A BRIEF DISCUSSION OF TWO RECENT MAGAZINE ACCIDENTS AT THE NAVAL SURFACE WARFARE CENTER

by

M. M. Swisdak, Jr.
Indian Head Division/Naval Surface Warfare Center

ABSTRACT

On 28 June 1992 there were two explosions in a Hazard Division 1.1 magazine at the White Oak Detachment of the Naval Surface Warfare Center. On 1 August 1994, a Hazard Division 1.3 magazine at the Indian Head Division of the Naval Surface Warfare Center was destroyed by fire and explosion. This paper will describe both events. It will first describe the magazines and then describe the damage produced by the events. From this damage, estimates of the explosive yields involved are deduced. Finally, the paper will discuss in most general terms the causes of both events and any associated issues.

EVENT DESCRIPTIONS

White Oak. On Sunday, 28 June 1992, an explosive incident occurred at the White Oak Detachment of the Naval Surface Warfare Center. Magazine 355 was destroyed by two explosions. The first event occurred at about 1300 hours Eastern Daylight Time and was followed by a second, significantly larger, event approximately two minutes later. After hearing and feeling the first blast, nearby eyewitnesses (from as close as 800 feet) observed a dark plume rising from the direction of the magazine and heard firecracker-like popping sounds. The witnesses did not observe any flying debris from this first event. The second blast was contrasted from the first by a heavy shower of debris. A dark grayish-brown cloud ascended approximately 500 feet into the air.

Indian Head. On Monday, 1 August 1994, an explosive incident occurred at the Indian Head Division of the Naval Surface Warfare Center. Magazine 518 was destroyed by explosion and fire. The incident consisted of at least five separate events with the first occurring at about 2225 Eastern Daylight Time. As described by eyewitnesses, these events were:

(i) rumble/thunder/large fire
(ii) fireworks/thunder/rocks hitting metal
(iii) explosion/sharp crack
(iv) small explosions/rumbling thunder
(v) major fire

Report Documentation Page						*Form Approved* *OMB No. 0704-0188*
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1. REPORT DATE **AUG 1996**		2. REPORT TYPE			3. DATES COVERED **00-00-1996 to 00-00-1996**	
4. TITLE AND SUBTITLE **A Brief Discussion of Two Recent Magazine Accidents at the Naval Surface Warfare Center**					5a. CONTRACT NUMBER	
					5b. GRANT NUMBER	
					5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)					5d. PROJECT NUMBER	
					5e. TASK NUMBER	
					5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center,Indian Head Division,101 Strauss Avenue,Indian Head,MD,20640-5035**					8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR’S ACRONYM(S)	
					11. SPONSOR/MONITOR’S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**						
13. SUPPLEMENTARY NOTES **See also ADM000767. Proceedings of the Twenty-Seventh DoD Explosives Safety Seminar Held in Las Vegas, NV on 22-26 August 1996.**						
14. ABSTRACT **see report**						
15. SUBJECT TERMS						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**15**		

Events (i) and (ii) lasted about 30 seconds; Events (iii) through (iv) lasted an additional 30 seconds. The entire process (Event (i) through Event (v)) lasted approximately 15-30 minutes. Several witnesses reported seeing an extremely bright light that illuminated the area "like daytime."

MAGAZINE DESCRIPTIONS

White Oak. Magazine 355 was a reinforced concrete, earth-covered structure constructed in 1951. Figure 1 shows some details associated with the structure. Figure 2 is an exterior photograph of Magazine 353. This structure was adjacent to Magazine 355 and was constructed at the same time using the same plans. In appearance, it is identical to Magazine 355.

At the time of the accident, the explosive limit for the structure was 7,000 pounds of Hazard Division (HD) 1.1 material. The magazine was located within the magazine complex at White Oak (Monroe Loop) and had an Inhabited Building Distance (IBD) of 1250 feet.

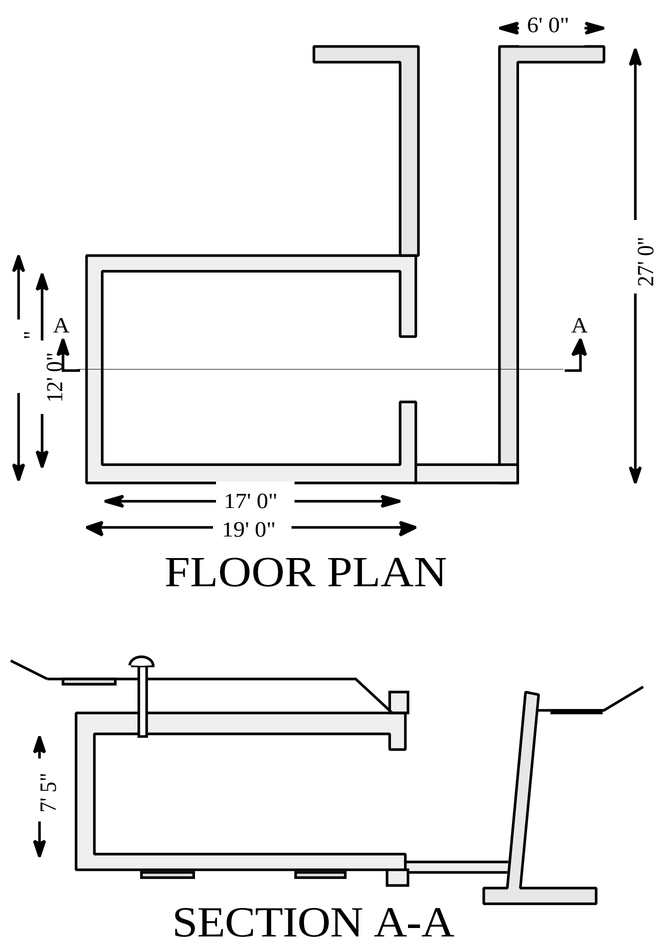

FIGURE 1. MAGAZINE 355 LAYOUT

FIGURE 2. EXTERIOR OF SIMILAR STRUCTURE

Indian Head. Magazine 518 was a nonstandard, aboveground, non-barricaded structure constructed in 1942. It was 52 feet wide and 102 feet long; the walls were constructed of four courses (thicknesses) of brick; the roof was transite (a construction material made from a mixture of 1-40% asbestos in Portland cement) supported by a steel truss frame and the floor was reinforced concrete (approximately 5" thick) over compacted earth. Figure 3 is a sketch of the layout of the building. Figure 4 shows two exterior views of another magazine whose appearance is identical to Magazine 518.

When the accident occurred, the structure was site-approved for the storage of 500,000 pounds of HD 1.3 material with an IBD of 600 feet.

MAGAZINE CONTENTS

White Oak. As indicated previously, Magazine 355 had an explosive limit of 7,000 pounds of HD 1.1 material. At the time of the accident, the Net Explosive Weight (NEW) of the contents was estimated to be 4,400 pounds. After a final inventory, this estimate was revised to a weight of about 5,180 pounds of HD 1.1 material. The inventory included, but was not limited to, detonation cord, gap test tubes (including both large scale and expanded large scale sizes) and test charges for various experimental programs.

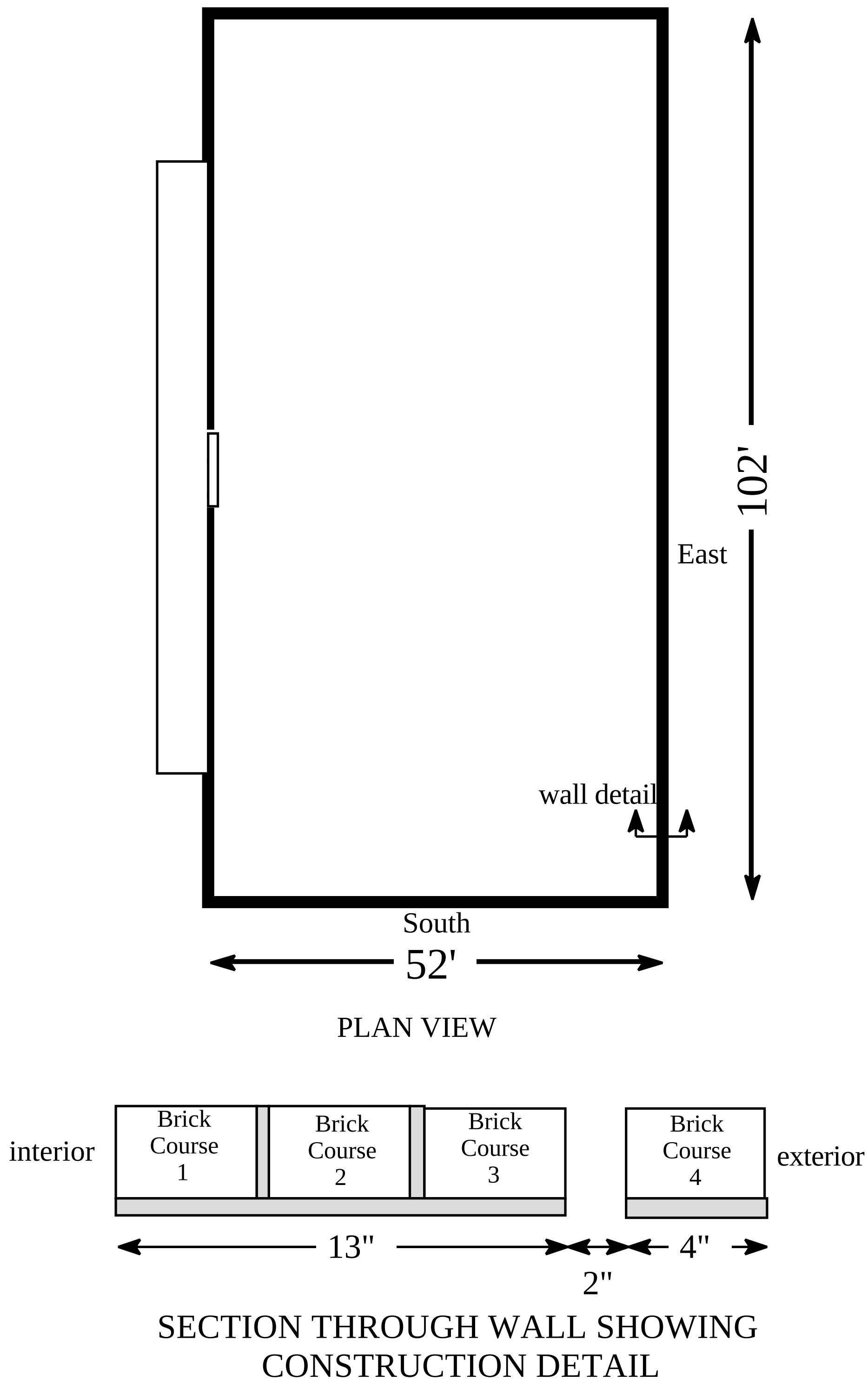

FIGURE 3. MAGAZINE 518 ARRANGEMENT

FIGURE 4. STRUCTURES SIMILAR TO MAGAZINE 518

Indian Head. Magazine 518 had an explosive limit of 500,000 pounds of HD 1.3 material. Based on a final inventory completed some time after the accident, the amount of energetic material in the magazine at the time of the accident was 98,131 pounds. Of this amount, 93,522 pounds was HD 1.3 material and 4,609 pounds was HD 1.1 material.

The majority of the materials stored in the magazine were bulk powders and propellants, held primarily as Government Furnished Material (GFM) for cartridge-actuated device/propellant-actuated device (CAD/PAD) contractor production. The structure also contained energetic materials returned from GFM CAD/PAD contractors that were excess to the contractors requirements.

The HD 1.1 material identified as being present at the time of the accident was improperly stored. This material was pyrotechnic/propellant material for which the hazard classification was in question. According to the Navy's Transportation and Storage Data for Ammunition, Explosives, and Related Hazardous Materials manual[1], the material had a hazard classification of HD 1.3. However, the Joint Hazard Classification System (JHCS)[2] from which Reference 1 is derived, indicates that the hazard classification is HD 1.1. The proper classification is HD 1.1.

DESCRIPTION OF THE DAMAGE

White Oak. Magazine 355 was destroyed. Debris and unexploded ordnance were scattered by the explosion and landed throughout the facility--resulting in several brush fires in and around the magazine area. Large debris (pieces of concrete 1-2 feet in diameter and various lengths of reinforcing bar) was thrown up to 800 feet. Smaller debris (concrete pieces up to 4 inches in diameter) was thrown as far as 2000 feet. Windows were broken out to ranges of about 2000 feet.

The radius of complete destruction was limited to the immediate vicinity of the magazine itself. Figure 5 contains two photographs that show the damaged area in and around the magazine. The explosions removed all of the earth cover and the structure itself--down to the depth of the floor slab. The floor slab was broken into several pieces. Some of these pieces were driven several feet into the earth below their original location. Large portions of the slab were missing entirely. Figure 6 is a plot of the crater and the remains of the floor slab. Superimposed on this plot is an outline of the original building. Figure 7 is a more detailed view of the floor slab--showing the locations of the pieces that remained after the accident. The origins of the coordinate systems used in Figures 6 and 7 have been translated to the center of the original floor slab. The average radius of the crater that was formed was 32.4 feet. No depth determination was possible.

Indian Head. The structure was damaged beyond economical repair but was not totally destroyed. Figures 8 and 9 present two aerial views of the remains of the structure. Approximately two-thirds of the West wall and one-third of the East wall were destroyed. The South wall was totally destroyed. The foundation below the South wall was bowed outward by as much as 12 inches. There was spalling evident over an 8-10 foot diameter area on the South foundation. Also present on this foundation were black striated deposits as well as cracks radiating from the center of the spall.

FIGURE 5. MAGAZINE 355 DAMAGE

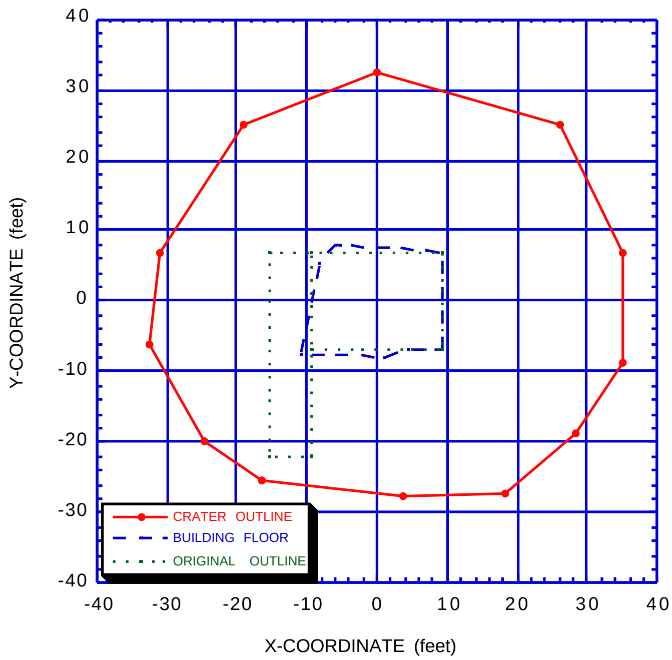

FIGURE 6. MAGAZINE 355 CRATER AND FLOOR OUTLINE

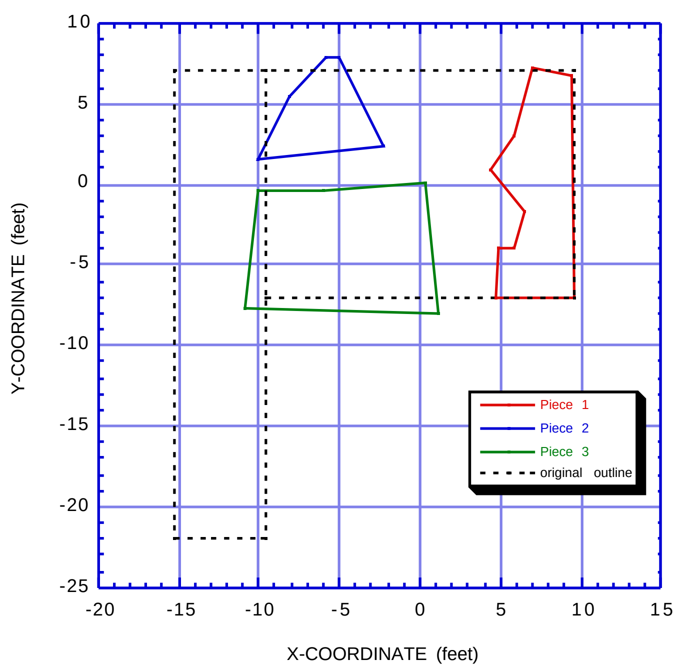

FIGURE 7. MAGAZINE 355--FLOOR SLAB PIECES

FIGURE 8. MAGAZINE 518 (NE TO SW VIEW)

FIGURE 9. MAGAZINE 518 (SW TO NE VIEW)

The East end of the South wall cracked away from the South end of the East wall. The Northeast (NE) corner of the East wall was bulging outward 2-3 inches. The NE corner of the North wall was pushed outward 4-6 inches. One of the roof trusses was thrown approximately 250 feet from its original position. Figure 10 shows four views of the damage that the structure received.

A crater was formed in the Southeast (SE) corner of the building. The crater was oblong with the following nominal dimensions: 3’1” deep at its center, 7’1” East-to-West, and 4’2” North-to-South. The center of the crater was located 6’11” from the exterior of the South wall and 12’1” from the exterior of the East wall. The floor was depressed along the entire width of the South wall. In addition to the primary crater, smaller craters were also observed along the South wall. Figure 11 is a profile of the floor taken along the South wall.

Structural damage beyond the ground zero area consisted of damaged roofs, damaged siding, and broken windows. Two buildings experienced damaged roofs. The farthest range of this damage was approximately 1000 feet. Siding was damaged on one building at a range of about 700 feet. Six buildings experienced window breakage with the farthest being at a range of 1500 feet.

YIELD ESTIMATES AND EVENT LOCATIONS

Information such as window breakage ranges and crater dimensions may be used to estimate the amount of HD 1.1 material that would be required to produce the various effects. Crater locations and dimensions may also provide insight into the locations of the materials involved in the event(s).

White Oak. Based on the crater dimensions shown in Figure 6, the yield is estimated to be between 3,000 and 5000 pounds of HD 1.1 material[3]. This estimate cannot be refined further because of the construction of the magazine itself--earth covered on and partially built into an earthen bank.

Window breakage is a probabalistic phenomena. Threshold or incipient window breakage seems to occur at a pressure level of approximately 0.029 psi (200 pascal). As the pressure increases, the probability of window breakage increases. The relationship between incident pressure level and window breakage probability is taken as a hypergeometric function that has been documented in the literature. Window breakage is also a function of the size of the window and the type of glass employed. For purposes of yield estimation, let us assume a breakage probability of 1% and an average window area of 1 square meter. With these assumptions, a 1% breakage probability corresponds to a pressure level of 0.11 psi[4]. Using an extrapolation of a pressure-distance curve generated for earth covered magazines, a pressure level of 0.11 psi corresponds to a scaled distance of 130 ft/lb$^{1/3}$. At a range of 2000 feet, this would require a charge weight of about 3,600 pounds[5].

FIGURE 10. MAGAZINE 518 REPRESENTATIVE DAMAGE

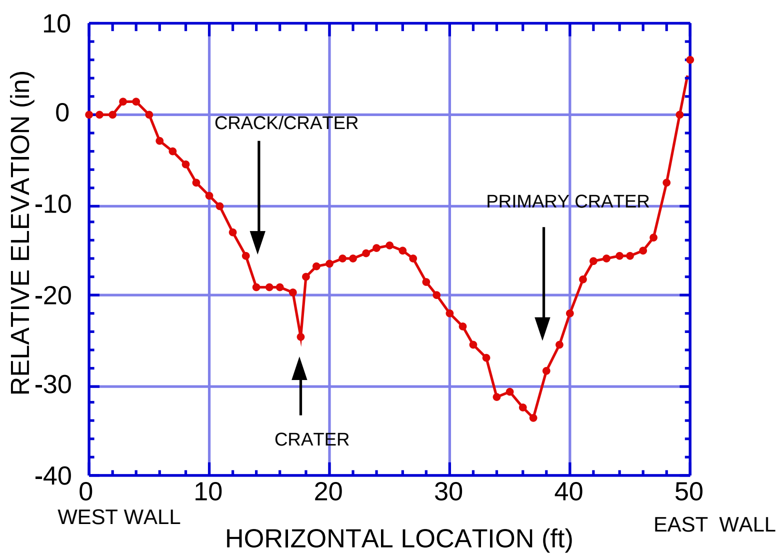

FIGURE 11. BUILDING 518 FLOOR PROFILE (PROFILE TAKEN ALONG SOUTH WALL)

As indicated previously, the location of the floor slab pieces are shown in Figure 7. Only about 62% of the original floor material remained in the crater. The floor directly under the explosion should suffer the greatest damage. If so, then Figure 7 shows that most of the material that detonated was located in a T-shaped pattern, with the crossbar of the Tee located about 10 feet from the door.

Indian Head. The only crater parameter available is the crater depth. This parameter is dependent upon the floor material, the explosive weight, and the height of the explosion above the floor. In our situation, this parameter may not provide a good estimate of the yield. Further, there are limited data on cratering in a layered medium such as we have here.With these constraints, the best estimate of the yield is between 200 and 2000 pounds of HD 1.1 material.

The brick construction used in this structure should not cause appreciable attenuation in the airblast produced. If this is the case, hemispherical surface burst data can be used to estimate the pressure-distance curve. If we use the same pressure level of 0.11 psi for 1% window breakage (see previous section), a scaled range can now be estimated. This scaled range is 225 ft/lb$^{1/3}$, corresponding to a 300-pound yield for window breakage at a range of 1500 feet[6].

OTHER INFORMATION

White Oak. Several bags of explosive scrap material could not be located after the accident. It is postulated that this material had been placed inside Magazine 355. This material was of unknown stability and should have been placed into segregated storage. In an attempt to determine the cause of the trigger events, the origins of this scrap material were examined in great detail. It was found that this material contained the remnants of several experimental explosive compositions. When these compositions were studied, it was found that several had the tendency to become unstable and give off gas. The hypothesis is that some of this material provided the trigger event for the larger explosion.

Indian Head. Some material identified on the inventory as present in Magazine 518 at the time of the accident was nitrocellulose (NC)-based material.s. At the time of the accident, the magazine contained propellants of unknown stability as well as propellants which were not in surveillance program.

Given the chemistry of NC, knowledge of past incidents involving autoignition of NC and the presence of NC with unknown stabilizer content, lacking other credible source of ignition, the most probable cause for the Magazine 518 fire was the autoignition of a NC-based propellant.

The locations of the craters that were formed in the floor correspond to the storage locations of much of the HD 1.1 material found to be present in the structure.

PROPOSED SEQUENCE OF EVENTS

White Oak. The trigger event most probably was an exothermic reaction in an experimental mixture of unknown stability. The heat released led to a cookoff reaction in some material present (the first explosion). This explosion produced additional heat and fire--leading to the second, larger explosion. After the trauma of the first event and the potential sensitization of the remaining materials, the second event involved most of the contents of the magazine.

Indian Head. The most likely sequence of events would describe a low-intensity fire caused by the autoignition of an NC-based propellant. The fire spreads and soon involves a relatively large quantity of Magnesium Teflon Viton (MTV) flare material, which in turn creates an intense boost to the fire. There soon follows the first and largest of the detonations near the Southeast corner of the structure. In short order, a series of smaller detonations occur along the south wall. The remaining materials burn until consumed, and the fire extinguishes itself by burning out.

OTHER ISSUES

Another issue arose because of the Indian Head accident. The roof of the structure was an asbestos-based material. As a result of the accident, this material was broken up and dispersed throughout the accident site. The Maryland Department of the Environment (MDE) determined that the transite fragments were brittle or easily crumbled and, thus, easily released, and therefore an asbestos hazard. After negotiations with MDE over compliance with Maryland environmental regulations and laws, cleanup procedures that would meet the Explosive Ordnance Disposal (EOD) requirements and still meet Maryland environmental concerns were developed.

The cleanup process was divided into three phases:

- Phase I. Pickup of propellant and debris outside the asbestos control zone--an area immediately surrounding the magazine.
- Phase II: Pickup of propellant and debris inside the asbestos control zone.
- Phase III: Pickup of propellant and cleanup of building rubble.

During Phase I, EOD were required to wear cotton gloves and receive a hazard control briefing. During Phase II, EOD personnel were required to wear total body coveralls, cotton gloves, and properly fitted/tested half-face respirators with filters. They had to complete a three-step decontamination process leaving the control zone. Only the latter, three stage decontamination process was relaxed for investigators. Heavy equipment was washed down daily. After EOD personnel removed all of the energetic material, Phase III of the clean-up involved the removal of heavy rubble--a task performed by a contractor.

During and after the clean-up, the concerns of the local community centered much more on the environmental or asbestos-related issues rather than on explosive safety issues.

DISCUSSION

In both accidents, the structures and the associated explosive siting rules functioned appropriately. The damage observed at IBD was no greater than that described in the Standards. The structures prevented propagation to adjacent storage locations. There were no injuries and no loss of life.

The presence of HD 1.1 material in Magazine 518 did not cause the accident nor was it the likely source of the trigger event. The majority of the damage observed to Magazine 518 was the result of the intense fire--not the detonations of the HD 1.1 material. Even if there were no HD 1.1 material present, the accident would have still occurred and the structure and its contents would have been destroyed

The major lesson learned from the White Oak explosion investigation was that the stowage of unstable or uncharacterized materials in magazines with other materials can lead to disastrous consequences. This same lesson can be derived from the Indian Head accident. The Magazine 518 accident points out the fact that "uncharacterized materials" or "materials of unknown stability" are not just those resulting from new formulations. They also include materials that should be under surveillance programs but are not.

The Indian Head accident also demonstrates another potential problem area that has not been addressed. Many explosives storage structures contain or are constructed with material that contain asbestos. If the Indian Head experience is not to be repeated, environmental cleanup and hazardous waste procedures should be incorporated into all disaster plans and contingencies. If further information in this area is required, contact should be established with the Indian Head Division of the Naval Surface Warfare Center. Moreover, EOD personnel should also consider the possibility of asbestos-contamination in their training.

REFERENCES

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