Designation: E1248 – 90 (Reapproved 2009)

Standard Practice for Shredder Explosion Protection[1]

This standard is issued under the fixed designation E1248; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers general recommended design features and operating practices for shredder explosion protection in resource recovery plants and other refuse processing facilities.

1.2 Hammermills and other types of size reduction equipment (collectively termed shredders) are employed at many facilities that mechanically process solid wastes for resource recovery. Flammable or explosive materials (for example, gases, vapors, powders, and commercial and military explosives) may be present in the as-received waste stream. There is potential for these materials to be released, dispersed, and ignited within or near a shredder. Therefore, explosion prevention and damage amelioration provisions are required.

2. Referenced Documents

2.1 *National Fire Protection Association Standards:*

National Electrical Code
NFPA 13 Sprinkler Systems
NFPA 68 Guide for Explosion Venting
NFPA 69 Explosion Prevention Systems
NFPA 497A Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

3. Terminology

3.1 *Definitions:*

3.1.1 *deflagration*—an explosion in which the flame or reaction front propagates at a speed well below the speed of sound in the unburned medium, such that the pressure is virtually uniform throughout the enclosure (shredder) at any time during the explosion.

3.1.2 *detonation*—an explosion in which the flame or reaction front propagates at a supersonic speed into the unburned medium, such that pressure increases occur in the form of shock waves.

3.1.3 *explosion*—a rapid release of energy (usually by means of combustion) with a corresponding pressure buildup capable of damaging equipment and building structures.

3.1.4 *explosion venting*—the provision of an opening(s) in the shredder enclosure and contiguous enclosed areas to allow gases to escape during a deflagration and thus prevent pressures from reaching the damage threshold.

3.1.5 *explosion suppression*—the technique of detecting and extinguishing incipient explosions in the shredder enclosure and contiguous enclosed areas before pressures exceed the damage threshold.

3.1.6 *inerting*—the technique by which a combustible mixture is rendered nonflammable by addition of a gas incapable of supporting combustion.

3.1.7 *shredder*—a size-reduction machine that tears or grinds materials to a smaller and more uniform particle size.

4. Significance and Use

4.1 Shredder explosions have occurred in most refuse processing plants with shredding facilities. Lessons learned in these incidents have been incorporated into this practice along with results of relevant test programs and general industrial explosion protection recommended practices. Recommendations in this practice cover explosion protection aspects of the design and operation of shredding facilities and equipment used therein.

4.2 This practice is not intended to be a substitute for an operating manual or a detailed set of design specifications. Rather, it represents general principles and guidelines to be addressed in detail in generating the operating manual and design specifications.

5. Design Practices

5.1 *Design Rationale:*

5.1.1 Each of the following design features is better suited for some types of combustible/explosive materials and shredders than for others. The selection of a particular combination of explosion prevention features or damage control features, or both, should be made with an understanding of the types of refuse entering the shredder, shredder operating conditions, the inherent strength of the shredder and surrounding structures, and the operating controls for screening input materials and restricting personnel access during shredding operations.

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[1] This practice is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.03 on Treatment, Recovery and Reuse.

Current edition approved Sept. 1, 2009. Published November 2009. Originally approved in 1990. Last previous edition approved in 2004 as E1248–90(2004). DOI: 10.1520/E1248-90R09.

5.1.2 Several of the following explosion protection design practices are effective for deflagrations but not for detonations. Deflagrations usually result from accumulations of flammable gas-air, vapor-air, or powder(dust) air mixtures in or around the shredder. However, commercial explosives and military ordnance usually generate detonations. A few flammable gases (for example, acetylene and hydrogen) are also prone to detonate when dispersed in highly turbulent, strong ignition source environments such as exist inside a shredder. Because many explosion protection design practices are not applicable to detonations, rigorous visual detection and removal of detonable material before it enters the shredder is particularly important (6.1).

5.1.3 In view of the difficulties in preventing and controlling all types of shredder explosions, it is important to isolate the shredder and surrounding enclosure from vulnerable equipment and occupied areas in the plant. This is best achieved by locating the shredder outdoors or, if indoors, in a location suitable for explosion venting directly outside. Locations in or near the center of a processing building are not desirable. If the shredder is situated in an isolated, explosion resistant structure, the structure should be designed to withstand the explosion pressures specified in NFPA 68.

5.1.4 The shredder and all contiguous enclosures should be equipped with an explosion protection system consisting of one or more of the following: inerting system (5.2); explosion vents (5.3); explosion suppression system (5.4). Water spray systems (5.5), combustible gas detectors (5.6), and industrial fire protection systems (5.7) should also be installed for additional protection. Adjacent structures and personnel should be protected (5.8).

5.2 *Inerting Systems:*

5.2.1 An inerting system is intended to prevent combustion explosions within a shredder (and contiguous enclosures) by maintaining oxygen concentrations below the level required to support combustion.

5.2.2 The following factors must be accounted for in designing a shredder inerting system: inert gas source and distribution; operating controls and associated instrumentation; leakage of inert gas from and entry of air into enclosures; maintenance and inspection constraints in an oxygen deficient atmosphere during normal operations; effect of inert gas on shredder materials and waste throughput; and contingency plans for inert gas source supply interruption.

5.2.3 Flue gas from an on-site furnace or boiler can be a suitable inert gas providing there is a reliable means to prevent flame propagation into the shredding system and providing flue gas conditioning is installed to maintain suitable temperature (to prevent steam condensation or spontaneous ignition) and flue gas composition (including dew point, oxygen, carbon monoxide, soot, and contaminant concentrations).

5.2.4 Steam from an on-site boiler can be a suitable inert gas providing the temperatures of the shredder and contiguous enclosures are sufficiently high (at least 180°F (82°C)) to prevent steam condensation and the associated increase in oxygen and flammable gas concentrations.

5.2.5 Oxygen concentrations in the shredder and all contiguous enclosures should be no higher than 10 % by volume, unless test data for the particular inert gas employed and the variety of combustibles expected in the shredder demonstrate that a higher oxygen concentration can be tolerated without generating a flammable mixture. Test data for maximum oxygen concentrations for nitrogen and carbon dioxide inerting are as listed in Appendix C of NFPA 69.

5.2.6 Reliable oxygen concentration monitors should be installed, calibrated, and maintained to verify that the maximum oxygen concentration is not being exceeded in the shredder and contiguous enclosures. This will require multiple monitors and sampling points depending on the extent and uniformity of flow in the enclosed volume. Provision for cleaning and clearing sample lines, as recommended in 5.4.5 are needed.

5.2.7 The inert gas distribution system should be designed in accordance with the provisions of Chapter 2 of NFPA 69.

5.3 *Explosion Venting:*

5.3.1 Explosion venting is intended to limit structural damage incurred during deflagrations by allowing unburned gas and combustion products to be discharged from the shredder or contiguous enclosures, or both, before combustion and the associated potentially destructive pressure rise is completed. The effectiveness of explosion venting for a particular explosion depends on the rate of combustion versus the rate of discharge of gases through the explosion vents. The rate of combustion in the shredder or adjacent enclosure depends upon the composition of the combustible gas-air, vapor-air, or dust-air mixture, the size of the shredder/enclosure, and the turbulence level as determined by air flow rates and hammer tip speed.

5.3.2 In general, explosion venting is most effective with large vent areas, low vent deployment pressures, low vent panel weight, and vent locations near the expected ignition source (which is often hammer impact sparks within the shredder). The following quantitative guidelines for these factors are intended to protect against near worst-case flammable gas-air mixtures occupying the entire shredder internal volume.

5.3.3 Explosion vent areas should be sufficiently large to maintain explosion pressures under the damage threshold value for the particular shredder installation. Previously published guidelines relating peak pressure to vent area are not directly applicable to Municipal Solid Waste (MSW) shredders because shredder hammer velocities can increase the combustion rate well above that considered in establishing previous guidelines. The following recommended relationship is based on propane-air explosion tests conducted in a full-scale large shredder mock-up, including rotating hammers (**1**).[2]

5.3.3.1 The vent area, A_v, required to maintain explosion pressures under the shredder damage threshold (in units of psig), P_M, is given by the equation:

$$A_v = 0.13V^{2/3}P_M^{-0.435}\left(5+0.034v_H\right) \tag{1}$$

where:

V = shredder internal volume, and

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[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

v_H = hammer tip velocity, ft/s.

The calculated vent area will be in the same units as $V^{2/3}$. The metric equivalent, if P_M is in bar, and v_H is in m/s, is

$$A_v = 0.041 V^{2/3} P_M^{-0.435} \left(5 + 0.112 v_H\right) \quad (2)$$

5.3.3.2 If the shredder discharge is at least 3 ft (0.91 m) above an unenclosed discharge conveyor, half the discharge area can be credited toward attaining the required vent area, A_v. The difference should be made up with unobstructed explosion vents. No credit should be taken for the inlet area which is usually too obstructed to be an effective vent.

5.3.3.3 To illustrate the use of Eq 1 and 2, consider a hypothetical shredder with an internal volume of 1000 ft^3 (28.3 m^3), including the portion of the inlet hood directly above the hammermill. Let us suppose that structural calculations indicate that the weakest structural member can withstand an applied load equivalent to a hydrostatic pressure of 10 psig (0.70 bar). At the design shaft speed in this shredder, the hammer tip speed is 250 ft/s (76.2 m/s). Substitution of these values into Eq 1 and 2 results in a calculated required vent area of 64 ft^2 (5.95 m^2). If the shredder discharge area is 20 ft^2 (1.9 m^2), an explosion vent of at least 54 ft^2 (5.0 m^2) area should be installed on the shredder.

5.3.4 The explosion vent opening should discharge combustion gases and flame into an unoccupied outdoor area. If the shredder is situated inside a building, vent ducting will be needed to channel gases and flame out of the building. This ducting, which should have a strength at least equal to the shredder itself, should be kept as short as possible in order to avoid further burning and gas compression during venting.

5.3.4.1 Vent ducting of any length will cause the pressure to increase significantly above the value expected for unrestricted venting. The increased pressure can be related to the unrestricted (no duct) vented explosion pressure through Fig. 1. The parameter in Fig. 1 that determines this relationship is the ratio of vent duct volume to shredder volume. In the example in 5.3.3.3, the use of only a 5.5-ft (1.7-m) long duct attached to the 54-ft^2 (5.0-m^2) vent area would represent a duct volume of 300 ft^3 (8.5 m^3), corresponding to a duct/shredder volume ratio of 0 to 3. According to Fig. 1, an explosion pressure of 10 psig (0.7 bar) without the duct would be increased to about 21 psig (1.5 bar) with a duct/shredder volume ratio of 0 to 3.

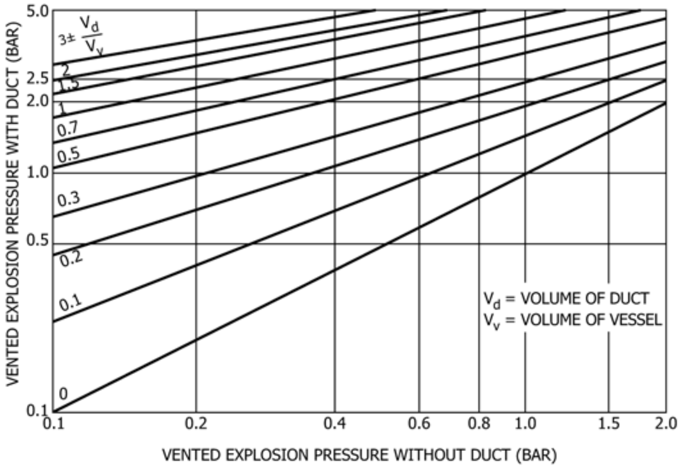

FIG. 1 Influence of Vent Duct Volume on Vented Explosion Peak Pressures (Ref. 2)

5.3.4.2 If the pressure increases shown in Fig. 1 are intolerable, a duct with a diverging cross-section area should be used. Apparently, there have not been any published test data on how much divergence is required to prevent significant pressure increases above the unrestricted vent values given by Eq 1 and 2. Even with large divergence angles, the vent duct should be designed to withstand a pressure equal to the shredder damage threshold pressure.

5.3.4.3 It is desirable to prevent flammable gas from entering and accumulating in a vent duct during normal shredder operation. Although this is difficult to achieve, two possible approaches are use of a sturdy vent cover (5.3.5), or vent cover and projectile deflector to separate the shredder from the vent duct; or, as a less desirable alternative, use of air sweeping of the vent duct by the induced draft of the shredder or by a high-capacity dust collection or pneumatic transport system, or both. These systems should be equipped with their own explosion protection systems.

5.3.5 Vent covers are usually needed either (preferably) directly on the shredder, or at the far end of the vent duct. Without these covers, dust and debris generated during the shredding process would be ejected and would possibly create a health and safety hazard to nearby personnel. Since impact forces from large ejected debris could prematurely open the vent cover, deflection gratings, heavy chain links, or wire rope are often employed to rebound these missiles back into the shredder.

5.3.5.1 The opening pressure of the vent cover should be low in comparison to the shredder structural damage threshold, P_M. Based on the explosion tests described in EPA Report M2052 (1), it is recommended that the static deployment pressure be no more than $P_M/5$ since the cover will open at a somewhat higher pressure under rapid explosion loads than under static test conditions. The vent opening pressure should also be higher than pressures developed by air motions and waste throughput during normal shredding operations.

5.3.5.2 Several different types of vent covers can be used. Some of the simplest covers consist of rubber flaps on the vent duct outlet. Rain hoods situated at least one vent duct diameter from the end of the duct have also been used in conjunction with a deflector grating inside the duct, but the rain hoods must be restrained from being blown off during the explosion. Vent cover construction and release mechanisms are described in NFPA 68.

5.3.5.3 If explosion vent panels or doors are used, they should satisfy several criteria in addition to the vent area and release pressure criteria cited-previously. First, vent panel/door inertia should be as low as possible, so as not to obstruct the open vent. NFPA 68 specifies that the vent panel area density be less than 2.5 lb/ft^2 (12.5 kg/m^2). Another important factor is that a rugged and shock-resistant hinge or steel cable (of at least 1-cm diameter) is required to prevent the panel/door from flying off during explosions. Finally, there is a need to periodically inspect the vent actuation mechanism so that it will function when needed. Some explosion doors have not