storage facility requirements, such as universal building codes, still apply to stored hazardous materials in each proposal, a chemical storage scenario may likely have multiple solutions depending on the compound's class, maximum allowable quantity (MAQ), and the total combined quantity of all oxidizers stored in the space.

NFPA regulations distinguish between several different types of hazardous material storage spaces by categorizing them as Control Area storage, Protection Level storage, and detached storage. Each of these distinctions comes with a long list of requirements that define how the space should be constructed, what fire protection measures should be in place, and how

to store hazardous materials inside safely. Understanding these storage categories is important when planning on-site projects, as process and capital engineers may face limitations with space, incompatible materials, and budget. Additionally, managing incompatible materials is a critical component of chemical storage planning. These can react violently when mixed, potentially generating heat, fumes, gases, or by-products hazardous to life or property.[2] Representative examples of materials incompatible with oxidizers (Table 1) and organic oxidizers (Table 2) are provided in Appendix C. Fully understanding the storage options in these categories can help capital project engineers choose the least capital-intensive design that still aligns with the current safety regulations, financial limitations, and project timeline for customer proposals. Control Area storage, defined as "a building or portion of a building or outdoor area within which hazardous materials are allowed to be stored, dispensed, used, or handled in quantities not exceeding the MAQ,"[2,8] is often the most feasible category, as it requires less stringent regulations. No additional construction provisions are required when only one control area exists within the building. Multiple control areas are allowed in the same building and on the same floors, so long as the barriers in between control areas follow proper fire resistance ratings and the amount being stored per floor level follows the MAQ percentages laid out in the NFPA 400 (see Table 1).

Table 1. Design and Construction Requirements for Control Areas

Floor Level	Maximum Allowable Quantity Percentage per Control Area	Number of Control Areas per Floor	Fire Resistance Rating for Fire Barriers
Above grade			
3	50.0	2	1
2	75.0	2	1
1	100	4	1

Protection Level storage indicates a storage space constructed for a higher degree of safety that "exceeds the construction requirements for control areas to accommodate quantities of hazardous materials in excess of those permitted using the control area concept."[2,5,9] Protection level storage requirements vary greatly based on how much chemical compound is stored in excess of the MAQ along with the class of the compound itself.

There are five Protection Levels, ranging from Level 1 (most hazardous) to Level 4 (least hazardous). In the scope of this project, only Protection Levels 2 and 3 are relevant.

- Protection Level 2 includes materials that present a deflagration hazard or hazard from accelerated burning, such as:
    - Class I organic peroxides
- Protection Level 3 includes materials that readily support combustion, such as:
    - Class IIA, IIB, and III organic peroxides
    - Class 2 and 3 oxidizers (Note: Class 3 oxidizers must be stored in a normally closed system at a gauge pressure of less than 15 psi

Generally, Protection Level storage requires more intense fire protection systems to be present surrounding the storage space. According to NFPA 400, Table 2 provides fire resistance ratings that are required for the separation of occupancies from each other or other use areas for Protection Level Storage (refer to Appendix B for a complete list of occupancy separation ratings). These fire resistance ratings for Protection Level Storage are typically higher than those required for the Control Area storage.

Table 2. Occupancy Separation Fire-resistance Ratings (hr) for Protection Level

Occupancy	Protection 2	Protection Level 3 (> 2 hours for separation for storage room > 150 ft^2)
Industrial, general and special purposes	2	1
Protection Level 2	—	1
Protection Level 3	1	—
Storage, low and ordinary hazard	2	1

Detached storage denotes a building for chemical warehousing separated from other structures to minimize hazardous material risk, usually at a defined separation distance from other buildings or the site property line, shown in Table 3. The building should be single-story and constructed without basements, crawl spaces, or other under-floor spaces.

Table 3. Minimum Separation Distance for Oxidizer Detached Storage

	Class 1	Classes 2 and 3	
	Nonsprinklered/ sprinklered	Nonsprinklered	Sprinklered
Distance to property line	25 ft	100 ft from industrial, mercantile, and storage occupancies; 500 ft from residential, assembly, educational occupancies	50 ft

For organic peroxide detached storage, the minimum required separation distances to the property line are 50 feet, 100 feet, and 150 feet, and the MAQ changes based on building attributes (property line distance and sprinkler status). As these categories are not commonly used terms at Evonik, it is important to conceptualize what each one would look like in the physical storage options available onsite at Evonik's Tippecanoe location. Based on the NFPA

codes, Control Area storage is equivalent to Evonik mixed or general warehousing storage, with a one-hour firewall enclosing the space. Detached storage could mean a detached warehouse, a refrigerated trailer, or other temporary, climate-controlled storage space. Protection Level storage can apply to multiple different types of storage spaces, distinguished by the enhanced safety measures for above-MAQ storage. Each of these categories can be further divided by different construction attributes. Due to the significant variance in storage facility attributes and the variety of oxidizers used for specific industrial tasks, condensing the NFPA 400 guidelines into an easy-to-follow flow chart that can be efficiently referenced becomes complicated quickly. Many of the proper storage conditions are contingent upon combinations of other conditions. Thus, early decision tree drafts became convoluted, with many branches pointing to lengthy and somewhat poorly formatted results. As a result, drafting the decision trees required extensive refinement from both capstone team members and involved input from impacted personnel who understand the physical spaces available onsite at Evonik.

The original decision tree format was subsequently amended to a series of tables. Figures 3 and 4 depict the early stage of the decision trees (refer to Appendix D for the full chart of Figure 3, Covering Class 1-3 Oxidizers). The initial draft was designed to quickly evaluate all potential storage options based on the quantity proposed by the customer, shown in Figure 3, specific to Class 3 oxidizer. When the proposed quantity is less than the MAQ, all storage options are listed and available for consideration. Otherwise, the evaluation process continues through a series of conditional loops until the quantity falls below the MAQ threshold or qualifies for sprinklered detached storage after reaching the unlimited amount of MAQ. Once the base MAQ is exceeded, all storage types in Figure 3 must comply with additional safety

requirements. Figure 4 serves as an example of a detailed follow-up chart, outlining the additional safety requirements specific to Class 3 oxidizers.

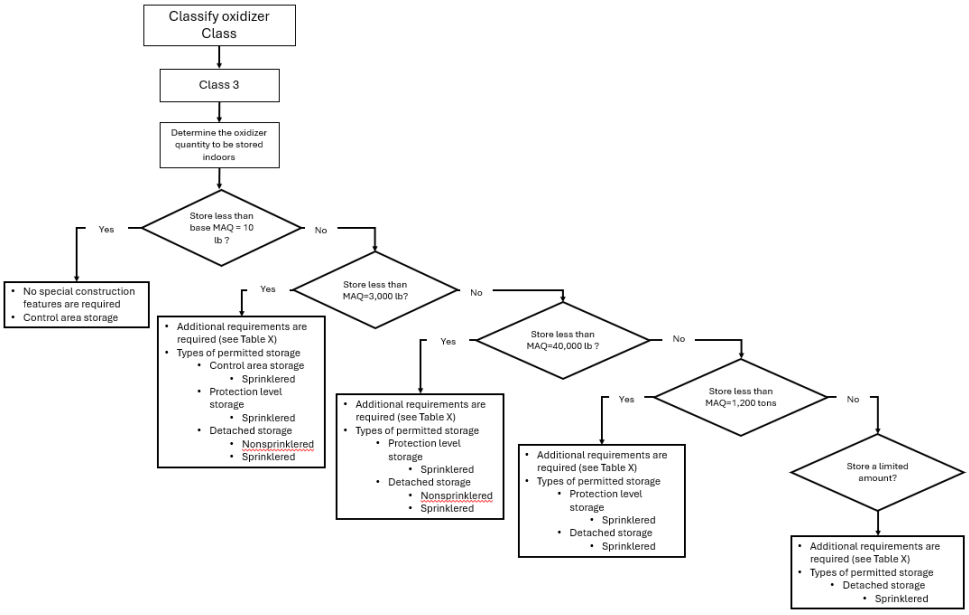


Figure 3. Initial Stage of the Decision Tree, intended as the Starting Point for Evaluating Storage Options for Class 3 Oxidizer

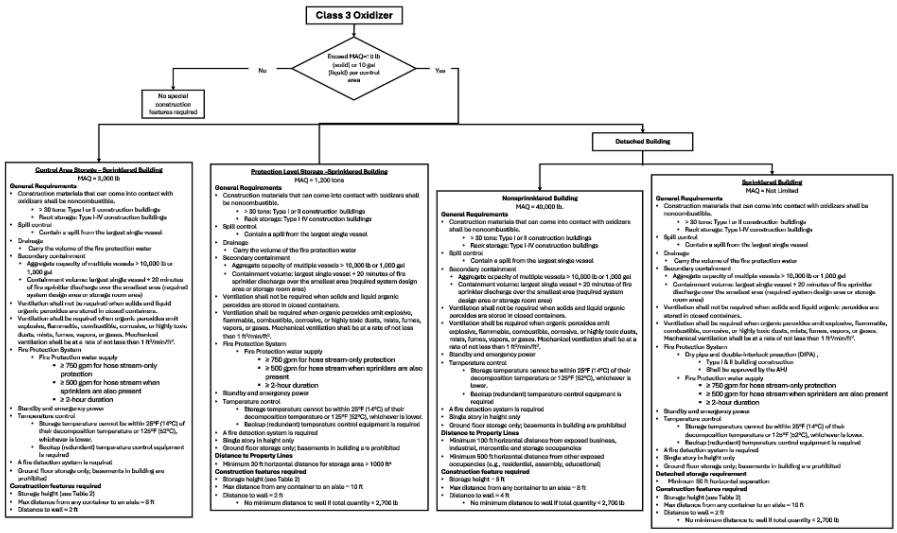


Figure 4. Follow-up Chart of the Initial Stage of the Decision Tree (Figure 3) for Class 3 Oxidizers, Detailing All Storage Options Available and Corresponding Safety Requirements.

Even through multiple drafting cycles, the decision tree format proved to be an inefficient way to display the hazardous material codes, as many branches on the initial decision tree would lead to the same, or slightly different, information, and tables were still needed alongside the subsequent decision trees to include detailed information specific to each class. Additionally, the decision tree format proved to be harder to structure as branches would become long lists of information instead of individual, consecutive decision points. These impracticalities prompted the capstone team to switch to formatting the desired information into a single beginning flowchart and a series of tables for easier referencing, presented below and in the Appendix.

The finalized format for the oxidizer and organic peroxide classification tools first involved using the flowchart in Figure 5 to follow the basic steps of the classification process. This process involves determining the hazardous material NFPA classification, either from the NFPA 400 Appendix, previous literature, or by conducting in-house testing on the compound to determine the proper class if no online data is available. Once a compound is classified and the quantity needed for testing is known, determining the use and MAQ of the compound is the next step. With this information, the proper NFPA storage type can be selected.

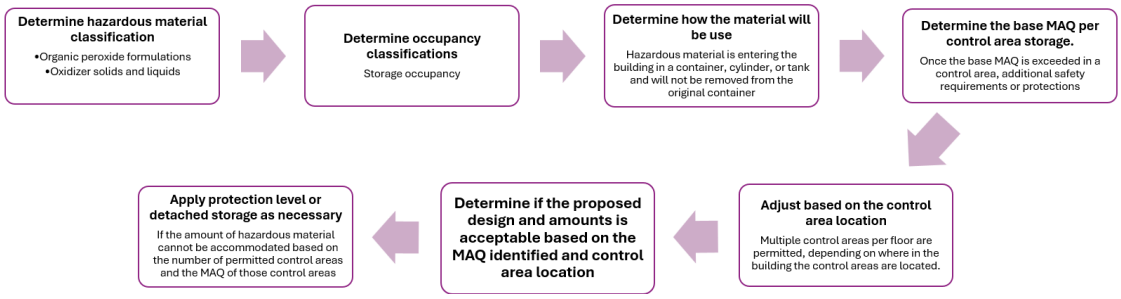


Figure 5. Step-by-Step Process for Determining the Compound MAQ and Storage Solutions[8]

Table 4 illustrates the finalized oxidizer storage decision tools, attributed to material class, storage type (Control Area storage, Protection Level storage, and Detached storage), along

with their corresponding MAQs (refer to Appendix E for an enlarged version of Table 4, complete footnote explanations, and supplementary tables referenced within). If more than one storage solution is possible, the table provides an efficient way to compare several storage types and their additional safety requirements. In the event of a more specialized project that may require a higher quantity or class of oxidizers in which the desired type of storage space is not available onsite, then the user can easily determine which type of storage would be least capital-intensive to create and propose a budget to the customer accordingly.

Table 4. Final storage decision tools for oxidizers

	Oxidizer 1		Oxidizer 2						Oxidizer 3			
	Detached Storage	**Control Area Storage Protection Level Storage Detached storage**	**Control Area Storage**		**Protection Level Storage[3]**		**Detached Storage**		**Control Area Storage**	**Protection Level Storage[3]**	**Detached Storage**	
	Nonsprinklered	**Sprinklered Building**	**Nonsprinklered**	**Sprinklered**	**Nonsprinklered**	**Sprinklered**	**Nonsprinklered**	**Sprinklered**	**Sprinklered**	**Sprinklered**	**Nonsprinklered**	**Sprinklered**
MAQ	Not Limited	Not Limited	2,250 lb	4,500 lb	9,000 lb	2,000 tons (4x if stored in Type I or II building)	100,000 lb	Not Limited	3,000 lb	1,200 tons (> 30 tons must be stored in a Type I or II building)	40,000 lb	Not Limited
Combustible Construction Material in Contact with Oxidizers	X (Unless coated to prevent oxidizer impregnation)	X (Unless coated to prevent oxidizer impregnation)	X	X	X	X	X	X	X (> 30 tons must be stored in a Type I or II building)	X (> 30 tons must be stored in a Type I or II building)	X (> 30 tons must be stored in a Type I or II building)	X (> 30 tons must be stored in a Type I or II building)
Distance To Property Line	25 ft	25 ft (Detached storage only)	X	X	30 ft	30 ft	100 ft[4a] or 500 ft[4b]	50 ft	X	30 ft	100 ft[4a] or 500 ft[4b]	50 ft
Egress	X	X	X	X	• Travel distance limit = 150 ft • Common path of travel distance limit = 25 ft • Additional requirements[5]	• Travel distance limit = 150 ft • Common path of travel distance limit = 25 ft • Additional requirements[5]	X	X	X	• Travel distance limit = 150 ft • Common path of travel distance limit = 25 ft • Additional requirements[5]	X	X
Spill Control	X	X	✓[6]	✓[6]	✓[6]	✓[6]	✓[6]	✓[6]	✓[6]	✓[6]	✓[6]	✓[6]
Drainage	X	✓[7]	X	✓[7]	X	✓[7]	X	✓[7]	✓[7]	✓[7]	X	✓[7]
Secondary Containment	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]
Ventilation (Assume stored in a closed vessel)	X	X	X	X	X	X	X	X	X	X	X	X
Dry Fire Sprinkler System	X	Permitted in Type I-IV building	X	X	X	X	X	Permitted in Type I or II building	X	X	X	Permitted in Type I or II building
Wet Fire Sprinkler System	X	✓[9]	X	✓[9]	X	✓[9]	X	✓[9]	✓[9]	✓[9]	X	✓[9]
Standby And Emergency Power	✓[10]	✓[10]	✓[10]	✓[10]	✓[10]	✓[10]	✓[10]	✓[10]	✓[10]	✓[10]	✓[10]	✓[10]
Temperature Control	✓[11]	✓[11]	✓[11]	✓[11]	✓[11]	✓[11]	✓[11]	✓[11]	✓[11]	✓[11]	✓[11]	✓[11]
Fire Detection System	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	X
Basement In Building	✓	✓	✓ Noncombustible construction materials	✓ Noncombustible construction materials	✓ Noncombustible construction materials	✓ Noncombustible construction materials	X	X	X	X	X	X
Storage Basement	✓	✓	Permitted in stationary tank	Permitted in stationary tank	Permitted in stationary tank	Permitted in stationary tank	X, Single-story height	X, Single-story height	X, Ground floor only	X, Ground floor only	X, Single-story height	X, Single-story height
Floor in Storage Room	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible
Storage Height	8 ft	20 ft	6 ft	See Table 2	8 ft	See Table 2	8 ft	See Table 2	See Table 3	See Table 3	6 ft	See Table 3
Max Distance From Any Container To An Aisle	8 ft	12 ft	4 ft	8 ft	6 ft	12 ft	8 ft	12 ft	8 ft	10 ft	8 ft	10 ft
Distance To Wall	–	–	4 ft	2 ft	4 ft	2 ft	4 ft (No minimum distance if total quantity < 4,500 lb)	2 ft (No minimum distance if total quantity < 4,500 lb)	2 ft	2 ft (No minimum distance if total quantity < 2,700)	4 ft (No minimum distance if total quantity < 2,700	2 ft (No minimum distance if total quantity < 2,700

Organic peroxide storage is inherently more complex due to the range in reactivity and high hazard level. Before any quantity can be stored, storage must meet all baseline standard requirements, shown in Table 5 (see Appendix E for a complete description of each requirement).

Table 5. Standard Requirements for Storing Any Quantities of Organic Peroxides

1. Building requirements	9. Flooring in the storage rooms
2. Spill control	10. Emergency relief system
3. Drainage (sprinklered building only)	11. Portable fire extinguishers
4. Secondary containment	12. Lighting protection
5. No ventilation required	13. Flood protection
6. Emergency and standby power	14. Fire detection system
7. Temperature control	15. Mixed storage in the same area
8. Pressure control	16. Storage arrangement

Although the safety requirements are mostly similar for storing organic peroxides, specific storage requirements can vary by organic peroxide class, storage type, and whether the building is nonsprinklered or sprinklered. To distinguish these criteria, tables are used in addition to the baseline storage requirements. Each class corresponds to different standards for safe construction, storage distances, and building configuration, making the tables somewhat extensive and challenging to depict in one figure. Figure 6 shows Class IV organic peroxides safety requirements (refer to Appendix E for an enlarged version of Table 4, tables of other classes (I-V), complete footnote explanations).

Table 6. Additional Storage Requirements for Class IV Organic Peroxides in Addition to Baseline Storage Requirements (Table 5)

	Control Area Storage		Protection Level Storage		Detached Storage 50 ft Distance to Property Line		Detached Storage 100 ft Distance to Property Line		Detached Storage 150 ft Distance to Property Line	
	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building
MAQ	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited
Dry Fire Sprinkler System	✗	✗	✗	✗	✗	Permitted in Type I-IV building[1b,1c]	✗	Permitted in Type I-IV building[1b,1c]	✗	Permitted in Type I-IV building[1b,1c]
Wet Fire Sprinkler System	✗	Discharge density[2a,2c]: 0.25 gpm/ft²	✗	Discharge density[2a,2c]: 0.25 gpm/ft²	✗	Discharge density[2a,2c]: 0.25 gpm/ft²	✗	Discharge density[2a,2c]: 0.25 gpm/ft²	✗	Discharge density[2a,2c]: 0.25 gpm/ft²
Incompatible and combustible materials separation from organic peroxides	• > 25 or, • 1-hour liquidtight fire barrier	• > 25 or, • 1-hour liquidtight fire barrier	✗	✗	✗	✗	✗	✗	✗	✗
Minimum Aisle Width (Stored in bags, drums,..)	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft
Minimum Access Aisle Width (Stored in bags, drums,..)	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft
Storage Basement	✓	✓	✗, Ground floor only	✗, Ground floor only	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height

To demonstrate how to use the chart correctly, it is helpful to walk through a few examples involving oxidizers and organic peroxides that were requested in past project proposals at Evonik. The first example is a request to handle or store 500 pounds of 30% hydrogen peroxide. The step-by-step process to determine the base MAQ and available storage options is shown in Figure 6. The process begins by classifying the compound, which is considered a Class 2 oxidizer according to the NFPA.[3] Based on the class, weight, and usage information, which dictates that the material will not be removed from its original container after transportation, the base MAQ is determined to be 250 pounds (see Appendix A). As the quantity needed for the project exceeds the MAQ, there are a few storage options that can be selected at this point. The first option is to check if the general warehousing has at least two control areas (mixed warehouses). The cheapest and most straightforward way is to split the 500 pounds in half equally and place them into those control areas. While this option may seem simple and capital-efficient, it is unrealistic considering the spaces available onsite at Tippecanoe Laboratories, as it is impractical for two storage areas separated by a one-hour firewall to be occupied by the same

compound. The better option in this scenario would be to store the entire quantity in a single Control Area storage and have this storage space be the only control area in the entire building. If there is only one control area in the building, then the MAQ increases to 2,250 pounds, which is feasible for the requested quantity of oxidizer. Several additional construction requirements need to be verified before storing the material, such as storage heights and distances, temperature controls, fire detection systems, and standby and emergency power. (See Figure 4 for the complete list of additional safety requirements that need to be implemented)

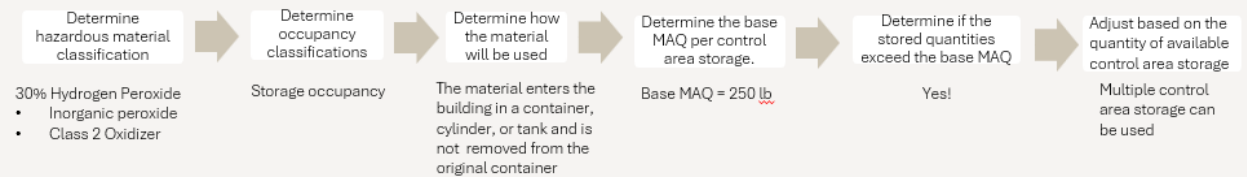


Figure 6. Step-by-step Process Determining Base MAQ and storage options for 500 pounds of 30% Hydrogen Peroxide (This was modified from Figure 5)

Another example comes from a recent project request to Evonik, which involves a proposal including 20,000 pounds of urea hydrogen peroxide (UHP). UHP was classified as a Class 3 oxidizer[10] that has a base MAQ of 10 pounds (see Appendix A). Because this is significantly more UHP than the MAQ allows for, the typical Control Area storage is not feasible for the project. Three possible storage options have been identified for this quantity of UHP. The first option is sprinklered Protection Level storage, with an MAQ of 1,200 tons. The second option would be to use nonsprinklered detached storage, which allows an MAQ up to 40,000 pounds. The third option is sprinklered detached storage, which has no MAQ limit. A detached storage may refer to a standalone warehouse building, trailer, or reefer (nonsprinklered configurations only), depending on what storage is already available onsite or budgeted in the project proposal for new construction. (See Figure 4 for the complete list of additional safety requirements for each different type of storage that needs to be implemented).

A third example involves finding storage solutions for a customer proposal requesting 80 gallons of 30% peracetic acid (approximately 760 pounds). While this is a much smaller quantity than many of the larger campaigns Evonik Tippecanoe Laboratories would undertake, it would likely be intended for Research, Development, and Innovation (RD&I) purposes. According to the NFPA 400 Appendix 14 Table F.1, peracetic acid at this concentration would be classified as a Class IV organic peroxide, meaning it is one of the lower-hazard level classes of organic peroxide, meaning that it has an unlimited base MAQ. This means that if the storage space meets the sixteen standard requirements for organic peroxide storage in Table 5, then there is considerable flexibility in what storage space can be used. Realistically, choosing Control Area storage (equivalent to mixed or general warehousing storage) would be the least capital-intensive and most obvious choice. However, if Control Area storage space is not available for the duration of the campaign, then Protection Level storage and detached storage can also work. These feasible alternatives would require additional safety requirements that are unnecessary for a small quantity of low-hazard organic peroxide. (See Figure 4 for the additional safety requirements that needs to be implemented beyond the baseline standards).

Discussion and Conclusion

The original purpose of this capstone was to address Evonik's challenges with complex and highly cross-referenced NFPA classification of oxidizers and organic peroxides through creating a customized set of decision trees as a resource to streamline customer project proposal decisions while maintaining consistent project advancement and safe manufacturing processes. Although the decision tree format was later adapted into a series of tables for easier visualization, the result preserved the original objectives of creating a set of user-friendly, code-compliant materials for hazardous chemical storage. When making the decision to bring oxidizers and

organic peroxides onsite, it is critical to fully understand and implement codes for safe storage and use, as missteps can have very real consequences that can be both dangerous and expensive. Industrial chemical incidents related to poor or improper storage of oxidizers and organic peroxides are unfortunately common and have done irreversible damage to the environment, the surrounding community, and the company's brand perception. It is one of Evonik's top priorities to ensure that, should the decision be made to utilize oxidizers and organic peroxides in future project campaigns, no incidents occur that could harm the local Lafayette community and environment, or the company's respected global reputation. The resources detailed above and in the Appendices can be effectively used by different engineering teams at Evonik to understand the level of risk and capital investment associated with a project proposal, ultimately supporting Evonik's ability to make informed decisions on customer projects while ensuring that their goals of site safety and compliance are met.

As outlined earlier, this work is essential for the speed, safety, and adaptability of Evonik employees responsible for making decisions on customer proposals. Last year, Evonik sponsored a similar capstone project in which a Purdue Professional Master's Program (PMP) student designed a decision tree for handling explosive materials in customer projects. Although the previous student's project focused on explosives rather than oxidizers, and handling/usage rather than storage, the outcome was the same: providing a valuable reference for employees to accelerate their decision-making process and adhere to safe processes for customer contracts. Further work on adapting safety standards into accessible and comprehensible resources for Evonik will only continue to improve any deficiencies and bottlenecks in their overall project preparation operations. The resources produced for this capstone project proved to assist Evonik's process safety and capital engineering teams by covering potential storage uncertainties

in customer proposals and helping create a quick guide to assist Evonik in quickly capturing opportunities, while mitigating risks, with the overall goal of maintaining their project momentum and meeting agreed contractual customer expectations.

Proposed Steps Forward

Finalizing and validating the resources created by the capstone team through Evonik employee peer review and ensuring that these resources are correctly incorporated into Evonik Tippecanoe Laboratories documentation for future use is the immediate next step for this project. Recommendations for future work include training key users, including points of contact for any questions on all relevant documentation, standardizing storage decision outputs, and implementing a continuous update process. Ideally, training key users should involve scheduling meetings with any impacted teams to review basic use of the resources, working through example scenarios using the tables, and providing written instructions for future reference. A point of contact should be established on all written documentation and in all meetings to emphasize that the maximum effectiveness of these resources depends on having open lines of communication and supporting ongoing dialogues to work through any uncertainties. Standardizing storage decision outputs can be achieved by analyzing upcoming projects and/or project proposals to identify common hazardous chemicals used across projects. If so, it would be beneficial to refine and consolidate outputs into a “common solution” section of the resources, listed in an Appendix for employee quick access and future reference. The capstone team’s last recommendation is to implement a protocol for updating guidance in the event of changes in Evonik company policies, state or federal regulations, or updates to the NFPA documents to ensure continued compliance in the long term.

References

(1) Burgess, H. *After Georgia Chemical Plant Fire, Learn More About the Hazards of Oxidizers*. NFPA. https://www.nfpa.org/news-blogs-and-articles/blogs/2024/10/11/georgia-chemical-plant-fire-and-oxidizers (accessed 2025-07-26).
(2) *NFPA 400 Hazardous Materials Code*; National Fire Protection Association, 2025.
(3) *Oxidizers*; Florida State University, n.d. https://safety.fsu.edu/safety_manual/oxidizers.pdf (accessed 2025-07-27).
(4) *Dicumyl Peroxide 40%*; Ataman Chemicals. https://www.atamanchemicals.com/dicumyl-peroxide-40_u29945/ (accessed 2025-07-31).
(5) *Lauroyl Peroxide (LPO)*; Perodox LUNA. https://www.perodox.com/perodox-luna (accessed 2025-07-31).
(6) *IARC Working Group on the Evaluation of Carcinogenic Risks to Humans*; 1999; Vol. 71.
(7) *What is a "Forbidden" Hazardous Material?* Daniels Training Services. https://danielstraining.com/what-is-a-forbidden-hazardous-material/#:~:text=Some%20hazardous%20materials%20are%20determined%20by%20the,commerce%20altogether%2C%20these%20are%20the%20%E2%80%9CForbidden%E2%80%9D%20Materials. (accessed 2025-07-26).
(8) Ziavras, V. *Determining the Maximum Allowable Quantity (MAQ) of a Hazardous Material*. NFPA.org. https://www.nfpa.org/news-blogs-and-articles/blogs/2022/07/08/determining-the-maximum-allowable-quantity-maq-of-a-hazardous-material (accessed 2025-07-26).
(9) Ziavras, V. *NFPA and IBC Occupancy Classifications When Hazardous Materials Are Present*. NFPA. https://www.nfpa.org/news-blogs-and-articles/blogs/2022/08/12/nfpa-and-ibc-occupancy-classifications-when-hazardous-materials-are-present (accessed 2025-07-27).
(10) *Urea Hydrogen Peroxide, Tablet*; Carlroth, 2019. https://www.carlroth.com/medias/SDB-7641-IE-EN.pdf?context=bWFzdGVyfHNlY3VyaXR5RGF0YXNoZWV0c3wzMjYxODN8YXBwbGljYXRpb24vcGRmfGFHWXlMMmcwWmk4NU1UYzVOREV6TWpneU9EUTJMMU5FUWw4M05qUXhYMGxGWDBWT0xuQmtaZ3wyNWYzZDUwM2Y1NWVjOWI5MGMyMTY5M2U0Njc3MGRiMDE4Y2Y1NDZhYWRhZTE5M2MwZmUwZjNlMGNmYWIzNTNi (accessed 2025-07-30).
(11) *Chemical Incompatibilities*; University of Pittsburgh, n.d. http://ccc.chem.pitt.edu/wipf/Web/Chemical_Incompatibilities.pdf (accessed 2025-07-27).
(12) *Safety Data Sheet: Tert-Butyl Hydroperoxide, 70% Solution in Water*; 2014. https://www.fishersci.com/store/msds?partNumber=AC180345000&productDescription=TERT-BUTYL+HYDROPEROXIDE+500GR&vendorId=VN00032119&countryCode=US&language=en#:~:text=Thermal%20decomposition%20can%20lead%20to,of%20ignition%20and%20flash%20back.&text=Carbon%20monoxide%20(CO).,tert%2Dbutanol.&text=As%20in%20any%20fire%2C%20wear,equivalent)%20and%20full%20protective%20gear. (accessed 1925-07-27).
(13) *Safety Data Sheet: Lauroyl Peroxide*; Synquest Laboratories, 2020. https://synquestprodstorage.blob.core.windows.net/msds/2100/2127-1-X0.pdf (accessed 205 AD-07-27).
(14) Hart, J. *Hazardous Materials Identification*. https://www.nfpa.org/news-blogs-and-articles/blogs/2021/11/05/hazardous-materials-identification (accessed 2025-07-31).

(15)*Chemical Decomposition, Fire, and Toxic Gas Release at Bio-Lab, Inc.*; 2024-04-I-GA; U.S. Chemical Safety and Hazard Investigation Board: Conyers, Georgia, 2024. https://www.csb.gov/assets/1/6/investigation_update_bio-lab_final_nov2024_(005).pdf (accessed 2025-07-26).
(16)*Massive Fire and Smoke Plume Led to Evacuation of 17,000 Residents and Shelter-in-Place Orders for 90,000 Others*. U.S. Chemical Safety Board. https://www.csb.gov/us-chemical-safety-board-issues-second-update/#:~:text=facility%20in%20Conyers%2C%20Georgia.,materials%2C%20and%20ignited%20multiple%20fires.
(17)*Rockdale County Issues Statement on Bio-Lab Fire Litigation*; 2024. https://www.rockdalecountyga.gov/rockdale-county-issues-statement-on-bio-lab-fire-litigation/#:~:text=ROCKDALE%20COUNTY%2C%20Ga.,SSacks@NapoliLaw.com (accessed 2025-07-27).
(18)*Organic Peroxide Decomposition, Release, and Fire at Arkema Crosby Following Hurricane Harvey Flooding*; 2017-08-I-TX; U.S. Chemical Safety and Hazard Investigation Board: Crosby, Texas, 2017. https://www.csb.gov/assets/1/20/final_arkema_draft_report_2018-05-23.pdf?16272 (accessed 2025-07-26).
(19)Vasquez, L. *Harris County settles lawsuit against Arkema over 2017 chemical plant fire*. Houston Public Media. https://www.houstonpublicmedia.org/articles/news/energy-environment/2024/08/27/497845/harris-county-settles-lawsuit-against-arkema-over-2017-chemical-plant-fire/ (accessed 2025-07-27).

APPENDICES

Appendix A. Base MAQ per Control Area Storage

Table A. Maximum Allowable Quantities (MAQ) of Organic Peroxides and Oxidizers per Control Area Storage

Materials and Their Class	Base MAQ per Control Area Storage (lb)
Class I Organic Peroxide	16
Class IIA Organic Peroxide	100
Class IIB Organic Peroxide	400
Class III Organic Peroxide	840
Class IV Organic Peroxide	Not Limited
Class V Organic Peroxide	Not Limited
Class 4 Oxidizer	1
Class 3 Oxidizer	10
Class 2 Oxidizer	250
Class 1 Oxidizer	4000

Appendix B. Occupancy Separation Requirements by Protection Level

Table B. Occupancy Separation Fire-resistance Ratings (hr) for Protection Level

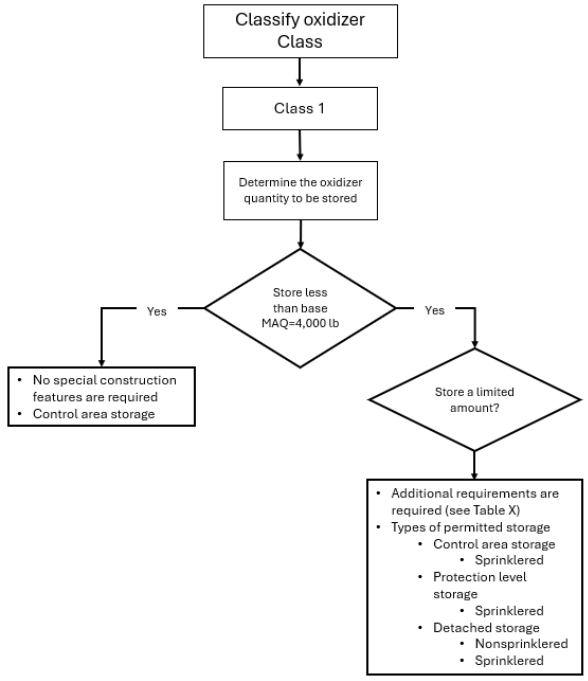
Occupancy	**Protection 2**	**Protection Level 3 (> 2 hour for separation for Class3 oxidizers in storage room > 150 ft^2)**
Apartment buildings	4	3
Assembly	4	3
Board and care	4	3
Business	2	1
Day-care > 12	4	3
Day-care homes	4	3
Detention and correctional	4	3
Dwellings, one- and two-family	4	3
Educational	4	3
Health care	4	4
Hotels and dormitories	4	3
Industrial, general and special purposes	2	1
Lodging and rooming houses	4	3
Mercantile, Class A, B, and C	2	1
Protection Level 2	—	1
Protection Level 3	1	—
Storage, low and ordinary hazard	2	1

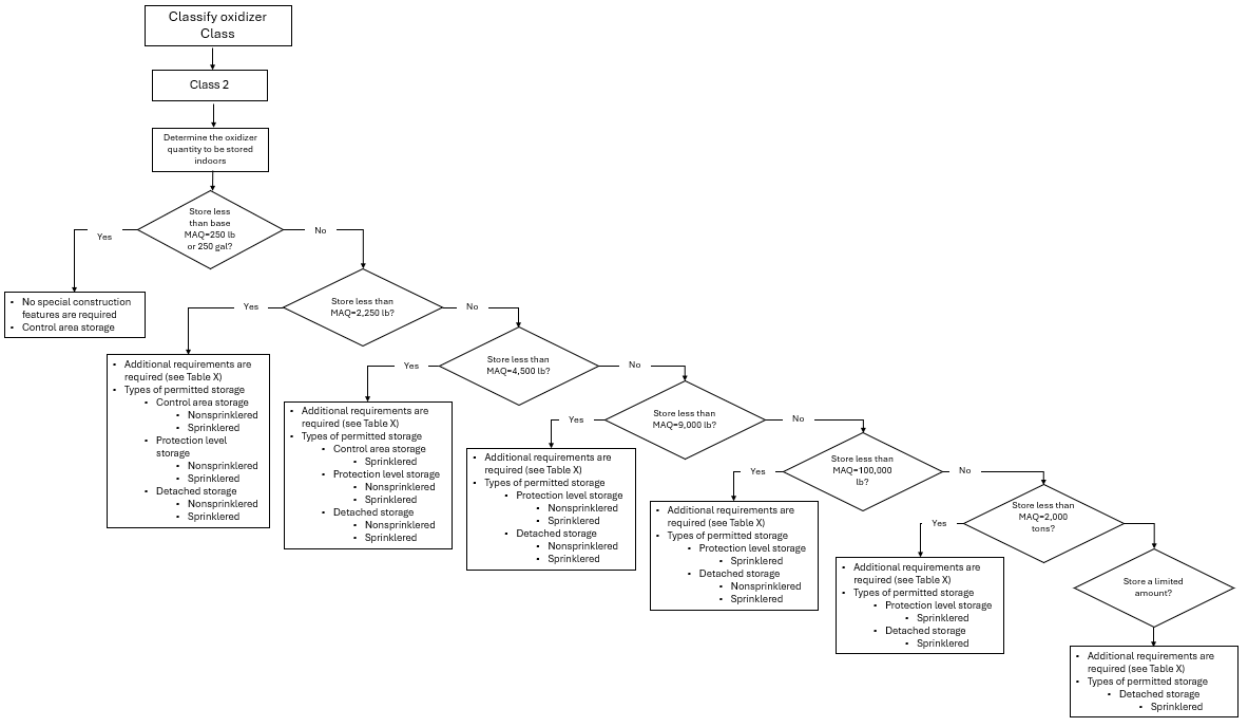
Appendix C. Example of Incompatible Chemicals

Table C. Examples of Reactive and Incompatible Chemicals with Oxidizers (Figure 1) and Organic Peroxide (Figure 2)

Chemical	**Keep out of contact with**
Nitric acid, fuming (HNO3)	Organic matter, nonmetals, most metals, ammonia, chlorosulfonic acid, chromium trioxide, cyanides, dichromates, hydrazines, hydrides, HCN, HI, hydrogen sulfide, sulfur dioxide, sulfur halides, sulfuric acid, flammable liquids and gases[11]
Perchloric acid (HClO4)	Acetic acid, acetic anhydride, alcohols, antimony compounds, azo pigments, bismuth and its alloys, methanol, carbonaceous materials, carbon tetrachloride, cellulose, dehydrating agents, diethyl ether, glycols and glycolethers, HCI, HI, hypophosphites, ketones, nitric acid, pyridine, steel, sulfoxides, sulfuric acid[5]
Silver nitrate (AgNO3)	Calcium Carbide, Iodoform, Nitrous acid, Phosphine[11]
Hydrogen Peroxide (H2O2)	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, flammable liquids, combustible materials[11]
Potassium permanganate (KMnO4)	Hydrogen chloride, Titanium, glycerol, ethylene glycol, benzaldehyde, sulfuric acid[11]
tert-Butyl hydroperoxide (TBHP), 70% solution in water	Organic materials, Acids, Bases, Metals, Reducing Agent, Finely powdered metals, Strong reducing agents, Combustible material[12]
Benzoyl Peroxide	Direct sunlight, sparks and open flames, shock and friction, acids, alcohols, amines, ethers, reducing agents, polymerization catalysts, metallic naphthenates[11]
Lauroyl peroxide	Strong acids. Strong bases. Reducing agents. Combustible materials. Alkali metals. Finely divided metals (Al, Mg, Zn)[13]

Appendix D. Early Stage of the Decision Tree





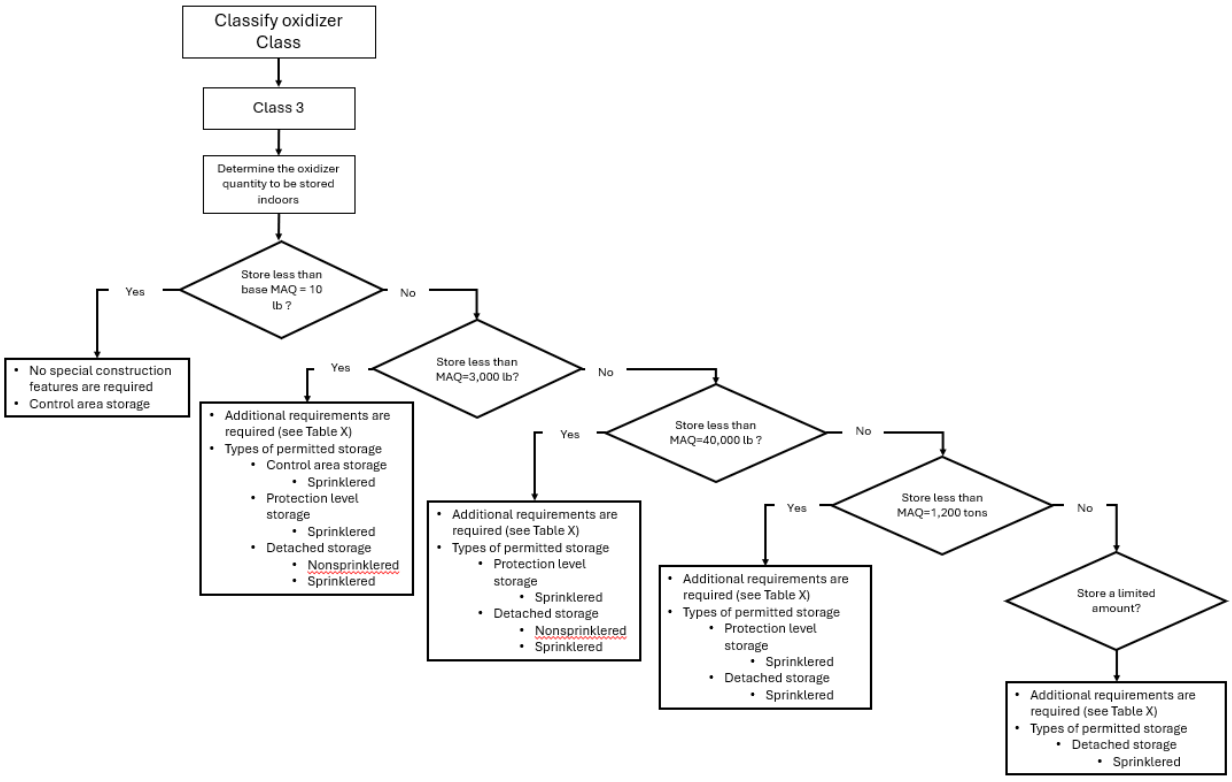


Figure C. Early stage of the initial decision tree, intended as the starting point for understanding storage options of the three classes of oxidizers.

Appendix E. Oxidizer and Organic Peroxide Tool Full PDF

See the attached document: Tables of Requirements for Oxidizers and Organic Peroxides .pptx

Table 1. Oxidizer Storage Requirements by Class When Stored Quantities Exceed the Maximum Allowable Quantity (MAQ) permitted in control areas storage[1,2]

	Oxidizer 1		Oxidizer 2						Oxidizer 3			
	Detached Storage	Control Area Storage Protection Level Storage Detached storage	Control Area Storage		Protection Level Storage[3]		Detached Storage		Control Area Storage	Protection Level Storage[3]	Detached Storage	
	Nonsprinklered	Sprinklered Building	Nonsprinklered	Sprinklered	Nonsprinklered	Sprinklered	Nonsprinklered	Sprinklered	Sprinklered	Sprinklered	Nonsprinklered	Sprinklered
MAQ	Not Limited	Not Limited	2,250 lb	4,500 lb	9,000 lb	2,000 tons (4x if stored in Type I or II building)	100,000 lb	Not Limited	3,000 lb	1,200 tons (> 30 tons must be stored in a Type I or II building)	40,000 lb	Not Limited
Combustible Construction Material in Contact with Oxidizers	X (Unless coated to prevent oxidizer impregnation)	X (Unless coated to prevent oxidizer impregnation)	X	X	X	X	X	X	X (> 30 tons must be stored in a Type I or II building)	X (> 30 tons must be stored in a Type I or II building)	X (> 30 tons must be stored in a Type I or II building)	X (> 30 tons must be stored in a Type I or II building)
Distance To Property Line	25 ft	25 ft (Detached storage only)	X	X	30 ft	30 ft	100 ft[4a] or 500 ft[4b]	50 ft	X	30 ft	100 ft[4a] or 500 ft[4b]	50 ft
Egress	X	X	X	X	• Travel distance limit = 150 ft • Common path of travel distance limit = 25 ft • Additional requirements[5]	• Travel distance limit = 150 ft • Common path of travel distance limit = 25 ft • Additional requirements[5]	X	X	X	• Travel distance limit = 150 ft • Common path of travel distance limit = 25 ft • Additional requirements[5]	X	X
Spill Control	X	X	√[6]	√[6]	√[6]	√[6]	√[6]	√[6]	√[6]	√[6]	√[6]	√[6]
Drainage	X	√[7]	X	√[7]	X	√[7]	X	√[7]	√[7]	√[7]	X	√[7]
Secondary Containment	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]	Required when the total vessel capacity > 10,000 lb or 1,000 gal[8]
Ventilation (Assume stored in a closed vessel)	X	X	X	X	X	X	X	X	X	X	X	X
Dry Fire Sprinkler System	X	Permitted in Type I-IV building	X	X	X	X	X	Permitted in Type I or II building	X	X	X	Permitted in Type I or II building
Wet Fire Sprinkler System	X	√[9]	X	√[9]	X	√[9]	X	√[9]	√[9]	√[9]	X	√[9]
Standby And Emergency Power	√[10]	√[10]	√[10]	√[10]	√[10]	√[10]	√[10]	√[10]	√[10]	√[10]	√[10]	√[10]
Temperature Control	√[11]	√[11]	√[11]	√[11]	√[11]	√[11]	√[11]	√[11]	√[11]	√[11]	√[11]	√[11]
Fire Detection System	√	√	√	√	√	√	√	X	√	√	√	X
Basement In Building	√	√	√ Noncombustible construction materials	√ Noncombustible construction materials	√ Noncombustible construction materials	√ Noncombustible construction materials	X	X	X	X	X	X
Storage Basement	√	√	Permitted in stationary tank	Permitted in stationary tank	Permitted in stationary tank	Permitted in stationary tank	X, Single-story height	X, Single-story height	X, Ground floor only	X, Ground floor only	X, Single-story height	X, Single-story height
Floor in Storage Room	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible	Liquidtight, noncombustible
Storage Height	8 ft	20 ft	6 ft	See Table 2	8 ft	See Table 2	8 ft	See Table 2	See Table 3	See Table 3	6 ft	See Table 3
Max Distance From Any Container To An Aisle	8 ft	12 ft	4 ft	8 ft	6 ft	12 ft	8 ft	12 ft	8 ft	10 ft	8 ft	10 ft
Distance To Wall	–	–	4 ft	2 ft	4 ft	2 ft	4 ft (No minimum distance if total quantity < 4,500 lb)	2 ft (No minimum distance if total quantity < 4,500 lb)	2 ft	2 ft (No minimum distance if total quantity < 2,700)	4 ft (No minimum distance if total quantity < 2,700	2 ft (No minimum distance if total quantity < 2,700

<u>The following footnotes apply to Table 1:</u>

[1]Each class of oxidizer shall be considered independent of the others, and a facility shall be permitted to carry up to the maximum quantity for each class of material.

[2]The construction requirements of this code shall not apply retroactively to the storage of solid and liquid oxidizers in existing buildings used for the storage of oxidizers at manufacturing plants.

[3]Protection Level 3 applies to Class 2 oxidizers and Class 3 oxidizers in normally closed containers or systems at gauge pressures of less than 15 psi (103.4 kPa).

[4a]Minimum 100 ft from exposed business, industrial, mercantile and storage occupancies

[4b]Minimum 500 ft from other exposed occupancies (e.g., residential, assembly, educational)

[5]Egress

- Capacity of means of egress
    - Stair: 0.7 in./person
    - Level components/ramps: 0.4 in./person
- Number of means of egress > 2 means of egress, unless all of the following conditions are met:
    - Room is ≤ 200 ft^2
    - Occupant load ≤ 3 persons
    - Travel distance to the room door ≤ 25 ft
- If the above conditions are met, dead ends in corridors are permitted.

[5]Spill control shall be required for Class 2 and 3 liquid oxidizers. The system shall be constructed to contain a spill from the largest single vessel by one of the following methods:

1) Liquidtight sloped or recessed floors in indoor locations or similar areas in outdoor locations
2) Liquidtight floors in indoor locations or similar areas in outdoor locations provided with liquidtight raised or recessed sills or dikes
3) Sumps and collection systems

- Except for surfacing, the floors, sills, dikes, sumps, and collection systems shall be constructed of noncombustible material, and the liquid-tight seal shall be compatible with the material stored.

[7]Drainage is required in a sprinklered building. The system must comply with the following methods:

1) The slope of floors in indoor locations to drains or similar areas in outdoor locations shall be not less than 1 percent.
2) Drains from indoor storage areas shall be sized to carry the volume of the fire protection water, as determined by the design density discharged from the automatic fire-extinguishing system over the minimum required system design area, or area of the room or area in which the storage is located, whichever is smaller.
3) Materials of construction for drainage systems shall be compatible with the materials stored.
4) Separate drainage systems shall be provided to avoid mixing incompatible materials where such materials are present in an open-use condition.

5) Drains shall terminate in an approved location away from buildings, valves, means of egress, fire access roadways, adjoining property, and storm drains.

[8]Secondary containment for indoor storage areas shall be designed to contain a spill from the largest vessel plus the design flow volume of fire protection water calculated to discharge from the fire-extinguishing system over the minimum required system design area, or area of the room or area in which the storage is located, whichever is smaller, for a period of 20 minutes. The system must use one of the following methods:

1) Liquidtight sloped or recessed floors in indoor locations or similar areas in outdoor locations
2) Liquidtight floors in indoor locations or similar areas in outdoor locations provided with liquidtight raised or recessed sills or dikes
3) Sumps and collection systems
4) Drainage systems leading to an approved location

[9]Fire protection water supply shall be adequate

- ≥ 750 gpm for hose stream-only protection
- ≥ 500 gpm for hose stream when sprinklers are also present
- ≥ 2-hour duration

[10]Standby and emergency power

- Standby power or emergency shall be provided where mechanical ventilation, treatment systems, temperature control, alarm, detection, or other electrically operated safety systems are present.
- Standby power for mechanical ventilation, exhaust treatment, and temperature control systems shall not be required where such systems are engineered and approved as fail-safe.
- The secondary source of power shall be an approved means of legally required standby power.

[11]Storage temperature cannot be within 25°F (14°C) of their decomposition temperature or 125°F (52°C), whichever is lower. A backup (redundant) temperature control equipment is required.

Table 2. Ceiling Sprinkler Protection for Class 2 Oxidizers in Palletized or Bulk and Rack Storage Areas

Type of Storage	Ceiling Sprinklers			In-Rack Sprinklers
	Storage Height (ft)	Density (gpm/ft²)	Area of Application (ft²)	
Palletized or bulk	8	0.20	3750	—
Palletized or bulk	12	0.35	3750	—
Rack	12	0.20	3750	One line above each level of storage, except the top level
Rack	16	0.30	2000	One line above each level of storage, except the top level

Notes:
- Ceiling sprinklers: high-temperature rated
- In-rack sprinklers:
  - Quick response, ordinary temperature, K ≥ 8.0
  - 25 psi to 6 most remote per level
  - 8 ft – 10 ft spacings in the longitudinal flue space at the intersection of the transverse flue spaces.

Table 3. Construction Features Required for Storage of Class 3 Oxidizers in a Sprinklered Building

Store Parameters	Shelf	Bulk or Pile	Bulk or Pile	Rack (Type I-IV building)
a. Class 3 Oxidizers Stored in Total Quantities Greater Than 200 lb but Less Than 2700 lb				
Maximum storage height	6 ft	5 ft	10 ft	10 ft
Maximum ceiling height	25 ft	25 ft	25 ft	Not Applicable
Ceiling design criteria (high-temp rated)	0.45 gpm/ft²/2000 ft²	0.35 gpm/ft²/ 5000 ft² or 0.6 gpm/2000 ft²	0.65 gpm/ft²/5000 ft²	0.35 gpm/ft²/ 5000 ft² or 0.6 gpm/ft²/2000 ft²
In-rack sprinklers	Not permitted	Not permitted	Not applicable	• Install above every level • Maximum 4 ft spacings in flue spaces • Quick response, ordinary temp, K ≥ 8.0 • 25 psi for 6 most remote per level
b. Class 3 Oxidizers Stored in Total Quantities Greater Than or Equal to 2700 lb				
Maximum storage height		5 ft	10 ft	10 ft
Maximum ceiling height		25 ft	25 ft	Not Applicable
Ceiling design criteria (high-temp rated)		0.35 gpm/ft²/5000 ft²	0.65 gpm/ft²/5000 ft²	Predominant for other commodities but not less than ordinary hazard Group II
In-rack sprinklers		Not permitted	Not permitted	(See below In-rack sprinkler Requirements)

In-rack sprinkler requirements:

1. Racks shall be of steel construction.

2. Racks shall have vertical supports spaced no more than 10 ft (3.1 m) apart.

3. Horizontal rack members shall be spaced not more than 6 ft (1.8 m) apart vertically.

4. Display or storage shall be limited in height to two protected tiers.

5 Horizontal barriers constructed of plywood at least 3⁄8 in. (9.5 mm) thick shall be provided above each level of oxidizing material storage, and the following criteria also shall be met:

I. The barriers shall extend from rack face to rack face and shall be tight to the vertical barriers.

- Transverse vertical barriers constructed of plywood at least 3⁄8 in. (9.5 mm) thick shall be provided at the rack uprights extending from rack face to rack face.
- For double-row racks, longitudinal vertical barriers constructed of plywood at least 3⁄8 in. (9.5 mm) thick shall be provided at the rack uprights in the center of the rack.

II. The barriers shall be supported by horizontal rack members.

6. If intermediate shelves are used between the horizontal barriers, the shelves shall be constructed of open wire mesh or steel grating.

7. Pallets, if used, shall be of the solid-deck type.

8. In-rack automatic sprinklers shall be provided under each horizontal barrier.

9. For double-row racks, two lines of in-rack sprinklers shall be provided between the face of the rack and the longitudinal vertical barrier located in the center of the rack.

10. For single-row racks, two lines of in-rack sprinklers shall be provided between each rack face.

11. Three in-rack sprinklers shall be provided on each in-rack sprinkler line as follows:

I. Two sprinklers on each line shall be spaced approximately 11⁄2 in. (38.1 mm) from each transverse vertical barrier.

II. One in-rack sprinkler on each in-rack sprinkler line shall be located approximately equidistant between the transverse vertical barriers.

12. In-rack sprinklers shall be of the upright or pendent type, with the fusible element located no more than 6 in. (152.4 mm) from the horizontal barrier.

13. The stock shall be maintained at least 6 in. (152.4 mm) below the sprinkler deflector.

14. In-rack sprinklers shall be K = 8.0, quick-response, ordinary-temperature-rated sprinklers.

15. The in-rack sprinkler system shall be designed to supply 6 sprinklers on each line, with a total of 12 sprinklers operating at gauge pressure of 25 psi (172 kPa).

16. The design of the in-rack sprinkler system shall be independent of, and shall not be required to be balanced with, ceiling sprinkler systems.

Standard Requirements for Organic Oxidizers (All Quantities)

1. Building requirements

No contact with materials of the building construction that affect the thermal stability of the organic peroxide.

2. Spill control

The system shall be constructed to contain a spill from the largest single vessel by one of the following methods:

1) Liquidtight sloped or recessed floors in indoor locations or similar areas in outdoor locations
2) Liquidtight floors in indoor locations or similar areas in outdoor locations provided with liquidtight raised or recessed sills or dikes
3) Sumps and collection systems

- Except for surfacing, the floors, sills, dikes, sumps, and collection systems shall be constructed of noncombustible material, and the liquid-tight seal shall be compatible with the material stored.

3. Drainage

Drainage is required in a sprinklered building. The system must comply with the following methods:

1) The slope of floors in indoor locations to drains or similar areas in outdoor locations shall be not less than 1 percent.
2) Drains from indoor storage areas shall be sized to carry the volume of the fire protection water, as determined by the design density discharged from the automatic fire-extinguishing system over the minimum required system design area, or area of the room or area in which the storage is located, whichever is smaller.
3) Materials of construction for drainage systems shall be compatible with the materials stored.
4) Separate drainage systems shall be provided to avoid mixing incompatible materials where such materials are present in an open-use condition.
5) Drains shall terminate in an approved location away from buildings, valves, means of egress, fire access roadways, adjoining property, and storm drains.

4. Secondary containment

Secondary containment shall be designed to contain at least 10 percent of the maximum quantity stored in the area or the quantity from the largest vessel, whichever is higher, plus the design flow volume of fire protection water calculated to discharge from the fire-extinguishing system over the minimum required system design area, or area of the room or area in which the storage

is located, whichever is smaller, for a period of 20 minutes. The system must use one of the following methods:

1) Liquidtight sloped or recessed floors in indoor locations or similar areas in outdoor locations
2) Liquidtight floors in indoor locations or similar areas in outdoor locations provided with liquidtight raised or recessed sills or dikes
3) Sumps and collection systems
4) Drainage systems leading to an approved location

5. No ventilation (assume stored in a closed vessel)

Ventilation shall not be required when solids and liquid organic peroxides are stored in closed containers.

6. Emergency and standby power

- Standby power or emergency shall be provided where mechanical ventilation, treatment systems, temperature control, alarm, detection, or other electrically operated safety systems are present.
- Standby power for mechanical ventilation, exhaust treatment, and temperature control systems shall not be required where such systems are engineered and approved as fail-safe.
- The secondary source of power shall be an approved means of legally required standby power.

7. Temperature control

- Materials that must be kept at temperatures other than normal ambient temperatures to prevent a hazardous reaction shall be provided with an approved means to maintain the temperature within a safe range.
- Redundant temperature control equipment that will operate on failure of the primary temperature control system shall be provided.

8. Pressure control

Stationary tanks and equipment containing hazardous material liquids that can generate pressures exceeding design limits due to exposure fires or internal reaction shall have some form of construction or other approved means that will relieve excessive internal pressure.

9. Floors in Storage Rooms

- Liquidtight, noncombustible construction
- Watertight floor with safe storage

10. Emergency Relief Systems

Storage tanks and dosing vessels shall be equipped with a vent or other relief device

11. Portable fire extinguishers

12. Lighting protection

13. Flood protection

- Buildings, or portions thereof, used for the storage of temperature-controlled organic peroxides in flood hazard areas shall be constructed at sufficient elevation and/or incorporate other protection mechanisms to prevent organic peroxide packages coming in contact with flood water during conditions of floods.
- Temperature control, alarm, detection, standby and emergency power supply or other electrically operated safety systems, or other emergency systems in organic peroxide storage areas or buildings in flood hazard areas shall be provided at sufficient elevation and/or other protection mechanisms to prevent loss of power or performance during conditions of floods.

14. Fire detection system

15. Mixed storage in same area

- Maximum quantity permitted $= \sum_{i=1}^{n}(\frac{Stored\ Quantity\ of\ Class\ i}{Maximum\ Permitted\ Quantity\ of\ Class\ i}) * 100\%$
    - n = Number of different classes stored
- Maximum quantity permitted of n class ≤ 100%

16. Storage arrangements

- A clear space of at least 1 ft (0.3 m) shall be maintained between organic peroxide storage and any walls of combustible or limited combustible construction.
- A clear space of at least 1 ft (0.3 m) shall be maintained between organic peroxide storage and uninsulated metal walls.
- A clear space of at least 0.5 ft (0.15 m) shall be maintained between organic peroxide storage and insulated walls.
- A clear space of at least 0.25 ft (0.075 m) shall be maintained between temperature controlled organic peroxide pallets.

Note: Tables 4a through 4d present additional requirements for organic peroxides in addition to the 16 standard requirements applicable to all quantities. These tables apply when there are differences in peroxide class, storage type, or whether the building is sprinklered or nonsprinklered.

Table 4a. Maximum Allowable Quantities and Storage Requirements for Class I Organic Peroxide Formulations										
	Control Area Storage		Protection Level Storage		Detached Storage 50 ft Distance to Property Line		Detached Storage 100 ft Distance to Property Line		Detached Storage 150 ft Distance to Property Line	
	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building
MAQ	16 lb	32 lb	16 lb	2,000 lb	1,000 lb	2,000 lb	4,000 lb	20,000 lb	10,000 lb	175,000 lb
Egress	✗	✗	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]
Dry Fire Sprinkler System	✗	✗	✗	✗	✗	Permitted in Type I or II building[1b,1c]	✗	Permitted in Type I or II building[1b,1c]	✗	Permitted in Type I or II building[1b,1c]
Wet Fire Sprinkler System	✗	Discharge density[2a,2c]: 0.50 gpm/ft Open-head deluge sprinkler when quantities ≥ 2000	✗	Discharge density[2a,2c]: 0.50 gpm/ft Open-head deluge sprinkler when quantities ≥ 2000	✗	Discharge density[2a,2c]: 0.50 gpm/ft Open-head deluge sprinkler when quantities ≥ 2000	✗	Discharge density[2a,2c]: 0.50 gpm/ft Open-head deluge sprinkler when quantities ≥ 2000	✗	Discharge density[2a,2c]: 0.50 gpm/ft Open-head deluge sprinkler when quantities ≥ 2000
Blast-Resistant Interior Wall	✗	✗	✗	432 psf	✗	✗	✗	✗	✗	✗
Deflagration venting via exterior walls or roofs	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗
Incompatible and combustible materials separation from organic peroxides	• > 25 or, • 1-hour liquidtight fire barrier	• > 25 or, • 1-hour liquidtight fire barrier	✗	✗	✗	✗	✗	✗	✗	✗
Minimum Aisle Width (Stored in bags, drums,..)	8 ft	8 ft	8 ft	8 ft	8 ft	8 ft	8 ft	8 ft	8 ft	8 ft
Minimum Access Aisle Width (Stored in bags, drums,..)	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft
Storage Basement	✓	✓	✗, Ground floor only	✗, Ground floor only	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height

Table 4b. Maximum Allowable Quantities and Storage Requirements for Class IIA and IIB Organic Peroxide Formulations										
	Control Area Storage		Protection Level Storage		Detached Storage 50 ft Distance to Property Line		Detached Storage 100 ft Distance to Property Line		Detached Storage 150 ft Distance to Property Line	
	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building
Type IIA										
MAQ	100 lb	200 lb	100 lb	50,000 lb	20,000 lb	100,000 lb	80,000 lb	200,000 lb	500,000 lb	Not limited
Egress	✗	✗	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]
Dry Fire Sprinkler System	✗	✗	✗	✗	✗	Permitted in Type I or II building[2b,2c]	✗	Permitted in Type I or II building[2b,2c]	✗	Permitted in Type I or II building[2b,2c]
Wet Fire Sprinkler System	✗	Discharge density[2a,2c]: 0.4 gpm/ft	✗	Discharge density[2a,2c]: 0.4 gpm/ft	✗	Discharge density[2a,2c]: 0.4 gpm/ft	✗	Discharge density[2a,2c]: 0.4 gpm/ft	✗	Discharge density[2a,2c]: 0.4 gpm/ft
Incompatible and combustible materials separation from organic peroxides	• > 25 or, • 1-hour liquidtight fire barrier	• > 25 or, • 1-hour liquidtight fire barrier	✗	✗	✗	✗	✗	✗	✗	✗
Minimum Aisle Width (Stored in bags, drums,..)	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft
Minimum Access Aisle Width (Stored in bags, drums,..)	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft
Storage Basement	✓	✓	✗, Ground floor only	✗, Ground floor only	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height

	Type IIB									
MAQ	400 lb	800 lb	400 lb	80,000	55,000	175,000	160,000	Not Limited	600,000	Not limited
Egress	✗	✗	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[5]	•Travel distance limit = 150 ft •Common path of travel distance limit = 25 ft •Additional requirements[5]	✗	✗	✗	✗	✗	✗
Dry Fire Sprinkler System	✗	✗	✗	✗	✗	Permitted in Type I or II building[2b,2c]	✗	Permitted in Type I or II building[2b,2c]	✗	Permitted in Type I or II building[2b,2c]
Wet Fire Sprinkler System	✗	Discharge density[2a,2c]: 0.4 gpm/ft	✗	Discharge density[2a,2c]: 0.4 gpm/ft	✗	Discharge density[2a,2c]: 0.4 gpm/ft	✗	Discharge density[2a,2c]: 0.4 gpm/ft	✗	Discharge density[2a,2c]: 0.4 gpm/ft
Incompatible and combustible materials separation from organic peroxides	• > 25 or, • 1-hour liquidtight fire barrier	• > 25 or, • 1-hour liquidtight fire barrier	✗	✗	✗	✗	✗	✗	✗	✗
Minimum Aisle Width (Stored in bags, drums,..)	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft
Minimum Access Aisle Width (Stored in bags, drums,..)	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft
Storage Basement	✓	✓	✗, Ground floor only	✗, Ground floor only	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height

Table 4c. Maximum Allowable Quantities and Storage Requirements for Class III Organic Peroxide Formulations

	Control Area Storage		Protection Level Storage		Detached Storage 50 ft Distance to Property Line		Detached Storage 100 ft Distance to Property Line		Detached Storage 150 ft Distance to Property Line	
	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building
MAQ	840 lb	1,680 lb	840 lb (20,000 when using 4-hour fire-rated walls)	100,000	70,000	200,000	200,000	Not Limited	750,000	Not limited
Egress	✗	✗	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]	•Travel distance limit = 100 ft •Common path of travel distance limit = 25 ft •Additional requirements[1]
Dry Fire Sprinkler System	✗	✗	✗	✗	✗	Permitted in Type I or II building[2b,2c]	✗	Permitted in Type I or II building[2b,2c]	✗	Permitted in Type I or II building[2b,2c]
Wet Fire Sprinkler System	✗	Discharge density[2a,2c]: 0.3 gpm/ft^2	✗	Discharge density[2a,2c]: 0.3 gpm/ft^2	✗	Discharge density[2a,2c]: 0.3 gpm/ft^2	✗	Discharge density[2a,2c]: 0.3 gpm/ft^2	✗	Discharge density[2a,2c]: 0.3 gpm/ft^2
Incompatible and combustible materials separation from organic peroxides	• > 25 or, • 1-hour liquidtight fire barrier	• > 25 or, • 1-hour liquidtight fire barrier	✗	✗	✗	✗	✗	✗	✗	✗
Minimum Aisle Width (Stored in bags, drums,..)	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft	6 ft
Minimum Access Aisle Width (Stored in bags, drums,..)	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft
Storage Basement	✓	✓	✗, Ground floor only	✗, Ground floor only	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height

Table 4d. Maximum Allowable Quantities and Storage Requirements for Class IV andV Organic Peroxide Formulations										
	Control Area Storage		Protection Level Storage		Detached Storage 50 ft Distance to Property Line		Detached Storage 100 ft Distance to Property Line		Detached Storage 150 ft Distance to Property Line	
	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building	Nonsprinklered building	Sprinklered building
MAQ	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited	Not Limited
Dry Fire Sprinkler System	✗	✗	✗	✗	✗	Permitted in Type I-IV building[1b,1c]	✗	Permitted in Type I-IV building[1b,1c]	✗	Permitted in Type I-IV building[1b,1c]
Wet Fire Sprinkler System	✗	Discharge density[2a,2c]: 0.25 gpm/ft^2	✗	Discharge density[2a,2c]: 0.25 gpm/ft^2	✗	Discharge density[2a,2c]: 0.25 gpm/ft^2	✗	Discharge density[2a,2c]: 0.25 gpm/ft^2	✗	Discharge density[2a,2c]: 0.25 gpm/ft^2
Incompatible and combustible materials separation from organic peroxides	• > 25 or, • 1-hour liquidtight fire barrier	• > 25 or, • 1-hour liquidtight fire barrier	✗	✗	✗	✗	✗	✗	✗	✗
Minimum Aisle Width (Stored in bags, drums,..)	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft	4 ft
Minimum Access Aisle Width (Stored in bags, drums,..)	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft	3 ft
Storage Basement	✓	✓	✗, Ground floor only	✗, Ground floor only	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height	✗, Single-story height

The following footnotes apply to Tables 4a through 4d:

[1]Egress

- Capacity of means of egress
  - Stair: 0.7 in./person
  - Level components/ramps: 0.4 in./person
- Number of means of egress > 2 means of egress, unless all of the following conditions are met:
  - Room is ≤ 200 ft^2
  - Occupant load ≤ 3 persons
  - Travel distance to the room door ≤ 25 ft
- If the above conditions are met, dead ends in corridors are permitted.

[2a]The system shall provide the required density over the hydraulically most remote 3000 ft^2 area for areas protected by a wet pipe sprinkler system or single-interlock preaction sprinkler system.

[2b]Buildings using a dry pipe sprinkler system shall be provided with a required density over the hydraulically most remote 3900 ft^2 design area and, if used, the clearance between the sprinkler deflector and the top of any stored organic peroxide formulation shall not exceed 6 ft.

[2c]The entire area of any building of less than 3000 ft^2 shall be used as the area of application.

Appendix F. Literature Review of NFPA-Classified Oxidizers

See the attached document: NFPA-classified Oxidizer Literature Review Report.docx

The text is provided below in case the link does not work

Purpose: The purpose of this report is to compile any literature that documents completed research involving oxidizers with defined NFPA classifications, along with all search parameters used to identify information sources.

Search Methodology:

Databases Searched: The following academic databases were accessed through Purdue University Libraries and utilized:

- Google Scholar
- CHEMLIBnetBASE
- Knovel
- Reaxys
- SciFinder-n
- Web of Science

Search Terms: The search was conducted using combinations of the following terms:

“NFPA 400 Oxidizer Class”

“Oxidizer Name” + “NFPA 400”

“Organic Peroxide Name” + “NFPA 400”

“NFPA" + “400” + “Classification”

“NFPA” + “Oxidizer CAS Number”

“NFPA” + “Organic Peroxide CAS Number”

Search Criteria: All scholarly articles, journals, textbooks, engineering handbooks, material safety data sheets, material property data, chemical reaction data, reviews, and research papers published in English pertaining to NFPA-classified oxidizer research, usage, or other involvement were included. Non-peer-reviewed sources were excluded from results. Filters were used to display newer publications over older ones as well as to prioritize official standards and technical documents.

Search Process: The search began using search terms in combination with the Oxidant Table_010925 docx and Oxidizers pdf documents supplied by McKenzie Temme, with each individual reagent searched, starting with oxidizers currently in use at Evonik Tippecanoe Laboratories, to maximize relevancy to current Evonik processes. Individual oxidizers and organic peroxides were prioritized based on what was already used onsite at Evonik Tippecanoe Laboratories as well as which compounds were considered high probability for future use in customer projects, including trichloroisocyanuric acid (TCCA), 35% hydrogen peroxide, Urea hydrogen peroxide, potassium permanganate, 35% peracetic acid, meta-chloroperoxybenzoic acid, and potassium periodate. Oxidizers and organic peroxides marked as low probability for use at Evonik Tippecanoe Laboratories or commonly used in pharmaceutical API manufacturing but not featured on the Oxidant Table list were lower priorities but still searched following the above search terms.

Informal Consulted Resources: Several internal contacts within Purdue University were consulted for feedback on the literature search. First, David Zwicky, Associate Professor and Chemical Information Specialist at Purdue Libraries, was consulted for an overview of Purdue University Libraries' available databases as well as an in-depth, targeted search through several of the relevant chemical engineering databases. Dr. G.V. Reklaitis and Dr. Zoltan Nagy were consulted for any recommendations pertaining to pharmaceutical engineering databases as their work may potentially interface with relevant data sources for the search. Finally, Dr. Ray Mentzer was consulted for feedback, and he shared the request with additional process safety industry contacts to help identify relevant search databases or potential sources of information.

Summary of Findings: The comprehensive search did not yield many documents on oxidizers or organic peroxides with established NFPA classifications that were directly applicable to pharmaceutical API manufacturing. Most documents involving oxidizers and organic peroxides with NFPA classifications of compounds relied only on the NFPA hazard classifications (health, flammability, instability, and special information)[14], instead of oxidizer and organic peroxide-specific classifications, further obscuring potential results. A few articles did provide the correct NFPA oxidizer and organic peroxides classifications but did not reference relevant data to verify these results and were also not applicable compounds for pharmaceutical API manufacturing. All consulted parties either did not use NFPA and instead opted for different sets of safety standards or did not have research conducive to utilizing industrial safety standards for oxidizers and organic peroxides.

Discussion and Next Steps: The NFPA 400 Appendix provides general guidance and class information on commonly used oxidizers and organic peroxides that should be consulted as a starting point to determine the storage class of compounds in Tables F.1, F2.3, F3.3, F4.3, F5.3, F6.3, F7.3, G2.2, G2.3, G2.4, and G2.5[2]. The information in these tables may be useful in most general cases; however, it is not all-encompassing and would most likely be insufficient for

specialized customer requests. The inability to find relevant information on this topic could in part be due to limitations of the databases, ineffective search terms, or applicable information being proprietary. Future search efforts could include looking towards other safety standard codes and determining an appropriate conversion between the two standard codes if possible or contacting chemical suppliers or collaborator ESHS departments and inquiring as to whether either group may have access to this information.

Appendix G. Summary on Recent Industrial Incidents Involving Oxidizers

Recent industrial incidents surrounding improper oxidizer storage more than suggest the importance of fully developed tools for understanding safe hazardous material storage. One example of this is the 2024 Bio-Lab, Inc. fire in Conyers, Georgia in which an onsite-manufactured chemical, trichloroisocyanuric acid (TCCA), reacted with water. The reaction produced an explosive biproduct, nitrogen trichloride, which then sparked a large warehouse fire and chemical explosions over the course of several hours.[15] Approximately 17,000 residents were evacuated from the surrounding area, with an additional 90,000 households issued shelter-in-place guidance.[16] Fully deconstructing the damaged warehouse and destroying the rest of the TCCA took weeks after the incident, with full remediation taking seven additional months. Bio-Lab, Inc. has made the decision to cease manufacturing at the Conyers plant location and is presently facing extensive legal action. Currently there is an open class action lawsuit working through the federal court system against Bio-Lab, Inc., specifically citing the company's violation of the Clean Air Act and the damage done to the local community and environment.[17]

Similarly, in 2017 the Arkema plant in Crosby, Texas experienced fires and explosions due to extensive flooding from Hurricane Harvey that decomposed organic peroxides stored in a refrigerated trailer onsite. Arkema had a hurricane preparedness plan completed in advance of Hurricane Harvey, but the levels of flooding the plant received were unprecedented, and preparations for refrigerated storage were inadequate. Several refrigerated trailers burned due to loss of refrigeration, bringing the storage temperature high enough to be in the Self-Accelerating Decomposition Temperature. The organic peroxide in the remaining refrigerated trailers was destroyed with a controlled burn to safely end the incident. While significantly smaller in scale than the Bio-Lab, Inc. fire, the Arkema incident still displaced a few hundred residents within a

1.5-mile radius of the plant.[18] This incident is especially surprising, as Arkema had adequate safeguards in place to ensure refrigeration and safe storage even through "100-year floods," however the flooding and rainwater proved to be more excessive than the regulations and guidance had anticipated. Despite this, legal action was still taken against Arkema, and a $1.1 million dollar settlement was reached in 2024.[19]

Small mistakes can lead to millions of dollars paid out in fines, extended legal action, community resentment, damaged brand reputation, and environmental harm. In the worst cases, these events can injure and displace thousands of community members. These incidents, along with countless others with similar outcomes, are unfortunately common in the United States, and reinforce the importance of developing practical resources for safe storage of chemical hazards that ensure all regulations are properly addressed for each onsite project.

Appendix H. Summary of NFPA Terminology

See the attached document: NFPA Definition.docx

The text is provided below in case the link does not work

Purpose: This document provides precise definitions for all terminology used in the storage decision tools for oxidizers and organic peroxides, based on NFPA standards.

1. List of Terms

Accessible Means of Egress - [101:3.3.185.1]

Authority Having Jurisdiction (AHJ) - [400:3.2.2]

Automatic Sprinkler - [13:3.3.223.1]

Commodity - [13:3.3.40]

Conductor - [780:3.3.92.1]

Bonding Conductor - [780:3.3.9.1]

Counterpoise Conductor - [780:3.3.9.2]

Down Conductor - [780:3.3.9.3]

Ground Loop Conductor- [780:3.3.9.4]

Loop Conductor - [780:3.3.9.5]

Main Conductor - [780:3.3.9.6]

Roof Conductor - [780:3.3.9.7]

Container - [400:3.2.24]

Secondary Containment Tank - [400:3.3.24.1.2]

Combustible Containers - [400:3.3.24.4]

Noncombustible Containers- [400:3.3.24.10]

Containment - [30:3.3.13]

Primary Containment - [13:3.3.13.1]

Secondary Containment - [13:3.3.13.2]

Control Area - [400:3.3.5.1]

Construction Types - [220:4]

- Type I - [220:4.3.1]
- Type II - [220:4.3.1]
- Type III - [220:4.4.1]
- Type IV - [220:4.5.1]
- Type V - [220:4.6]

Deflagration - [68:3.3.4]

Detonation - [68:3.3.6]

Detached Building - [400:3.3.86.1]

Detached Storage (Oxidizers) - [400:3.3.86.2.2]

Emergency Power Supply (EPS) - [110:3.3.3]

Emergency Power Supply System (EPSS) - [110:3.3.4]

Flammable Liquid - [400:3.3.49]

Flammable Solid - [400:3.3.50]

Fire Protection System - [400:3.3.48]

Grounding Electrode - [780:3.3.20]

Hydraulically Designed System - [13.3.3.115]

Integral Lightning Protection System - [780:3.3.24]

Lightning Protection System - [780:3.3.27*]

Liquidtight - [96.3.3.35]

Material - [400:3.3.67]

Combustible Material - [400:3.3.67.1]

Incompatible Material - [400:3.3.67.5]

Noncombustible Material - [400:3.3.67.7]

Maximum Allowable Quantity Per Control Area (MAQ) - [400:3.3.68]

Occupancy - [400:3.3.74]

Assembly Occupancy - [400:3.3.74.1]

Business Occupancy - [400:3.3.74.2]

Day-Care Occupancy - [400:3.3.74.3]

Detention and Correctional Occupancy - [400:3.3.74.4]

Educational Occupancy - [400:3.3.74.5]

Health Care Occupancy - [400:3.3.74.6]

Ambulatory Health Care Occupancy - [400:3.3.74.6.1]

Industrial Occupancy - [400:3.3.74.7]

Mercantile Occupancy - [400:3.3.74.8]

Multiple Occupancy - [400:3.3.74.9]

Residential Board and Care Occupancy - [400:3.3.74.10]

Residential Occupancy - [400:3.3.74.11]

Storage Occupancy - [400:3.3.74.12]

Ordinary Hazard Occupancies - [13:4.3.3]

Ordinary Hazard Group 1 - [13:4.3.3.1]

Ordinary Hazard Group 2 - [13:4.3.3.2]

Organic Peroxide Formulation - [400:3.3.76]

Class I Organic Peroxide - [400:3.3.76.1]

Class II Organic Peroxide - [400:3.3.76.1]

Class IIA Organic Peroxide - [400:3.3.76.1]

Class IIB Organic Peroxide - [400:3.3.76.1]

Class III Organic Peroxide - [400:3.3.76.1]

Class I Organic Peroxide - [400:3.3.76.1]

Class I Organic Peroxide - [400:3.3.76.1]

Oxidizer - [400:3.3.78]

Class 1 - [400:3.3.78.1]

Class 2 - [400:3.3.78.2]

Class 3 - [400:3.3.78.3]

Class 4 - [400:3.3.78.4]

Sprinkler System - [13:3.3.224]

Combined Dry Pipe Preaction Sprinkler System - [13:3.3.224.2]

Deluge Sprinkler System - [13.3.3.224.3]

Dry Pipe Sprinkler System - [13:3.3.224.4]

Preaction Sprinkler System - [13:3.3.224.9]

Wet Pipe Sprinkler System - [13:3.3.224.12]

Protection Level - [400:3.3.80]

Portable Fire Extinguisher - [780:3.4.3]

Storage Height - [400:3.3.87]

Surge Protector - [780:3.3.46*]

Surge-Protective Device (SPD) - [780:3.3.47]

2. Full Definitions

Accessible Means of Egress – A means of egress that provides an accessible route to an area of refuge, a horizontal exit, or a public way. (SAF-MEA)

Authority Having Jurisdiction (AHJ) – An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Automatic Sprinkler – A fire suppression or control device that operates automatically when its heat-activated element is heated to its thermal rating or above, allowing water to discharge over a specified area. (AUT-SSI)

Commodity – The combination of products, packing material, and container that determines commodity classification.

Conductor.

> **Bonding Conductor** – A conductor used for potential equalization between grounded metal bodies or electrically conductive objects and a lightning protection system.
>
> **Counterpoise Conductor** – A bare underground electrical conductor providing an area of protection from the effects of lightning for underground raceway(s) or cable(s).
>
> **Down Conductor** – A main conductor used to connect roof conductors to grounding electrodes.
>
> **Ground Loop Conductor** – A main-size loop conductor installed within 12 ft (3.6 m) vertically of the base of the structure to provide a common ground potential.
>
> **Loop Conductor** – A main-sized conductor encircling a structure that is used to interconnect grounding electrodes, main conductors, or other electrically conductive bodies.
>
> **Main Conductor** – A conductor intended to be used to carry lightning currents between strike termination devices and grounding electrodes.
>
> **Roof Conductor** – A main conductor used to interconnect strike termination devices.

Container – A containment device including, but not limited to, cylinders, tanks, intermediate bulk containers, pressure vessels, drums, carboys, cans, bottles, boxes,

bags, bins, and portable tanks that vary in shape, size, and material of construction and are used for holding, storing, and transporting hazardous materials covered by this code.

Secondary Containment Tank [Ignitable (Flammable or Combustible) Liquid] – A tank that has an inner and outer wall with an interstitial space (annulus) between the walls and that has a means for monitoring the interstitial space for a leak.

Combustible Containers – Containers that include paper bags, fiber drums, plastic containers, and wooden or fiber boxes or barrels, as well as noncombustible containers having removable combustible liners or packing, and noncombustible containers having combustible overpacks.

Noncombustible Containers – Containers constructed of glass or metal that can be coated with a polymeric material no more than 1⁄32 in. (2 mils) in thickness.

Containment – A means of preventing the spread of a liquid.

Primary Containment – The first level of containment, consisting of the inside portion of the container that comes into immediate contact on its inner surface with the material being contained.

Secondary Containment – The level of containment that is external to and separate from primary containment.

Control Area – A building or portion of a building or outdoor area within which hazardous materials are allowed to be stored, dispensed, used, or handled in quantities not exceeding the MAQ.

Construction Types

Type I – Noncombustible (or limited-combustible) construction with a high level of fire resistance, typically concrete construction.

Type II – Noncombustible (or limited-combustible) construction with a lower level of fire resistance than Type I, typically this is steel construction with or without fireproofing.

Type III – Exterior walls and structural elements are noncombustible or limited-combustible materials, and interior structural elements, walls, arches, floors, and roofs are wood that is smaller than what is required for Type IV construction. This is usually called ordinary construction and an example of this is a mixed masonry/wood building.

Type IV– Fire walls, exterior walls, and interior bearing walls are approved noncombustible or limited-combustible materials. Other interior structural elements, arches, floors, and roofs are solid or laminated wood or cross-laminated timber. There are certain dimensional requirements:

- Columns – 8in (205mm) x 8in (205mm) if supporting floor, 6in (150mm) x 8in (205mm) if supporting roof
- Beams – 6in (150mm) x 10in (255mm) if supporting floor, 4in x 6in (150mm) if supporting roof
- Arches – Varies 8in (205mm) x 8in (205mm) to 4in (100mm) x 6in (150mm)
- Floors – 3in (75mm) or 4in (100mm) thick

Type V– Structural elements, walls, arches, floors, and roofs are wood or other approved material. Most residential construction is Type V.

Deflagration – Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.
Detonation – Propagation of a combustion zone at a velocity greater than the speed of sound in the unreacted medium.

Detached Building – A separate single-story building, without a basement or crawl space, used for the storage or use of hazardous materials and located an approved distance from all other structures.

Detached Storage (Oxidizers) – Storage in either an open outside area or in a separate building containing no incompatible materials and located away from all other structures.

Emergency Power Supply (EPS) – The source of electric power of the required capacity and quality for an emergency power supply system (EPSS).

Emergency Power Supply System (EPSS) – A complete functioning EPS system coupled to a system of conductors, disconnecting means and overcurrent protective devices, transfer switches, and all control, supervisory, and support devices up to and including the load terminals of the transfer equipment needed for the system to operate as a safe and reliable source of electric power.

Flammable Liquid – An ignitible liquid that is classified as a Class I liquid. *(See **4.9.1**.)* [**30,** 2024] Class I liquids shall be further subclassified in accordance with the following:

1) *Class IA Liquid*. A liquid that has a flash point below 73°F (22.8°C) and a boiling point below 100°F (37.8°C).
2) *Class IB Liquid*. A liquid that has a flash point below 73°F (22.8°C) and a boiling point at or above 100°F (37.8°C).
3) *Class IC Liquid*. A liquid that has a flash point at or above 73°F (22.8°C), but below 100°F (37.8°C).

Flammable Solid – A solid substance, other than a substance defined as a blasting agent or explosive, that is liable to cause fire resulting from friction or retained heat from manufacture, that has an ignition temperature below 212°F (100°C), or that burns so vigorously or persistently when ignited that it creates a serious hazard.

Fire Protection System – Any fire alarm device or system or fire-extinguishing device or system, or combination thereof, that is designed and installed for detecting, controlling, or extinguishing a fire or otherwise alerting occupants, or the fire department, or both, that a fire has occurred.

Grounding Electrode – A component of a lightning protection system installed for the purpose of transferring the current on the lightning conductors into the earth.

Integral Lightning Protection System – A lightning protection system directly attached to the structure.

Lightning Protection System – A complete system of strike termination devices, conductors (which could include conductive structural members), grounding electrodes, interconnecting conductors, surge protection, and other connectors and fittings required to complete the system.

Liquidtight – Constructed and performing in a way that prevents the passage of any liquid at any temperature.

Material

Combustible Material – A material that, in the form in which it is used and under the conditions anticipated, will ignite and burn; a material that does not meet the definition of noncombustible or limited-combustible.

Incompatible Material – Materials that, when in contact with each other, have the potential to react in a manner that generates heat, fumes, gases, or by-products that are hazardous to life or property.

Noncombustible Material – A material that complies with any one of the following shall be considered a noncombustible material:

1) The material, in the form in which it is used, and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.
2) The material is reported as passing ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*.
3) The material is reported as complying with the pass/fail criteria of ASTM E136 when tested in accordance with the test method and procedure in ASTM E2652, *Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace with a Cone-Shaped Airflow Stabilizer, at 750°C*.

Maximum Allowable Quantity Per Control Area (MAQ) – A threshold quantity of hazardous material in a specific hazard class that once exceeded, requires the application of additional administrative procedures, construction features, or engineering controls.

Occupancy – The purpose for which a building or other structure, or part thereof, is used or intended to be used.

Assembly Occupancy – An occupancy (1) used for a gathering of 50 or more persons for deliberation, worship, entertainment, eating, drinking, amusement, awaiting transportation, or similar uses; or (2) used as a special amusement building, regardless of occupant load.

Business Occupancy – An occupancy used for the transaction of business other than mercantile.

Day-Care Occupancy – An occupancy in which four or more clients receive care, maintenance, and supervision, by other than their relatives or legal guardians, for less than 24 hours per day.

Detention and Correctional Occupancy – An occupancy, other than one whose primary intended use is health care, ambulatory health care, or residential board and care, used to lawfully incarcerate or lawfully detain one or more persons under varied degrees of restraint or security where such occupants are mostly incapable of self-preservation because of security measures not under the occupants' control.

Educational Occupancy.

An occupancy used for educational purposes through the twelfth grade by six or more persons for 4 or more hours per day or more than 12 hours per week.

Health Care Occupancy.

An occupancy used to provide medical or other treatment or care simultaneously to four or more patients, on an inpatient basis, where such patients are mostly incapable of self-preservation due to age, physical or mental disability, or because of security measures not under the occupants' control.

Ambulatory Health Care Occupancy – An occupancy used to provide services or treatment simultaneously to four or more patients that provides, on an outpatient basis, one or more of the following: (1) treatment for patients that renders the patients incapable of taking action for self-preservation under emergency conditions without the assistance of others; (2) anesthesia that renders the patients incapable of taking action for self-preservation under emergency conditions without the assistance of others; (3) treatment for patients who, due to the nature of their injury or illness, are incapable of taking action for self-preservation under emergency conditions without the assistance of others.

Industrial Occupancy – An occupancy in which products are manufactured or in which processing, assembling, mixing, packaging, finishing, decorating, or repair operations are conducted.

Mercantile Occupancy – An occupancy used for the display and sale of merchandise.

Multiple Occupancy – A building or structure in which two or more classes of occupancy exist.

Residential Board and Care Occupancy – An occupancy used for lodging and boarding of four or more residents, not related by blood or marriage to the owners or operators, for the purpose of providing personal care services.

Residential Occupancy – An occupancy that provides sleeping accommodations for purposes other than health care or detention and correctional.

Storage Occupancy – An occupancy used primarily for the storage or sheltering of goods, merchandise, products, or vehicles.

Ordinary Hazard Occupancies

Ordinary Hazard (Group 1) – The following shall be protected with OH1 occupancy criteria in this standard:

1) Spaces with moderate quantity and low combustibility of contents
2) Stockpiles of contents with low combustibility that do not exceed 8 ft (2.4 m)

Ordinary Hazard (Group 2) – The following shall be protected with OH2 occupancy criteria in this standard:

1) Spaces with moderate to high quantity and combustibility of contents
2) Stockpiles of contents with moderate rates of heat release rate that do not exceed 12 ft (3.7 m) and stockpiles of contents with high rates of heat release that do not exceed 8 ft (2.4 m)

Organic Peroxide Formulation – A pure or technically pure organic peroxide or a mixture of organic peroxides with an active oxygen (aO) concentration greater than 1 percent alone or in combination with one or more materials. The transport type for organic peroxide formulations is determined by the UN *Manual of Tests and Criteria, Part II*. Terms such as *accelerator*, *catalyst*, *initiator*, and *curing agent* are sometimes used to describe organic peroxide formulations and are misleading because they can also refer to materials that are not or do not contain organic peroxides, some of which might present increased hazard when mixed with organic peroxides.

Class I Organic Peroxide – Describes organic peroxide formulations that are more severe than a Class II but do not detonate and that are characterized as "explosive in package" or by a very fast burning rate. Includes those characterized for transport as Type B, those characterized for transport as Type C and Type D with a large-scale burning rate equal to or greater than 300 kg/min, and those characterized for transport as Type C and Type D with a small-scale burning rate equal to or greater than 9.0 kg/min × m^2 unless the large-scale burning rate is less than 300 kg/min.

Class II Organic Peroxide

Class IIA Organic Peroxide – Describes organic peroxide formulations that burn very rapidly and that present a severe reactivity hazard, and those characterized for transport as Type C and Type D with a large-scale burning rate equal to or greater than 140 kg/min but less than 300 kg/min and those characteZrized for transport as Type E with a large-scale burning rate equal to or greater than 140 kg/min. Includes those characterized as Type C and Type D if the small-scale burning rate is equal to or greater than 2.2 kg/min × m^2, but less than 9.0 kg/min × m^2 and Type E if the small-scale burning rate is equal to or greater than 2.2 kg/min × m^2.

Class IIB Organic Peroxide – Describes organic peroxide formulations that burn very rapidly and that present a severe reactivity hazard, and those characterized for transport as Type C with a large-scale burning rate of less than 140 kg/min. Includes those characterized for transport as Type D and Type E with a large-scale burning rate equal to or greater than 60 kg/min but less than 140 kg/min, those characterized

as Type C if the small-scale burning rate is less than 2.2 kg/min × m^2, and those characterized as Type D and Type E if the small-scale burning rate is equal to or greater than 0.9 kg/min × m^2 but less than 2.2 kg/min × m^2.

Class III Organic Peroxide – Describes organic peroxide formulations that burn rapidly and present a moderate reactivity hazard. Includes those characterized for transport as Type D with a large-scale burning rate less than 60 kg/min, those characterized for transport as Type E with a large-scale burning rate equal to or greater than 10 kg/min but less than 60 kg/min, those characterized for transport as Type F with a large-scale burning rate equal to or greater than 10 kg/min, and those characterized as Type D and Type E if the small-scale burning rate is less than 0.9 kg/min × m^2 and Type F irrespective of the small scale burning rate.

Class IV Organic Peroxide – 3.3.76.4. Describes organic peroxide formulations that burn in the same manner as ordinary combustibles and present a minimal reactivity hazard. Includes those characterized for transport as Type E or Type F with a large-scale burning rate less than 10 kg/min.

Class V Organic Peroxide – 3.3.76.5. Describes organic peroxide formulations that burn with less intensity than ordinary combustibles or those that do not sustain combustion and present no reactivity hazard, and those characterized for transport as Type G without additional subsidiary risks

Oxidizer – Any solid or liquid material that readily yields oxygen or other oxidizing gas or that readily reacts to promote or initiate combustion of the combustible materials and that can, under some circumstances, undergo a vigorous self-sustained decomposition due to contamination or heat exposure.

Class 1 – An oxidizer that does not moderately increase the burning rate of combustible materials with which it comes into contact or a solid oxidizer classified as Class 1 when tested in accordance with the test protocol set forth in Section G.1.

Class 2 – An oxidizer that causes a moderate increase in the burning rate of combustible materials with which it comes into contact or a solid oxidizer classified as Class 2 when tested in accordance with the test protocol set forth in Section G.1.

Class 3 – An oxidizer that causes a severe increase in the burning rate of combustible materials with which it comes into contact or a solid oxidizer classified as Class 3 when tested in accordance with the test protocol set forth in Section G.1.

Class 4 – An oxidizer that can undergo an explosive reaction due to contamination or exposure to thermal or physical shock and that causes a severe increase in the burning rate of combustible materials with which it comes into contact.

Sprinkler System – A system that is commonly activated by heat from a fire and discharges water over the fire area, that consists of an integrated network of piping designed in accordance with fire protection engineering standards, and that includes a water supply source, a control valve, a waterflow alarm (where required), and a drain. The portion of the sprinkler system above ground is a network of specifically sized or hydraulically designed piping installed in a building, structure, or area, generally overhead, and to which sprinklers are attached in a systematic pattern. (AUT-SSI)

Combined Dry Pipe Preaction Sprinkler System – A sprinkler system employing automatic sprinklers attached to a piping system containing air under pressure with a supplemental detection system installed in the same areas as the sprinklers. Operation of the detection system actuates tripping devices that open dry pipe valves simultaneously and without loss of air pressure in the system. The detection system also serves as an automatic fire alarm system. (AUT-SSI)

Deluge Sprinkler System – A sprinkler system employing open sprinklers or nozzles that are attached to a piping system that is connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers or the nozzles. When this valve opens, water flows into the piping system and discharges from all sprinklers or nozzles attached thereto. (AUT-SSI)

Dry Pipe Sprinkler System – A sprinkler system employing automatic sprinklers that are attached to a piping system containing air, nitrogen, or other approved gas under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve, and the water then flows into the piping system and out the opened sprinklers. (AUT-SSI)

Preaction Sprinkler System – A sprinkler system employing automatic sprinklers that are attached to a piping system that contains air that might or might not be under pressure, with a supplemental detection system installed in the same areas as the sprinklers. (AUT-SSI)

Wet Pipe Sprinkler System – A sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by heat from a fire. (AUT-SSI)

Protection Level – A term used to describe a tier of building safety that exceeds the construction requirements for control areas to accommodate quantities of hazardous materials in excess of those permitted using the control area concept.

Portable Fire Extinguisher – A portable device, carried or on wheels and operated by hand, containing an extinguishing agent that can be expelled under pressure for the purpose of suppressing or extinguishing fire.

Storage Height – The height from the finished floor to the top of the highest container or a pile's peak.

Surge Protector – A protective device for limiting excessive potential and current on signal, data, and communication circuits caused by lightning, contact with power conductors, power induction, and rises in ground potential, while also preventing the continued flow of the follow current while remaining capable of repeating these functions.

Surge-Protective Device (SPD) – A protective device for limiting transient voltages by diverting or limiting surge current and preventing continued flow of follow current while remaining capable of repeating these functions.