PREVENTING EXPLOSION DAMAGE IN PRIMARY AND SECONDARY REFUSE SHREDDERS

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The author of this paper has contributed more information on this troubling problem of refuse shredder explosions.

The author has indicated his concern with the design of most new plants under design, construction or initial operation. It is hoped that these thoughts have been transmitted to the respective facilities.

As many resource recovery systems require refuse shredding, the question of explosions is of paramount interest. This paper clearly summarizes many of the means used to alleviate explosions and their consequences.

There has been only limited reporting of the results of shredder explosion investigations. It would be of great service to the industry to compile such a report and keep it current. The only constraints might be legal liability problems.

The primary problem is for the observer to eliminate his preconceived conclusions and bias that can cloud his vision when he views the actual operation. As the writer has mentioned much can be learned from existing plants.

Housekeeping and dust control can also be contributing factors that should be considered along with the prime shredder concern.

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Discussion by

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Rick Haverland’s paper is a general review of the subject of explosions in refuse shredders. It does not seem to offer any specific advice for system designers.

I begin with a comment on the title of this paper, which implies that it is possible to prevent explosion damage in primary and secondary refuse shredders. Just as it is possible to devise an explosion that sinks a battleship or destroys a tank, so it is possible to experience an explosion that will destroy any shredder. It is not possible to prevent explosion damage. It may be possible to alleviate such damage in some, or even in most, circumstances.

The author begins his paper with four “logical conclusions.” His fourth conclusion is: “Any secondary shredder explosions are probably caused by dust.” I would add “and/or by explosive vapors,” as it is not necessarily correct that there will always be an ignition source in the primary shredder to initiate combustion of volatilized liquids or gases.

After the author clearly (and correctly) states that there are two basic types of explosions—deflagrations and detonations, he describes a typical deflagration—and then states that the (deflagration) process “occurs so rapidly that it is perceived as an explosion by an observer.” No doubt the observer...
perceives it as an explosion because it is, in fact, one of the two basic types of explosion. The author also states, “It is the rapid expansion of the fireball (in a deflagration) that produces the destructive shock wave.” However, most authorities agree that a deflagration involves subsonic propagation of the flame front. Thus, in a deflagration, there cannot be a “destructive shock wave.” There may be, and probably will be, a destructive overpressure that is not associated with a shock wave.

The statement, “An external oxidizing agent is not required for a detonation,” is not strictly correct. Such oxidizing agents are certainly required for detonations resulting from dust or vapor explosions that result in supersonic propagation of the wave front. Deflagrations are usually understood to mean explosions that propagate at less than sonic velocity, while detonations are usually understood to mean explosions that propagate at or above sonic velocity [1]. While I consider it unlikely that supersonic wave fronts will occur in shredder explosions resulting from dusts or from vapors, nevertheless such supersonic propagation is possible, particularly if a highly-combustible dust or vapor is mixed with oxygen along the length of a long tube such as a covered conveyor [2].

I wonder what support the author could give for the statement: “In addition, the material that causes dust explosions in shredders is usually very fine pieces of paper.” I would guess that the material that causes dust explosions in shredders is more likely to be boxes of corn starch, bags of flour, discards from vacuum cleaners and similar dusts. Powdered paper requires 0.055 g/liter concentration in air to be explosive, and the minimum ignition energy is about 60 mJ. The maximum explosion pressure from such paper is about 96 lb/in² and the maximum rate of pressure rise is only about 3,600 lb/in² sec. [1] In these respects, powdered paper is quite similar to wheat flour. Corn starch, on the other hand, requires 27 percent less concentration to be explosive; it requires 50 percent of the energy to initiate the explosion; it produces maximum overpressure of 145 lb/in²; and the maximum rate of pressure rise is 9,500 lb/in² sec [1]. Palmer’s book, “Dust Explosions and Fires” lists several hundred dusts and their explosive properties. A number of these dusts will explode in the absence of oxygen. I commend this document to the author’s attention.

The author’s discussion of mechanical preprocessing equipment is good as far as it goes. A rotary drum air-classifier should cause all explosives except dusts to report to the heavy fraction. The dusts would report to a dust collector. Thus, the light fraction from such a device should not contain explosive material. Rotary drum air-classifiers have been the subject of a number of papers that might have been referenced [3,4,5]. The author is correct in stating that the explosion hazards within preprocessing equipment should be considered; he could have noted that these hazards have been considered and reported upon.

The author lists three common methods of suppressing a deflagration – water sprays, inert atmosphere and chemical suppression. He points out that water sprays have disadvantages if refuse-derived fuel is an output of the plant, because the water decreases the fuel characteristics of the refuse. A water fog system, which was described in 1978, has been installed in a shredding plant for nearly five years [6]. This water fog system, which may be somewhat effective against certain dust and vapor explosions, uses only about 1 percent water as a percentage of waste shredded. It is doubtful that this small amount of water would seriously affect the operation of a resource recovery plant in view of the average moisture content of RDF of about 20 percent. I concur with the author that inert atmosphere is difficult and expensive to provide.

The author discusses chemical suppression systems, and states that such systems would be expected to prevent deflagrations from occurring if the system is properly maintained and “armed” whenever the shredder is operating. While I concur that chemical suppression systems should definitely be installed in systems that shred as the first step, I do not believe it is true that such systems will prevent all deflagrations from occurring. I suspect that some deflagrations involve such a high rate of rise of pressure that suppression systems cannot release their chemicals in time to stop the deflagration. The author knows of only one supplier of this type of system in the United States. I know of two suppliers, and there may be more.

In discussing venting, the author states that this technique has met with limited success due to the original design criteria. To what design criteria is he referring? The author quotes Robinson as listing two disadvantages of venting – the possible build-up of explosive dust-air mixtures in the vent, and the direct transmission of shock forces to the building roof and wall. Thereupon the author notes correctly that these shock forces could be isolated. He fails to comment on the vent design on the New Castle County Reclamation Plant, although this design

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has been discussed in the literature [6]. The author did not comment on the fact that any vent design must have provisions for preventing the escape of high-velocity ballistic objects outside the vent—while, at the same time, allowing the rapid opening of the vent when an overpressure is detected. My company has such a design that we are happy to make available to the industry.

I cannot agree with the author that a vent system will “minimize the damages from detonation explosions that cannot be suppressed . . . .” To the contrary, the pressure behind a shock wave is proportional to the square of the Mach number of the shock wave. Thus, a shock wave propagating at Mach 4, will produce a pressure behind the shock of about 214 psig. The only thing that a vent will do for such a wave will be to reduce its reflection back to the shredder. Vents will, however, be effective in releasing gases that are produced by deflagrations that have not been suppressed by water fog or by chemical suppression systems.

I like the basic idea of shredder isolation, but the present problem is to install quick fixes in plants that were initially poorly designed. We do not think that shredding has long-term viability as the first processing step for solid waste. I do not think it wise to imply that any suppression system will be effective at all times in all shred-first plants.

I believe that solid waste should be sorted by air-classification as the first processing step in all new plants. I believe that if one must shred first, then one should install water fog, chemical suppression and vents. Control stations in existing plants should be moved far away from the shredders, and personnel revetments should be provided for personnel who must work in a line-of-sight to the shredding system. An alternative to personnel revetments would be to isolate the shredder by thick walls as suggested by the author. But I will never again be associated with the design of a plant that shreds solid waste as the first processing step.

I like the prelude to the author’s recommendations: “The following procedures are recommended to reduce the probability of shredder explosions, personal injury, and equipment damage.” (emphasis supplied.) The obvious difference between this cautious statement and the title of the paper is noteworthy.

The author has done a service to the industry by once more bringing to our attention the fact that explosions will probably occur in plants that shred solid waste as the first processing step.


REFERENCES


Discussion by

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INTRODUCTION

This paper nicely reviews some basic definitions, causes and general remedies in Shredder Explosion Analysis; therefore, I would like to submit a few observations and theories which have not yet appeared in the industry dialogue.

Dissatisfaction with the trend toward certain remedial nostrums, explosion venting in particular, has prompted this response [1].

The current popular venting criteria for shredders seem too pragmatically based on the literature for closed vessel systems and appears to be over simplified. It considers a singular volume index and a vent area for localized pressure relief only.

Likewise, it ignores certain system configurations and dynamics, i.e.: The shredder feed and discharge openings which serve as undesirable and inevitable vents.

Significant rotor windage which not only assures a pervasive distribution of combustible vapors/dust throughout the system cavities but also provides a turbulent mixing efficiency of combustible and air.

Adding a vent(s) by ducting does not necessarily prevent the feed and discharge openings from acting as alien vents when rotor windage disperses an explosive mixture throughout the contiguous shred-
der cavities, with ignition possible almost anywhere in the entire enclosure.

It is not likely that additional venting can reverse an outbound flame front having an increasing dp/dt and which is approaching a feed or discharge opening.

Therefore, it would make sense to use the feed opening as an intended vent, and to design the system accordingly with the additional venting out the side or roof. (Boyko and Ahlberg of the Ontario Ministry of the Environment appear to have recognized this) [2].

Shredder discharge efflux usually has massive concrete foundation piers on two sides for partial containment, and it is necessary to thoroughly vent any discharge hopper/conveyor/duct enclosures. Also, the building lower walls (or isolated shredder compartments) should be equipped with blow-out panels/vents.

SCENARIOS INSIDE THE SHREDDER, HORIZONTAL TOPFEED MILLS

1. The flammable liquid container is ruptured as it is rejected (bounces off the hammers initially, but finally ingested), the volatile liquid/vapor is dispersed above the rotor by windage vectors:
   - up into the hood cavity;
   - back out the feed opening & through the conveyor shroud tunnel;
   - and/or induced into a dust collection duct.

2. The container penetrates the hammer circle, ruptures almost anywhere inside the mill, with rotor windage dispersing the liquid/vapor:
   - mostly out through the grates with partial mixing/absorption by MSW undergoing attrition;
   - partially upward into the hood & feed opening.

In either case, windage turbulence can be expected to enhance the mixing of combustible and air, with significantly increased and unwelcome combustion efficiency and deflagration pressures [3]. Ignition can be by:
   - metal/metal friction temperature (not necessarily from the culprit container);
   - burning or hot incandescent particles of dry combustible in contact with hot ruptured metal (suddenly exceeding its elastic limit) and fanned by windage [4];
   - fires in the mill from accumulated combustible debris between end discs and housing, etc.

Because of this ineluctable rotor windage, a delayed ignition can allow more thorough mixing and pervasive distribution of an explosive (deflagrating) fuel-air mixture with greater blast scope. Conversely, it might dilute the combination out of ignitable range.

ALTERNATES TO PRIMARY SHREDDING*

Alternates to shredding as a primary size reduction have appeared in several recent installations and are incorporated in a number of forthcoming projects.

The initial size reduction is by a “flail” mill † or a “slow-turning” rotary shear ‡.

Advantages claimed for both are:
   - significantly lower power consumption,
   - minimal pulverized glass,
   - less dust, and
   - lower explosion probability.

Further downstream processing might include classification by air, screens and magnets, with, perhaps, secondary shredding.

FLAIL MILL

The flail mill might, conceivably, pass the smaller flammable liquid (vapor) containers without rupture, but anything larger than a quart would likely be a gamble. Since flail mills are usually of lighter construction than the aforementioned shredder, the possibility of mill damage must be considered.

ROTARY SHEAR

High capacity units (~ 60 tons/hr of MSW) are now being presented to the trade. Heretofore, they have been offered mainly for low capacity industrial and commercial oversize (dunnage, tires, etc.) service.

The rotary shear will surely rupture a flammable vapor container, but there is uncertainty about its ignition source characteristics and a following fire or vapor deflagration, in MSW service.

If insignificant rotor windage is assumed, then the distribution of any flammable vapor should

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* For this discussion, shredding will be considered reduction to a nominal 6 in. topsize, with say a characteristic particle size (63%) minus 3 in. in a Hammermill > 100 rpm.
† A “flail” mill in this context means any type of Hammermill which slightly reduces only the largest of the raw infeed topsizes (“a bag breaker”).
‡ For this discussion, “rotary shear” defines a set of slow-turning (<100 rpm) rotary disc knives.
not be pervasive other than induction into a contiguous dust collection system.

Another scenario might be considered, however. If a container of flammable liquid is ruptured without ignition and the contents is mixed and absorbed by MSW, would the agitation of downstream processing (trommel screen, secondary shredder, etc.) release sufficient ignitable vapor for at least a flash fire?

A somewhat similar “leaking can” rationale has been claimed as the cause of a recent major MSW process plant deflagration.

REFERENCES


