

key variables and parameters. Thus, a sensitivity analysis should be conducted that provides the model user with data that indicates how the effects of a real fire could vary and how the response of the proposed fire safety design could also vary.

The interpretation of a model's predictions can be a difficult exercise if the model user does not have knowledge of fire dynamics or human behavior.

Reasonableness Check. The model user should first try to determine whether the predictions actually make sense; that is, they don't upset intuition or preconceived expectations. Most likely, if the results don't pass this test, an input error has been committed.

Sometimes the predictions appear to be reasonable but are, in fact, incorrect. For example, a model can predict higher temperatures farther from the fire than close to it. The values themselves could be reasonable; for example, they are not hotter than the fire, but they don't "flow" down the energy as expected.

A margin of safety can be developed using the results of the sensitivity analysis in conjunction with the performance criteria to provide the possible range of time during which a condition is estimated to occur.

Safety factors and margin of safety are two concepts used to quantify the amount of uncertainty in engineering analyses. Safety factors are used to provide a margin of safety and represent, or address, the gap in knowledge between the theoretically perfect model; that is, reality and the engineering models that can only partially represent reality.

Safety factors can be applied to either the predicted level of a physical condition or to the time at which the condition is predicted to occur. Thus, a physical or a temporal safety factor, or both, can be applied to any predicted condition. A predicted condition (that is, a parameter's value) and the time at which it occurs are best represented as distributions. Ideally, a computer fire model predicts the expected or nominal value of the distribution. Safety factors are intended to represent the spread of these distributions.

Given the uncertainty associated with data acquisition and reduction, and the limitations of computer modeling, any condition predicted by a computer model can be thought of as an expected or nominal value within a broader range. For example, an upper layer temperature of 1110°F (600°C) is predicted at a given time. If the modeled scenario is then tested (that is, full-scale experiment based on the computer model's input data), the actual temperature at that given time could be 1185°F (640°C) or 1085°F (585°C). Therefore, the temperature should be reported either as 1110°F, +75°F or -25°F (600°C, +40°C or -15°C) or as a range of 1085°F to 1184°F (585°C to 640°C).

Ideally, predictions are reported as a nominal value, a percentage, or an absolute value. As an example, an upper layer temperature prediction could be reported as 1112°F (600°C), 86°F (30°C), or 1112°F (600°C), 5 percent. In this case, the physical safety factor is 0.05 (i.e., the amount by which the nominal value should be degraded and enhanced). Given the state-of-the-art of computer fire modeling, this is a very low safety factor. Physical safety factors tend to be on the order of tens of percent. A safety factor of 50 percent is not unheard of.

Part of the problem in establishing safety factors is that it is difficult to state the percentage or range that is appropriate. These values can be obtained when the computer model predictions are compared to test data. However, using computer fire models in a design mode does not facilitate this since (1) the room being analyzed has not been built yet and (2) test scenarios do not necessarily depict the intended design.

A sensitivity analysis should be performed based on the assumptions that affect the condition of interest. A base case that uses all nominal values for input parameters should be developed. The input parameters should be varied over reasonable ranges, and the variation in predicted output should be noted. This output variation can then become the basis for physical safety factors.

The temporal safety factor addresses the issue of when a condition is predicted and is a function of the rate at which processes are expected to occur. If a condition is predicted to occur 2 minutes after the start of the fire, then this can be used as a nominal value. A process similar to that described for physical safety factors can also be employed to develop temporal safety factors. In this case, however, the rates (e.g., of heat release and toxic product generation) will be varied instead of absolute values (e.g., material properties).

The margin of safety can be thought of as a reflection of societal values and can be imposed by the AHJ for that purpose. Since the time for which a condition is predicted is most likely the focus of the AHJ (e.g., the model predicts occupants have 5 minutes to safely evacuate), the margin of safety is characterized by temporal aspects and tacitly applied to the physical margin of safety.

Escaping the harmful effects of fire (or mitigating them) is, effectively, a race against time. When assessing fire safety system designs based on computer model predictions, the choice of an acceptable time is important. When an AHJ is faced with the predicted time of untenability, a decision needs to be made regarding whether sufficient time is available to ensure the safety of facility occupants. The AHJ is assessing the margin of safety. Is there sufficient time to get everyone out safely? If the AHJ feels that the predicted egress time is too close to the time of untenability, then the AHJ can impose an additional time that the designer has to incorporate into the system design. In other words, the AHJ can impose a greater margin of safety than that originally proposed by the designer.

A.10.7.1 The *SFPE Engineering Guide to Performance-Based Fire Protection* describes the documentation that should be provided for a performance-based design.

Proper documentation of a performance design is critical to the design acceptance and construction. Proper documentation also ensures that all parties involved understand what is necessary for the design implementation, maintenance, and continuity of the fire protection design. If attention to details is maintained in the documentation, then there should be little dispute during approval, construction, startup, and use.

Poor documentation could result in rejection of an otherwise good design, poor implementation of the design, inadequate system maintenance and reliability, and an incomplete record for future changes or for testing the design forensically.

A.10.7.2 The sources, methodologies, and data used in performance-based designs should be based on technical refer-

ences that are widely accepted and used by the appropriate professions and professional groups. This acceptance is often based on documents that are developed, reviewed, and validated under one of the following processes:

- (1) Standards developed under an open consensus process conducted by recognized professional societies, codes or standards organizations, or governmental bodies
- (2) Technical references that are subject to a peer review process and published in widely recognized peer-reviewed journals, conference reports, or other publications
- (3) Resource publications such as the *SFPE Handbook of Fire Protection Engineering*, which are widely recognized technical sources of information

The following factors are helpful in determining the acceptability of the individual method or source:

- (1) Extent of general acceptance in the relevant professional community. Indications of this acceptance include peer-reviewed publication, widespread citation in the technical literature, and adoption by or within a consensus document.
- (2) Extent of documentation of the method, including the analytical method itself, assumptions, scope, limitations, data sources, and data reduction methods.
- (3) Extent of validation and analysis of uncertainties. This includes comparison of the overall method with experimental data to estimate error rates as well as analysis of the uncertainties of input data, uncertainties and limitations in the analytical method, and uncertainties in the associated performance criteria.
- (4) Extent to which the method is based on sound scientific principles.
- (5) Extent to which the proposed application is within the stated scope and limitations of the supporting information, including the range of applicability for which there is documented validation. Factors such as spatial dimensions, occupant characteristics, and ambient conditions can limit valid applications.

In many cases, a method is built from and includes numerous component analyses. These component analyses should be evaluated using the same factors that are applied to the overall method as outlined in items (1) through (5).

A method to address a specific fire safety issue, within documented limitations or validation regimes, might not exist. In such a case, sources and calculation methods can be used outside of their limitations, provided that the design team recognizes the limitations and addresses the resulting implications.

The technical references and methodologies to be used in a performance-based design should be closely evaluated by the design team and the AHJ, and possibly by a third-party reviewer. The strength of the technical justification should be judged using criteria in items (1) through (5). This justification can be strengthened by the presence of data obtained from fire testing.

A.10.7.11 Documentation for modeling should conform to ASTM E1472, *Standard Guide for Documenting Computer Software for Fire Models*. The *SFPE Engineering Guide for Substantiating a Fire Model for a Given Application* provides guidance on selecting a fire model, ensuring a model is verified and validated, and documenting model inputs and outputs.

A.11.1.1 Determine the classification of ammonium nitrate in accordance with Chapter 4. Chapter 11 takes precedence to address the specific requirements for solid and liquid ammonium nitrate, when 1,000 lb is exceeded. The physical hazards of ammonium nitrate are dependent on the properties of the specific material or mixture of materials as a whole. Where used as a fertilizer, it is common for ammonium nitrate to exist as a component of a chemical mixture. It is not uncommon for the user to describe the mixture as ammonium nitrate when in reality the mixture can contain components that contribute to altering the end classification of the material. The manufacturer's safety data sheet (SDS) should be used to assess the overall hazards of these materials. The user is cautioned that the DOT shipping classification for transportation purposes alone is not a sufficient means by which to determine the storage and use hazards of these materials. Ammonium nitrate in the undiluted or pure form has a higher degree of overall hazard than does ammonium nitrate when mixed or blended with compatible materials that can reduce the concentration. The tables in Chapter 5 are hazard specific; they are not chemical specific. Ammonium nitrate as such is not included in the tables, because the actual hazard classification varies with the material under consideration. The question must be answered as to whether the material is an oxidizer, and, if so, what Class; whether it is an unstable reactive, and, if so, what Class; or whether there are other physical or health hazards attendant to the mixture under evaluation. (See Annex E for additional information.)

A.11.1.1.5 Ammonium nitrate and ammonium nitrate-based materials that are DOT Hazard Class 1 explosives should be stored in accordance with the requirements of NFPA 495. Sensitivity is determined by the application of the UN Test Series 1, which includes testing to determine impact sensitivity, friction sensitivity, sensitivity to electrostatic discharge, and thermal stability.

A.11.1.1.6 Agricultural application refers to the actual transporting and spreading of the fertilizers in fields. Storage in a building for eventual agricultural use is not an agricultural application.

A.11.1.4.9.1 This requirement is intended to prohibit floor drains, traps, tunnels, pits, or pockets into which any molten ammonium nitrate is able to flow and be confined in the event of fire.

A.11.1.4.9.2 The slope of the storage floor should be pitched in such a manner that it drains away from the ammonium nitrate pile and toward a containment area. As noted in other sections, no drainage pits, sumps, or confined piping should be designed into this drainage plan.

A.11.1.5 Where a documented risk analysis demonstrates to the AHJ that an equivalent level of fire safety can be achieved using alternatives to the requirements of this section, such an approach is an acceptable alternative. The risk analysis should be submitted to the AHJ in accordance with the requirements of 1.5.3. A risk analysis report should demonstrate equivalent fire safety by addressing relevant topics, including, but not limited to, the following:

- (1) Location of the facility
- (2) Distance to exposed structures and population density of public areas and other areas associated with the ammonium nitrate facility.
- (3) Construction type

- (4) Storage configuration
- (5) Exposing combustible materials
- (6) Emergency response capability
- (7) Water supply
- (8) Ammonium nitrate mixtures, blends, and uses
- (9) Fire protection features provided (fire barriers, fire detection and alarm, and so on)

A.11.2.1 Sumps and collection systems as required by 6.2.1.9.2 create confinement conditions and should be avoided with molten ammonium nitrate, which could be created in a fire.

A.11.2.3 Storage of ammonium nitrate prills at ambient temperature [up to 140°F (60°C)] does not create decomposition products to a level that would create hazards to personnel and is not sufficient to catalyze higher rates of decomposition and uncontrolled heating.

Ammonium nitrate storage facilities do not purposefully bring fresh air into buildings since ammonium nitrate is a hygroscopic material. Constant exposure to humid air leads to caking, product degradation, and breakdown. Some facilities, especially large manufacturing sites, use dehumidification to prevent moist air from contacting ammonium nitrate solids. Most retail facilities are substantially open to outside air (i.e., naturally ventilated and not mechanically refreshed with ambient air).

The following is stated in “Summary Report: Workshop on Ammonium Nitrate” from the European Commission’s Joint Research Center:

“Pure ammonium nitrate can undergo thermal decomposition if it receives enough energy. Gases are then emitted, especially nitrogen oxides and ammonia, both toxic. With proper ventilation, the decomposition stops as soon as the energy flow stops. The decomposition rate is not dangerously high at moderate temperatures, and the overall thermal effect is not significant since the exothermic reactions are accompanied by endothermic disassociation...”

Providing ventilation for severely contaminated product would not be practical because an appropriate hazardous gas production rate cannot be realistically predicted. Ventilation for fire conditions involving ordinary combustibles that are adequately controlled by automatic sprinklers has not been shown to have a significant effect on control of the fire.

The proper loss prevention approach is to prevent product contamination and either to eliminate combustible construction or occupancy (preferred) or to control burning combustibles by providing adequate automatic sprinkler protection.

A.11.2.5 It is not the intent to apply the requirements of 11.2.5, 11.2.7, or 11.2.8 to new or existing buildings of Type I and Type II construction storing only bulk ammonium nitrate.

A.11.2.5.1 Where existing or equivalent methods are intended to meet the retroactive criteria, suitable documentation should be submitted to the AHJ (*see 1.5.1 and 1.5.2*). The documentation should follow the guidelines outlined in the performance-based option (*see Chapter 10*) focused on the specific alternative.

A.11.2.5.3 Foam, dry-chemical, or gaseous extinguishing systems are ineffective in controlling fires involving ammonium nitrate, which is an oxidizer that supplies its own oxygen. Steam is similarly ineffective and should not be used due to the addition of heat to the decomposing mass. Water cools the ammo-

num nitrate and reduces molten ammonium nitrate formation and decomposition.

A.11.2.7.2 When first responders arrive at the facility after the emergency communications center has alerted them of activation of the alarm, detection, or automatic fire extinguishing system, they will need to size-up the situation and determine if the public notification/siren system needs to be activated.

A.11.2.11 Explosion control methods required by 6.2.1.6 are not warranted for ammonium nitrate regulated by this chapter. Deflagration control methods described in NFPA 69 (primarily deflagration venting) are not effective for the detonations that can sometimes result from ammonium nitrate that is involved in a fire situation. In Chapter 11, the emphasis is on explosion prevention, but using methods that will be effective on ammonium nitrate and not those required by NFPA 69 — namely combustible concentration reduction, oxidant concentration reduction, and deflagration control. The other requirements of Chapter 11 are intended to prevent ammonium nitrate explosions and are more effective than the requirements of 6.2.1.6 for this material. Ammonium nitrate that is formulated to be an explosive is regulated in accordance with NFPA 495 and not this chapter.

A.11.2.16.1.1 Provisions should be made to avoid the following conditions with ammonium nitrate:

- (1) Heating in a confined space
- (2) Localized heating potentially leading to development of high-temperature areas
- (3) Exposure to strong shock waves
- (4) Contamination with combustible materials or incompatible inorganic and organic substances that can result in sensitivity to explosion.
- (5) Low pH or acidic conditions

A.11.2.17 A pre-incident best practices plan should be developed by the local fire department in conjunction with any facility that stores, uses, or handles ammonium nitrate. NFPA 1620 can be used for further guidance.

A.11.2.17.1.3 A 1-mile (1.6 km) public evacuation distance has been recommended in the rare event of a facility containing ammonium nitrate becoming involved in a fire. This evacuation distance is recommended because the exact conditions of a facility during the emergency might not be known to the emergency response personnel. Under these potentially unknown conditions a worst-case scenario is assumed to ensure the public is evacuated to a safe distance. These unknown conditions can include the following:

- (1) The condition of the ammonium nitrate involved in the fire. For example, contamination from a material that can behave as a fuel could potentially lead to a more violent release of energy than uncontaminated ammonium nitrate.
- (2) Presence of a burning structure.
- (3) The quantity of ammonium nitrate involved in the fire.

Overpressure calculations alone are not adequate to determine evacuation distances and debris field modeling is necessary to help ensure public safety. The 1-mile (1.6 km) distance is based on a quantitative risk analysis of a scenario that involves ammonium nitrate mixed with a fuel source and the presence of a burning structure. Quantities up to one million pounds (453,592 kg) of ammonium nitrate were used in the determination based on projectile travel distance.

A.11.2.18 NFPA 704 currently lists ammonium nitrate under emergency conditions as Health = 0, Flammability = 0, Instability = 3, and Other = OX (oxidizer). Safety data sheets that provide NFPA 704 ratings typically agree with all ratings except Health where ratings of 0, 1, or 2 are reported by different manufacturers. Because decomposition products include various nitrogen oxides (NOx) and nitric acid, the minimum health rating should be considered 1.

A.11.3.1.2 Housekeeping information can be found in *Safety and Security Guidelines for the Storage and Transportation of Fertilizer Grade Ammonium Nitrate at Fertilizer Retail Facilities*, and EPA 550-F-15-001, *Chemical Advisory: Safe Storage, Handling, and Management of Solid Ammonium Nitrate Prills*.

A.11.3.2.3.1 Wood impregnated with ammonium nitrate is a fire hazard. It can be ignited by a low-energy source with a vigorous fire.

A.11.3.2.3.4 Metal bins can be protected by special coatings such as sodium silicate, epoxy coatings, or polyvinyl chloride (PVC) coatings.

A.11.3.2.3.5 Storage in aluminum transport vehicles is not recommended.

A.11.3.2.3.9 Bulk and bagged ammonium nitrate can become caked and degrade in storage. This is a factor affected by humidity and temperature in the storage space and by prill quality. Temperature cycles through 90°F (32°C) and high atmospheric humidity are undesirable for storage in depth.

A.11.4.3.3 Active loading or unloading of vehicles with ammonium nitrate from the hoppers/bins is not considered parking and is permitted. The vehicle operator should remain within 25 ft (7.6 m) of the vehicle during loading or unloading operations. Immediately upon completion of the loading/unloading activity, the vehicle should be moved at least 30 ft (9.1 m) away from the hopper/bins.

A.11.4.5 Many of the general principles for the storage of ammonium nitrate-based fertilizers apply equally to fertilizers stored in the open and those stored in a building. It is generally recommended that bagged ammonium nitrate fertilizers should not be stored in large piles outdoors.

It should be noted that repeated temperature cycles can cause physical deterioration of some products. Physical deteriora-

tion can result in the breakdown of the fertilizer particles and damage to packages. The product should be protected from direct sunlight. Due note should be taken of ground conditions when storing outdoors to avoid damage to the product. Outdoor storage areas should be protected against unauthorized access, for example, by means of a fence. Warnings against unauthorized entry should be posted.

A.11.5.5.1 Foam, dry-chemical, or gaseous extinguishing systems are ineffective in controlling fires involving ammonium nitrate, an oxidizer that supplies its own oxygen. Steam is similarly ineffective.

A.11.8.1.1.1 This includes battery-powered vehicles and vehicles powered by internal combustion engines such as motor vehicles, lift trucks, and cargo conveyors. It is recommended that electric or LP-Gas-powered trucks be employed rather than gasoline- or diesel to reduce the potential for contamination to ammonium nitrate. (See A.11.4.3.3.)

A.11.8.1.2 Examples of hollow spaces include hollow conveyor rollers and hollow screw conveyor shafts.

Δ A.14.1.1 The classification system for organic peroxides is transport classification and burn rate dependent as shown in Table A.14.1.1. To address the scope of NFPA 400 for storage, use, and handling, each organic peroxide formulation is to be classified with respect to quantity and type of container based upon testing performed to reach a transport classification per the United Nations *Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria*, Flow Chart Scheme for Organic Peroxides (http://www.unece.org/fileadmin/DAM/trans/danger/ST_SG_AC.10_11_Rev6_E_WEB.pdf). Classification should be done by professionals familiar with the properties of the organic peroxide formulation. Burn rate testing is performed in accordance with the test methods noted in Annex F of the Dutch Code PGS 8, *Organic peroxides: Storage Guidelines for the labour-safe, environment-safe, and fire-safe storage of organic peroxides*.

Transport classification along with the small-scale and sometimes large-scale burn rate data from actual experiments are used to reach the storage classification. For further guidance, see Annex F.

N Table A.14.1.1 Storage Classification Basis for Organic Peroxide Formulations

Transport Type	Burning Rate					
	Large-Scale Test (kg/min)	<10	≥10 and <60	≥60 and <140	≥140 and <300	> or =300
	Small-Scale Test* (kg/m ² /min)	or N/A	or <0.9	or ≥0.9 and <2.2	or ≥2.2 and <9.0	or ≥9.0
B		I	I	I	I	I
C		IIB	IIB	IIB	IIA	I
D		III	III	IIB	IIA	I
E		IV	III	IIB	IIA	IIA
F		IV	III	III	III	III
G		V	V	V	V	V

*Solid materials are only tested in the large-scale test.

N A.14.1.1.2 References to sections include any subsections or subparagraphs. Control area users shall also comply with applicable material specific requirements in Chapter 14 in addition to Chapter 5 and other requirements. An organic peroxide safety incident can occur irrespective of the quantity. In addition, there are many organic peroxides that are temperature controlled. Chapter 14 provides guidelines for many important aspects (temperature control, detection and alarm systems, electrical classification, separation from incompatible materials, compatible materials of construction, fire suppression and extinguishing systems, spill control, handling spills and disposal, use guidelines, etc.) that are critical for the safe storage, handling, and use of the organic peroxides. Control area users would require following all applicable material-specific requirements in the chapter and some specific storage requirements outlined for control areas in the indoor storage section but not extensive construction requirements like incombustible walls that would be required of protection level storage.

A.14.1.2 For information on combustible, **noncombustible**, or limited-combustible construction, see NFPA 220.

• **N A.14.1.3** Organic peroxides should be prevented from coming into contact with incompatible building construction materials (i.e., actual portions of the building). Incompatible materials can result in decomposition of organic peroxides, which can cause explosion and/or fire. In general, incompatible construction materials are steel, copper, brass, bronze, iron, and so forth. All steel should be primed and painted.

N A.14.2.3.1 To prevent the spread of the fire and soil pollution, the leaking organic peroxide and extinguishing water should be directed to a containment system. Different organic peroxide storage facilities can be connected to the same containment system. There should not be any openings in the containment system that are or can be directly connected to a sewer or to the surface water. In case of incident, it is expected the fire is controlled quickly with limited burning of organic peroxide area. If the fire is uncontrollable, at some point of time it is expected that a decision will be made to allow the controlled burning of the organic peroxides and prevent the fire from spreading to other premises within the establishment. The containment system should be designed such that the depth of the layer of organic peroxide is not more than 1.6 ft (0.5 m). Confinement of organic peroxides in channels, pipes, and pits should be avoided as it can lead to violent decomposition that can result in explosion and fire.

N A.14.2.5 Organic peroxides, once ignited, can burn relatively fast. It can be very difficult to control an organic peroxide fire due to the nature of decomposition. The best chance to fight an organic peroxide fire is in its incipient stage. An organic peroxide fire can be extinguished or controlled with a lot of water provided by the sprinkler system and supplemented by the water hose streams. The fire can also be extinguished with powder, but reignition is likely due to the high temperature. Burning of organic peroxides is often accompanied by a lot of smoke development and decomposition is accompanied by the formation of a mist or fog that can be toxic and flammable.

Where approved, sprinkler systems can be provided with additional remote valves for system shutoff by emergency responders. Fires with organic peroxide formulations can offer unique concerns during a fire event if the product temperature becomes elevated either due to the heat release from burning or the application of warm firefighting water. At the same time, the runoff can exceed the capacity of the firewater collection

system (fire duration of more than 20 minutes), and the residual product can be unrecoverable due to instability caused by the high temperature. The best approach might be to let the fire burn to completion while protecting surrounding structures and equipment. Under this scenario, emergency responders might not be able to safely approach the fire site to close the automatic sprinkler system valve. Therefore, the design might benefit from the installation of a remote valve, such as a monitored post indicator valve, that can be used to stop the flow of sprinkler water.

A.14.2.5.1 Fire protection systems for material in containers other than original DOT packaging, including bulk tanks, and materials in the unpackaged state should be designed by design professionals familiar with the nature of the product under fire conditions.

A.14.2.5.4 Dry pipe and double-interlock preaction (DIPA) sprinkler systems are not permitted for protection of buildings or areas containing Class I through Class III organic peroxide formulations, except as noted in 14.2.5.4.1. These formulations generally have a fast burning rate and high-heat release rate, requiring a quick response and immediate discharge of water from the sprinklers. Dry pipe and DIPA sprinkler systems generally result in delayed discharge of water when sprinkler activation occurs.

N A.14.2.6 The decomposition of an organic peroxide releases heat, which increases its temperature and consequently its speed of decomposition. If the heat generated by the decomposing organic peroxide exceeds the capability to expel heat to the surroundings, the reaction rate is liable to run away with the risk of thermal explosion. The intensity of the thermal runaway varies depending on the organic peroxide, its concentration, and eventual confinement. It can be an explosion with flame and effect of blast or of a more or less rapid emission of gas without flame nor significant increase of pressure. Decomposition of an organic peroxide does not necessarily lead to spontaneous ignition or thermal explosion. If the packaging or container is impermeable and not very resistant to pressure, the thermal runaway will be relatively slow and with little blasting effect. For this reason, organic peroxides are packaged in limited weight in containers or cartons that are mechanically strong enough to hold the organic peroxide but weak enough to give away in case of a thermal runaway. To prevent excessive pressure rise inside storage area or building due to prolonged decomposition and bursting of packages, the storage area or building should be provided with a pressure relief mechanism. A weak wall, a vent, or a light roof in the organic peroxide storage area or building makes it possible to reduce the pressure developed by the organic peroxide decomposition due to decomposition or fire exposure and therefore its consequences. The emergency pressure relief vent can consist of a door opening to the outside (not to be locked) — that is, fitted with a magnetic or spring closure. A hatch or dome can also be used as an emergency pressure relief vent. If the packaging or container is pressure-resistant, the thermal explosion will be quick with greater blast effect. For this reason, IBCs, storage tanks, and dosing vessels should be equipped with a sized vent or relief device (spring-loaded or frangible types like rupture discs or valves) in accordance with organic peroxide manufacturer's recommendations to prevent overpressurization and explosive rupture due to decomposition or fire exposure.

Organic peroxide formulations are classified for transportation from most hazardous to least hazardous based on their explosive hazard. The structure and composition determine the degree of hazard of each organic peroxide formulation, which is assessed by following a series of tests per the United Nations *Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria*, Flow Chart Scheme for Organic Peroxides (http://www.unece.org/fileadmin/DAM/trans/danger/ST_SG_AC.10_11_Rev6_E_WEB.pdf) or 49 CFR 173.128(e) and subsequently assigned a transport type and a UN number according to Table A.14.2.6. The classifications range from Type A, which are considered too hazardous to transport, to Type G, which are safe enough to be not regulated as an organic peroxide. The explosive hazard decreases from Type A to Type G.

The storage classification system for organic peroxides is transport classification and burn rate dependent as shown in Table A.14.1.1. As such, storage areas of organic peroxide formulations with higher storage class ratings (with high explosion hazard rating and high burn rates) are recommended to have a certain emergency vent relief area to reduce the pressure developed by the organic peroxide decomposition due to decomposition or fire exposure and therefore its consequences. Specifically, buildings, or portions thereof, used for the storage of Class I, Class IIA, Class IIB, and Class III organic peroxides are recommended to have an emergency vent area in accordance with the organic peroxide manufacturer's recommendation. In addition, the following considerations are recommended in designing the emergency vent area:

- (1) The storage buildings, or portions thereof, should be able to withstand a positive static internal pressure that is higher than the opening pressure of the emergency pressure relief vent.
- (2) The emergency pressure relief vent surfaces designed to release from the exterior walls or roofs should consist of lightweight building materials.
- (3) The emergency pressure relief vent should be in the roof or an exterior wall for the protected storage room.
- (4) The emergency pressure relief vent should be kept clear of the storage by at least 1.6 ft (0.5 m).
- (5) Within 20 ft (6.1 m) from the emergency pressure relief vent there should be no structures or obstacles including trees, bushes, and so forth. Smoking and open flames should be prohibited in this zone.

Alternatively, an emergency pressure relief vent area can be provided in accordance with NFPA 68 or an equivalent standard.

Organic peroxide ambient storage building designs with the roof and a wall as an emergency vent are illustrated in Figure A.14.2.6(a) and Figure A.14.2.6(b), respectively.

N A.14.2.7.1.1 Liquefied gas injection systems can be used as an alternate method of temperature control for organic peroxides in addition to redundant refrigeration systems. The use of such systems, however, requires very strict training and safety measures to eliminate any risk of accidental asphyxiation of the personnel possibly entering the storage.

N A.14.2.8 Temperature control is very important for organic peroxides to prevent runaway decompositions, evolution of gases and mists (that can lead to vapor phase explosions), auto-ignition, or loss of product quality. The manufacturer's recom-

N Table A.14.2.6 UN Transport Classification of Organic Peroxides

Organic Peroxide Transport Classification ^a	Maximum Container Size ^b	UN Number			
		Ambient Temperature Organic Peroxides ^c		Temperature Controlled Organic Peroxides ^c	
		Liquid	Solid	Liquid	Solid
Type A	Forbidden	Transportation of these formulations is forbidden.			
Type B	25 kg (55 lb)	3101	3102	3111	3112
Type C	50 kg (110 lb)	3103	3104	3113	3114
Type D	50 kg (110 lb)	3105	3106	3115	3116
Type E	400 kg (882 lb)/ 450 L (119 gal)	3107	3108	3117	3118
Type F	IBCs/tanks	3109	3110	3119	3120
Type G	Unrestricted	Formulations are not regulated as organic peroxides.			

^a The organic peroxide transport classification is determined as outlined in UN *Recommendations on the Transport of Dangerous Goods — Model Regulations*. Section 2.5.3.3 gives the principles for classification of organic peroxides for transportation. Figure 2.5.1 gives the logic tree for classification, which is reliant on testing outlined in the *Manual of Tests and Criteria*, Part II. The transportation type is found in Section 14 (Transport Information) of the manufacturer's safety data sheet. The type and form (liquid or solid) can be deduced from the UN number, as well.

^b The maximum container size indicated is a transportation-related limit. The limit for each type is shown as part of Figure 2.5.1 of the UN *Recommendations on the Transport of Dangerous Goods — Model Regulations*.

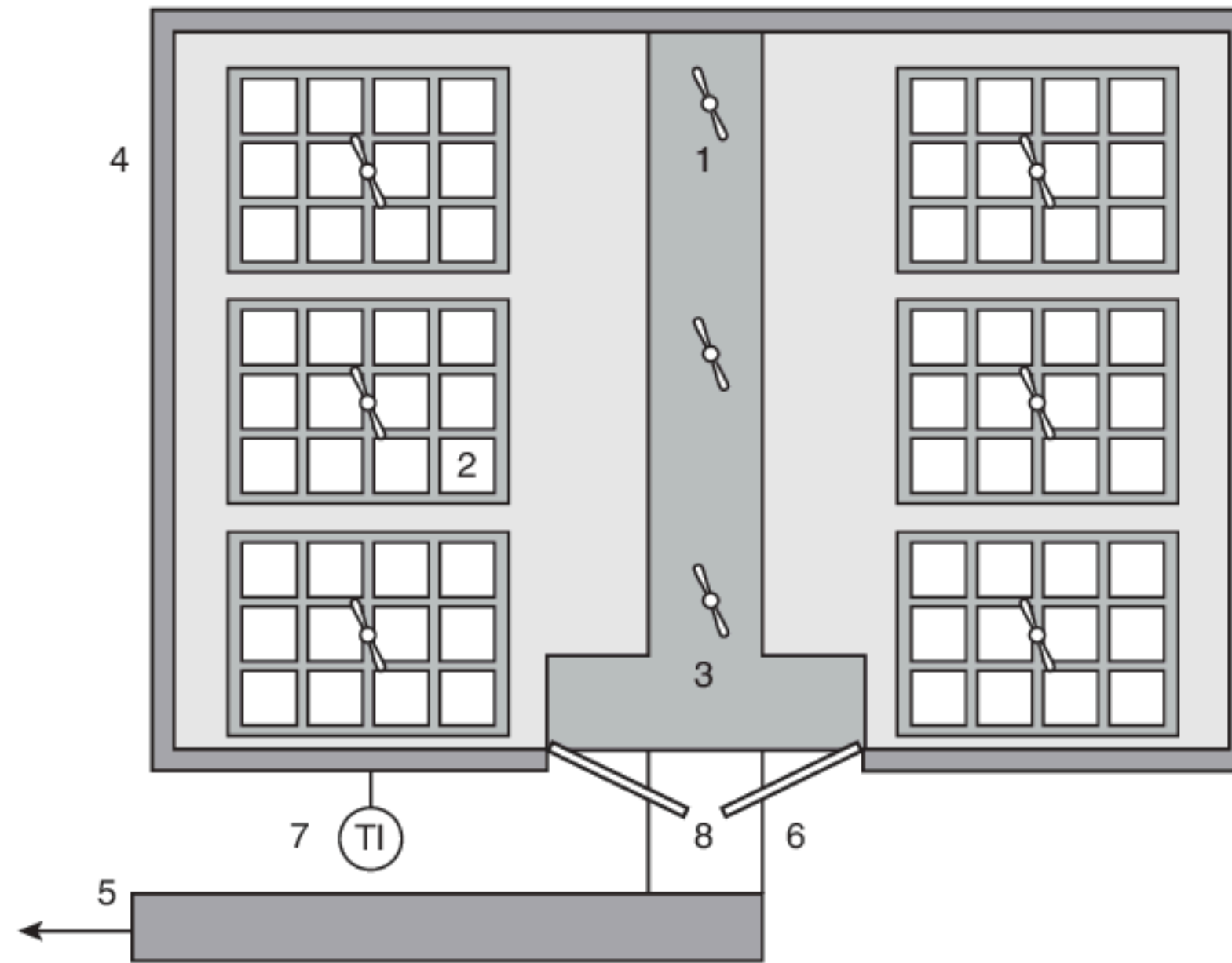
^c Temperature control requirements for transportation are determined as indicated in Section 2.5.3.4 of the UN *Recommendations on the Transport of Dangerous Goods — Model Regulations*. This is dependent on the self-accelerating decomposition temperature (SADT), which is determined by various methods found in the UN *Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria*, Part II, Section 28. The need for temperature control can be deduced from the UN number, which is indicated in Section 14 (Transportation Information) of the manufacturer's safety data sheet. UN numbers 3111 to 3120 require temperature control during transportation and UN numbers 3101 to 3110 do not. In addition to the safety relevant temperature control indication from the UN number, suppliers can also indicate a quality/shelf-life-related storage temperature limit that is not mandatory for safety in storage.

mended temperature range for storage should be rigorously followed.

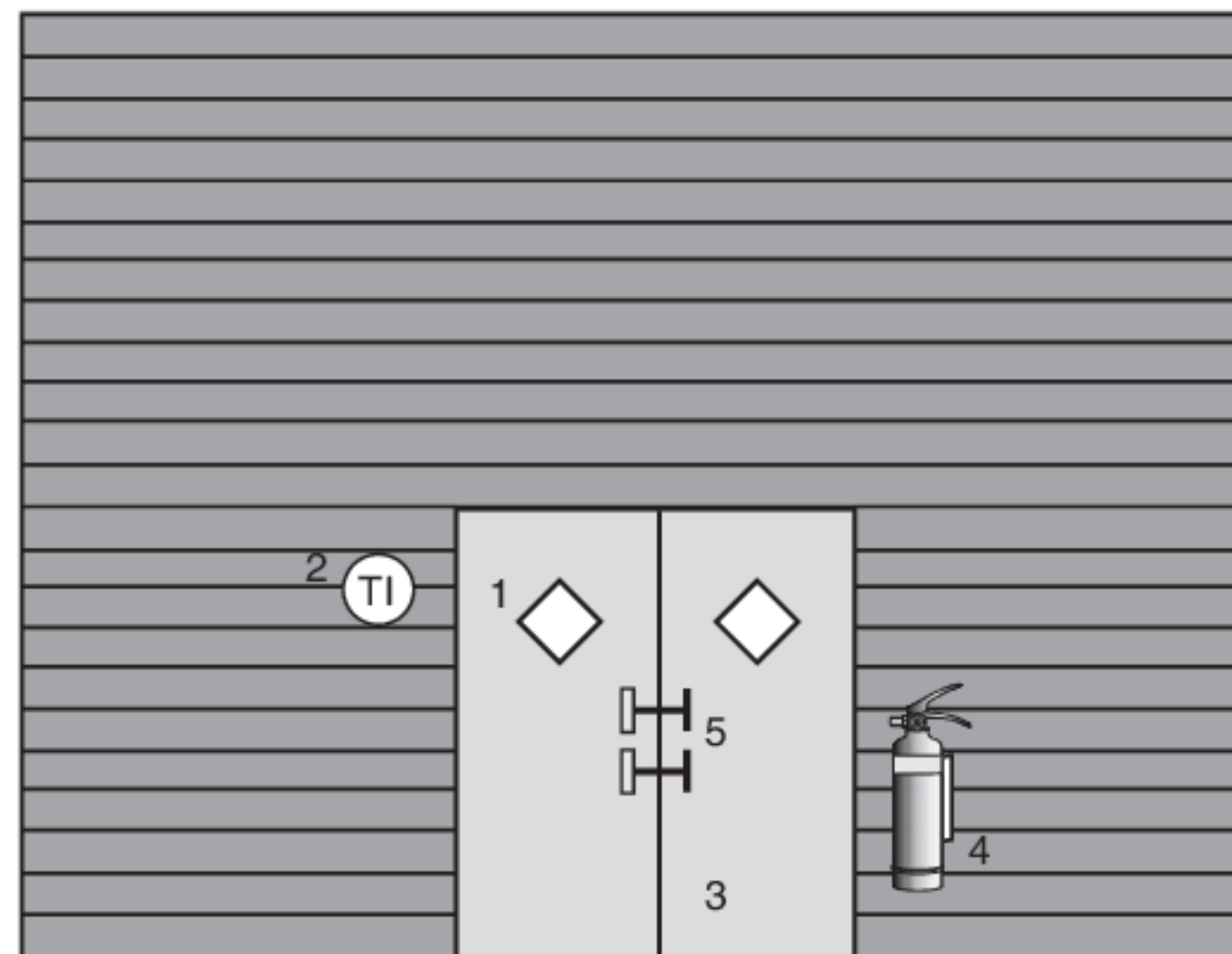
N A.14.2.10.6 Organic peroxide storage should only have closed containers, which would be classified as a Class I, Division 2 location as defined in Article 500 of NFPA 70. Organic peroxides or the decomposition products are confined in the closed containers from which they can escape only in case of accidental rupture or breakdown of containers or in case of loss of temperature control due to equipment failure or due to decomposition as a result of contamination.

Floorplan:

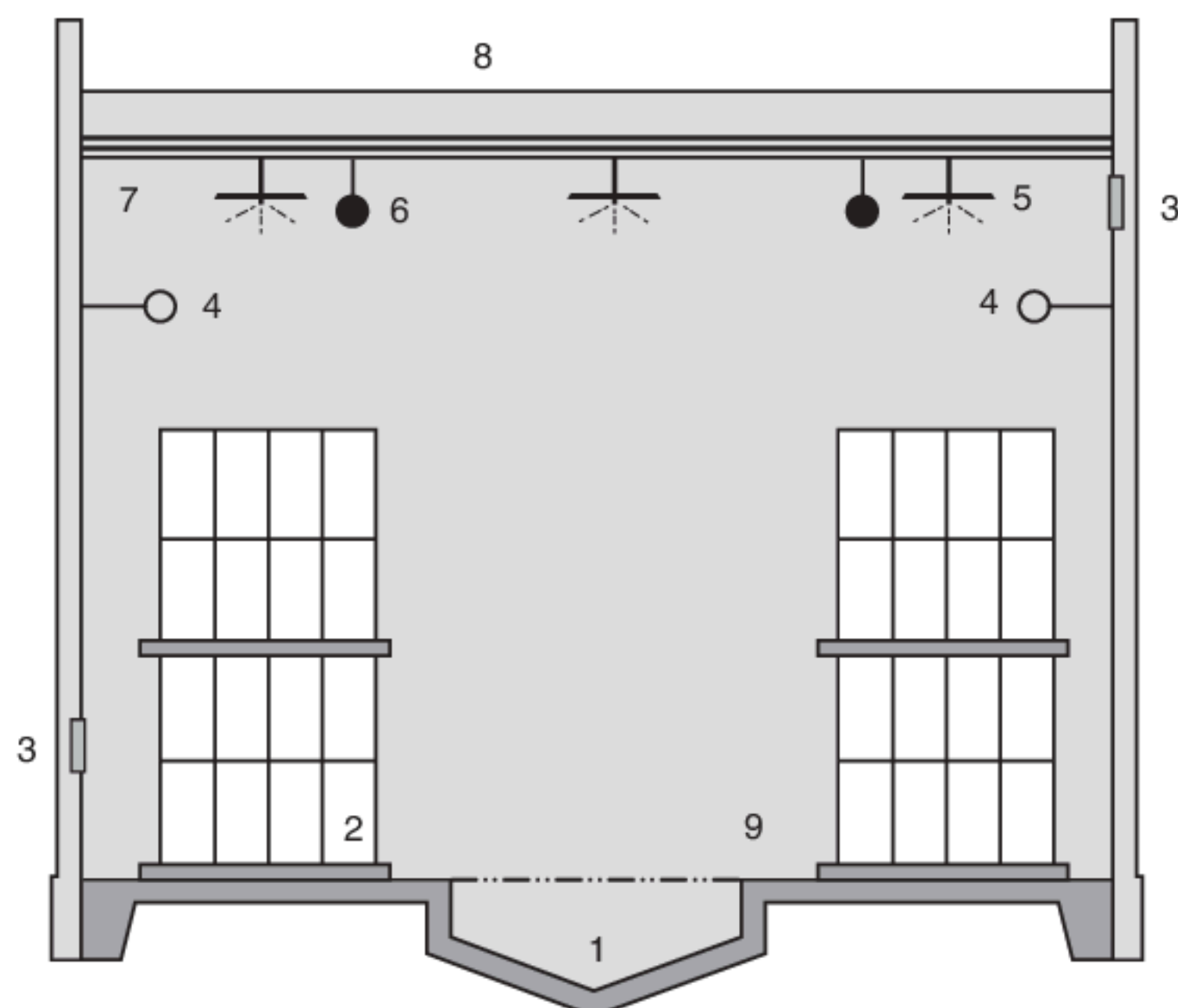
- 1 Sprinkler head
- 2 Pallet with packages
- 3 Gutter/basin system
- 4 Fire-resistant wall
- 5 Gutter system to outside basin
- 6 Doors
- 7 Temperature indicator
- 8 Gutter system to outside gutter

**Front:**

- 1 Placarding
- 2 Temperature indicator
- 3 Doors
- 4 Portable fire extinguisher
- 5 Locks

**Cross-section:**

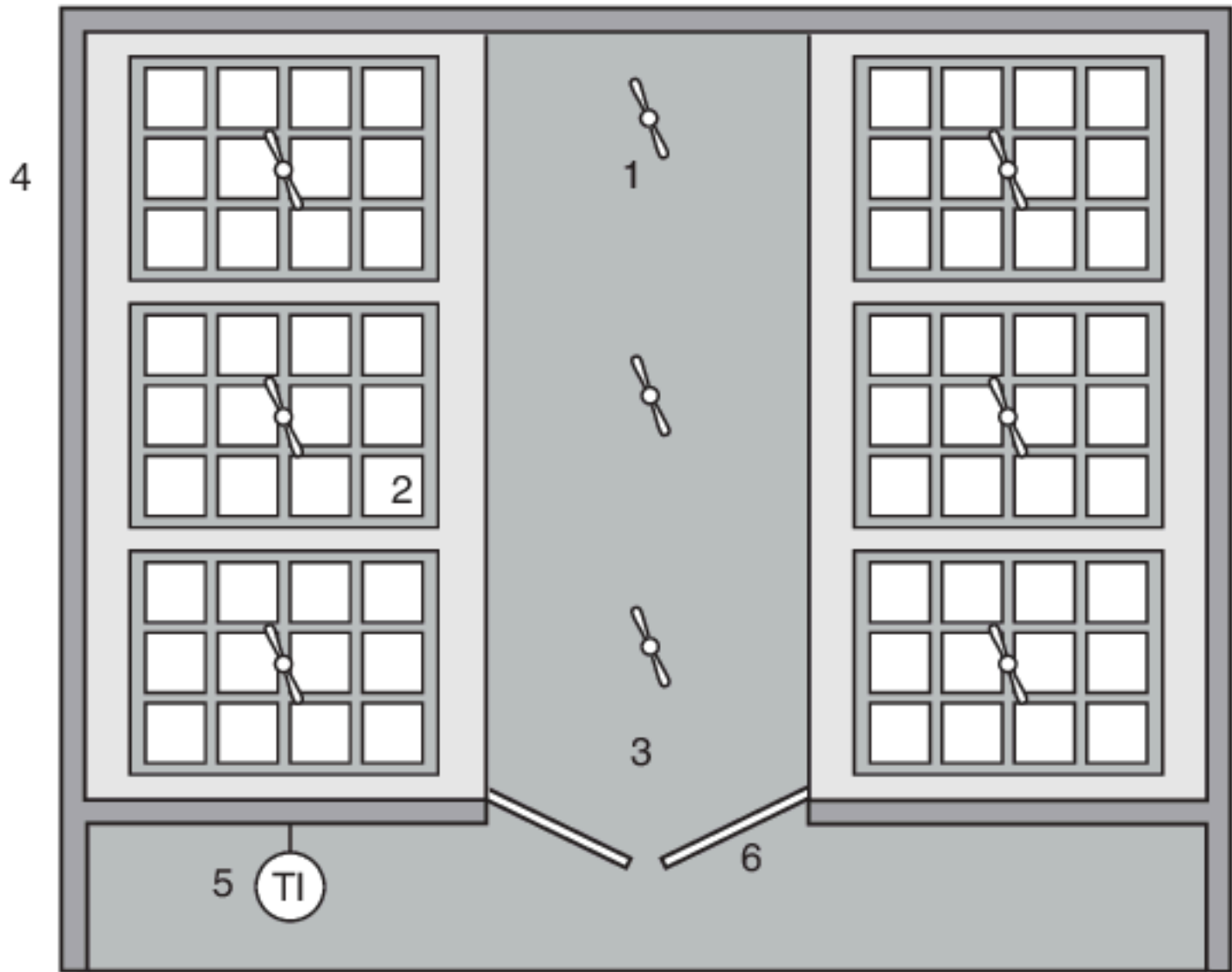
- 1 Gutter/basin system
- 2 Pallet with packages
- 3 Ventilation opening with gratings
- 4 Temperature sensor
- 5 Sprinkler head
- 6 Melting bulb
- 7 Steel beam
- 8 Loosely constructed roof (emergency vent)
- 9 Sloped floor



N FIGURE A.14.2.6(a) Storage Building Design With the Roof as an Emergency Vent.

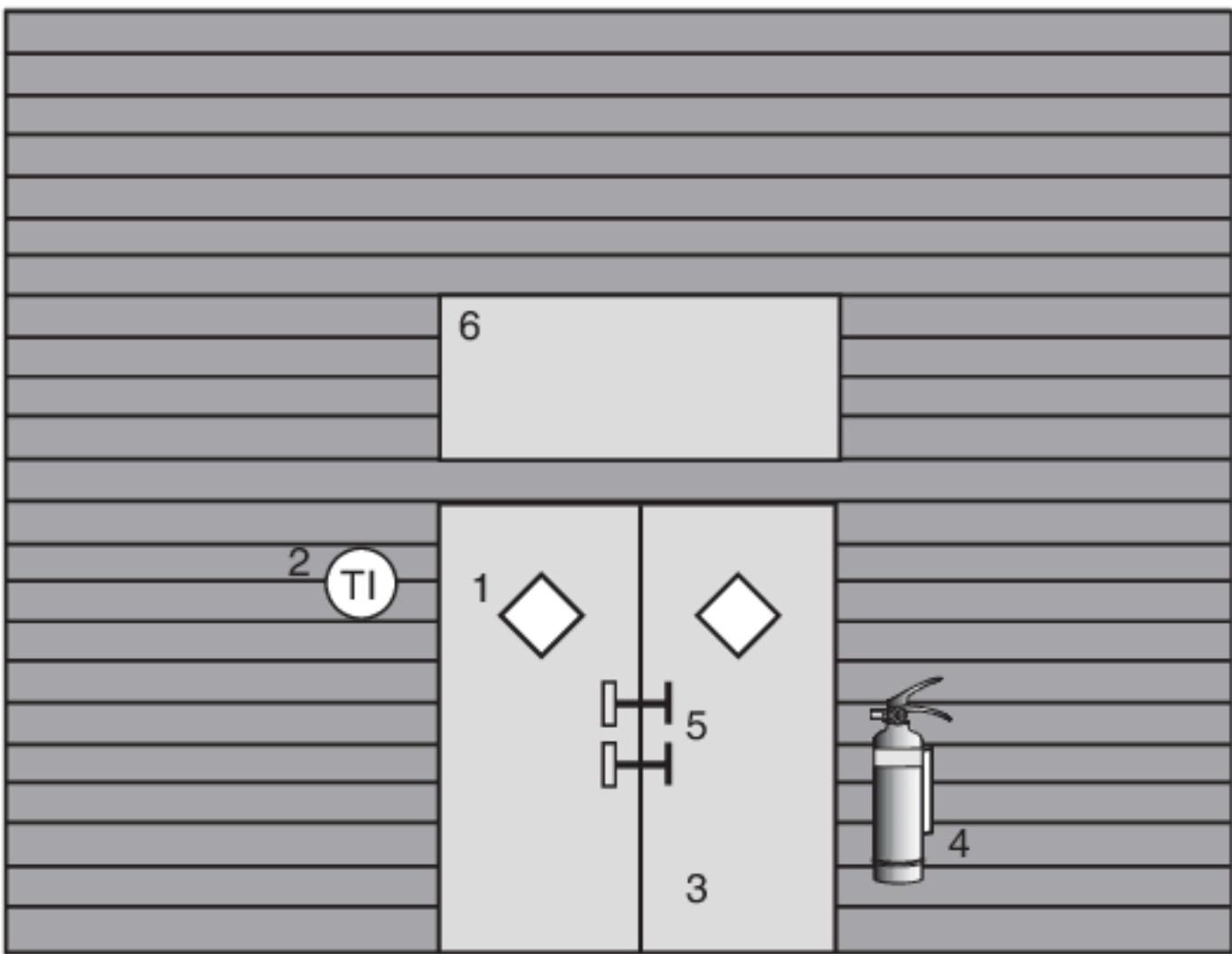
Floorplan:

- 1 Sprinkler head
- 2 Pallet with packages
- 3 Gutter/basin system
- 4 Fire-resistant wall
- 5 Temperature indicator
- 6 Doors



Front:

- 1 Placarding
- 2 Temperature indicator
- 3 Doors
- 4 Portable fire extinguisher
- 5 Locks
- 6 Venting panel



Cross-section:

- 1 Gutter/basin system
- 2 Pallet with packages
- 3 Ventilation opening with gratings
- 4 Temperature sensor
- 5 Sprinkler head
- 6 Melting bulb
- 7 Lower part of double roof
- 8 Upper part of double roof, rigid constructed
- 9 Sloped floor

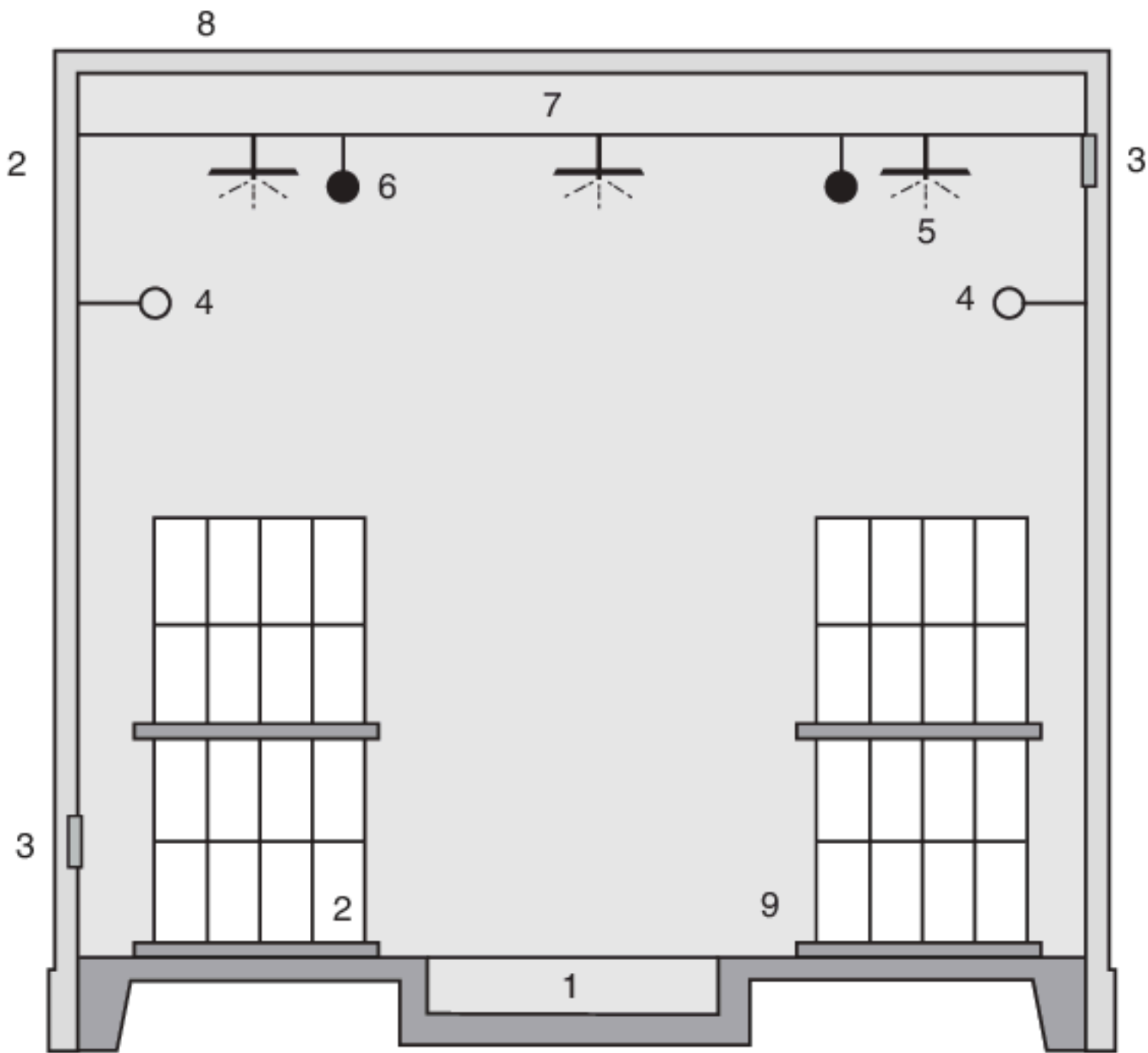


FIGURE A.14.2.6(b) Storage Building Design With a Venting Panel Above the Doors.

N A.14.2.10.7 The storage area should always be kept clean. Accumulation of combustible waste like litter, rags, pallet pieces, paper, and plastic should be prohibited.

A.14.2.10.8.1 Organic peroxide spill should be attended to immediately to avoid the risks of chemical reactions that can result in fire and/or explosion, as well as the possible contamination of soil and/or water. Contact your organic peroxide manufacturer prior to acting, if there are any questions regarding safety issues. The method of disposal can vary depending on the specific formulation and materials with which they might have been contaminated. Contact the organic peroxide manufacturer prior to acting and refer to the manufacturer or the supplier of the specific formulation for advice if there are any questions regarding safety issues.

Spilled liquid organic peroxide formulations should be attended to immediately by a competent individual by spreading organic peroxide manufacturer recommended inert absorbent material directly on the spill. The inert absorbent material should be collected using nonsparking tools and placed in polyethylene bags for disposal, ensuring no residual material remains outside of the bag before it is placed in a loosely confined plastic container. The disposal of spilled materials should not be combined with any ordinary trash. Dispose of the waste material immediately according to applicable regulations using an approved disposal company. If the waste material cannot be disposed of immediately and needs to be stored for a period of time at the site, the waste container should be appropriately labelled and stored in a dedicated area, away from the organic peroxide storage area. The recovered material must be stored in accordance with the temperature control requirements of the organic peroxide formulation in order to avoid a thermal decomposition.

Once the inert material has been collected from the floor, the spill area should be washed down with surfactant and water to remove any traces of organic peroxide and allowed for sufficient ventilation to aid in the removal of fumes that might be present.

Spilled material should not be returned to the original container or the storage area.

It is also recommended that spill kits be available in all areas in which organic peroxide formulations are stored and used. The spill kit should be comprised of organic peroxide manufacturer recommended inert absorbents, nonsparking clean-up tools, plastic bags, closeable plastic containers, hazardous material labels, and a source of water. Inert absorbent materials are, but not limited to, sodium bicarbonate and sand. Materials such as vermiculite, sawdust, peat moss, and kitty litter or other absorbent clay granules should not be used. Refer to plasticsindustry.org/oppsd for links to disposal companies and the liquid organic peroxide disposal guide.

N A.14.2.10.8.2 Refer to plasticsindustry.org/oppsd for links to disposal companies and the solid and liquid organic peroxide disposal guides.

N A.14.2.10.9 The requirement of compatible materials of construction is very important as incompatible materials can result in decomposition of organic peroxides, which can cause explosion and/or fire. In general, preferred materials of construction are 304 or 316 stainless steel (316 preferred) or polyethylene. Do NOT use copper, brass, or iron. Polytetrafluoroethylene (PTFE) is preferred material for diaphragms,

wetted seals, and o-rings in equipment that will come in contact with the organic peroxide formulation. Contact the organic peroxide manufacturer for recommendations.

N A.14.2.10.10.2 Temperature control is very important for organic peroxides to prevent runaway decompositions, evolution of gases and mists (that can lead to vapor phase explosions), autoignition, or loss of product quality. A self-accelerating decomposition occurs when the rate of peroxide decomposition is sufficient to generate heat at a faster rate than it can be dissipated to the environment. Temperature is the main factor in the rate of decomposition. The lowest temperature at which a packaged organic peroxide will undergo a self-accelerating decomposition within a week is defined as the self-accelerating decomposition temperature (SADT). The SADT is an important consideration in the proper storage of organic peroxides. For this reason, the manufacturer's recommended temperature range [the maximum ($T_{s\max}$) and sometimes minimum ($T_{s\min}$)] for storage should be rigorously followed. A refrigerated organic peroxide formulation should never be allowed to be left in a receiving area for any extended period. It is critical that all personnel involved in the process of receiving, handling, and storing the organic peroxide formulation be familiar with its properties and storage temperature requirements. The user should also be familiar with the control and emergency temperature (T_c and T_e) of an organic peroxide. T_c , the control temperature, is the maximum temperature at which the organic peroxide can be safely transported. T_c is derived from SADT. T_c is not required if the SADT is greater than 50°C (122°F). T_e is the emergency temperature and is also derived from the SADT. T_e is the temperature at which emergency procedures must be implemented. T_e is higher than T_c but below the SADT. T_c can be exceeded if maintenance is necessary or until alternative cooling (e.g., dry ice or wet ice) is available. However, if the T_e is reached, immediate steps must be taken to remove the personnel from the area and if possible, safely cool down the organic peroxides. Dispose of the organic peroxides if necessary. Often, $T_{s\max}$ is lower than the T_c , not for safety but for quality reason; the lower temperature will minimize the active oxygen loss and decomposition products formation due to gradual decomposition. $T_{s\min}$ must be followed for some organic peroxides when they must be stored above a certain minimum temperature as turbidity, phase separation, crystal deposits or solidification can occur if stored below that temperature. The most serious situation is if the organic peroxide is separated from the diluent due to phase separation while frozen. These critical temperatures for each organic peroxide can be found on the package label and in the corresponding technical literature or safety data sheet (SDS). If more than one product is stored in a storage, the highest $T_{s\min}$, the lowest $T_{s\max}$, T_c , and T_e shall apply. Please consult the manufacturer of the organic peroxides for recommendations in such cases.

N A.14.2.10.14 The signs of organic peroxide decomposition must be known to all personnel that handle organic peroxides. In an individual container, it is the bubbling, foaming, venting, smoke, and fire, in increasing order of severity, that confirm decomposition of an organic peroxide. If a sign of decomposition is observed, the personnel present must immediately move away and evacuate the building, alert other personnel at the site by triggering the alarm and implement the emergency actions. Similarly, if a rapid rise in temperature, fire, or smoke is observed from outside the storage building, it is essential not

to enter the storage but to trigger the alarm and implement the emergency actions. Always, check the actual storage temperature of the organic peroxide storage prior to entering the building.

N A.14.2.10.15 Emergency situations that shall be considered are the self-accelerating decomposition of the organic peroxide and the situation where the vessel or container is surrounded by fire. The emergency relief device(s) can be of the spring loaded or frangible types designed to relieve all the decomposition products and vapors evolved during an emergency of decomposition or fire exposure. Vent sizing for organic peroxides can be accomplished by several methods including Design Institute for Emergency Relief Systems (DIERS), UN *Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria*, Appendix 5 (https://www.unece.org/fileadmin/DAM/trans/danger/ST_SG_AC.10_11_Rev6_E_WEB_-With_corrections_from_Corr.1.pdf), and the OPPSD/PLASTICS Methodology (<https://www.plasticsindustry.org/supply-chain/material-suppliers/organic-peroxide-producers-safety-division-oppsd>). The DIERS vent sizing method is based on data obtained from small-scale adiabatic calorimetry while the UN and OPPSD methods test the venting of the organic peroxide on larger scale (~10 L).

N A.14.2.11 Use of a portable fire extinguisher in storage areas should be undertaken only by those having proper training and a clear understanding of the storage conditions and the characteristics of fires involving organic peroxides. Industry guidance recommends portable fire extinguishers be present in the storage, use and handling areas for organic peroxides. The principle method of firefighting should rely on automatic methods. Portable fire extinguishers can be useful to extinguish small coincident fires or those with organic peroxides only during the incipient periods or can be useful to assist during emergency escape. Selection of type, location, and size of portable units should be undertaken with careful consideration of these goals.

A.14.3.2 The classification system described in Section 4.1 is used only to determine the storage requirements established by this code. It is not meant to be a substitute for the hazard identification system established by NFPA 704. Since the hazard characteristics of organic peroxide formulations vary widely depending on the type of organic peroxide, the diluent, and their relative concentrations, each specific formulation will have to be rated individually according to the criteria established in NFPA 704.

For the purpose of this document, an important building is one that is occupied or that contains facilities vital to the operation of the plant.

A.14.3.2.4 In the venting equation, use the fuel characteristic constant for “gases with fundamental burning velocity less than 1.3 times that of propane.” See NFPA 68 for information on vent design. Refer to manufacturers’ technical data for information on organic peroxide formulations that give off flammable gases upon decomposition.

A.14.3.2.5 For example, a sprinklered building, detached by 50 ft (15.3 m), can contain up to 500 lb (227 kg) of Class I, 50,000 lb (22,700 kg) of Class IIA, and 50,000 lb (22,700 kg) of Class III formulations, according to the following ratios:

(1) Class I:

[A.14.3.2.5a]

$$\frac{500 \text{ lb}}{2000 \text{ lb (max)}} \times 100 = 25\% \quad \frac{227 \text{ kg}}{907 \text{ kg (max)}} \times 100 = 25\%$$

(2) Class IIA:

[A.14.3.2.5b]

$$\frac{50,000 \text{ lb}}{100,000 \text{ lb (max)}} \times 100 = 50\% \quad \frac{22,700 \text{ kg}}{45,400 \text{ kg (max)}} \times 100 = 50\%$$

(3) Class III:

[A.14.3.2.5c]

$$\frac{50,000 \text{ lb}}{200,000 \text{ lb (max)}} \times 100 = 25\% \quad \frac{22,700 \text{ lb}}{90,700 \text{ lb (max)}} \times 100 = 25\%$$

In no case does the quantity in storage exceed the maximum for its class, nor does the sum of the percentages exceed 100 percent.

N A.14.3.2.8 Whenever possible, packages should not be partially emptied. If a certain quantity that requires partial emptying is required, a separate area away from the organic peroxide storage should be designated for dispensing and weighing. Once a package has been opened, there is potential for contamination of the organic peroxide, thereby reducing its stability, and if it is then returned to the storage building it can pose more of a threat at the storage temperature than it did prior to opening.

N A.14.3.2.10 Incompatible materials are materials that adversely affect the thermal stability of the organic peroxide. These are materials that can catalyze or accelerate the decomposition of organic peroxide formulations or that can cause hazardous reactions when in contact with such formulations. These typically are heavy metals (e.g., iron, copper, cobalt), rust, reducing agents, accelerators, acids, bases, amines, and monomers. Consult the manufacturer of the organic peroxide for compatibility of materials. Contamination can lead to rapid decomposition and similar problems to those associated with lack of temperature control. Decomposition due to contamination can happen very rapidly and result in catastrophic results. Susceptibility of organic peroxides to induced decomposition from contamination varies greatly between the types of organic peroxides and the specific contaminants. To avoid problems from contamination, never return unused organic peroxides to the original container. Use only scrupulously clean equipment and make certain that all materials that the organic peroxide comes in contact with are compatible. Use dedicated equipment for organic peroxide transfer and handling.