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Naval Sea Systems Command
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From: Commander, Naval Sea Systems Command

Subj: NAVSEA SW020-AD-SAF-010, FIRST REVISION, "EXPLOSIVES SAFETY ACCIDENTS AND LESSONS LEARNED" OF 15 SEP 09

Ref: (a) NAVSEA SW020-AD-SAF-010 of 15 Apr 05

1. This letter issues Revision One of the subject publication. Revision One supersedes reference (a), which should be destroyed.

2. NAVSEA SW020-AD-SAF-010 provides the background of actual case histories and illustrations of ammunition and explosives mishaps. Each description of an incident is followed by a lesson to be learned, which outlines the necessity for strict adherence to established explosives safety precautions. Four recent mishaps/lessons learned have been added with Revision One. One of these, Mishap 9-4, which addresses the safety issue of complacency, is illustrated with a video of the incident.

3. This revision includes a new chapter, "Origin of Ordnance Safety Tests", which provides the history and importance of ordnance threat hazard assessment. The content of the new chapter 11 is based upon a study conducted in 1997 for the Combat System Safety Engineering Division, Naval Surface Warfare Center Dahlgren Division.

4. Another significant change occurring with this manual is the reorganization of the Mishap Index found in Appendix A. The list of mishaps outlined in the subject manual can now be referenced by the safety issue requiring corrective action, such as complacency, failure to follow standard operating procedures, etc.

5. It is intended that this manual be continually updated with new data as it occurs. A repository of historical information has been established with the publication of this manual;

however, both new and old information and illustrations are continuously solicited. Feedback and input are strongly encouraged. For feedback/input, the point of contact is Jeri DiMaggio, Naval Surface Warfare Center Indian Head Detachment Earle (E421), DSN 449-2976, Commercial (732) 866-2976 or e-mail jeri.dimaggio@navy.mil.

6. The Naval Ordnance Safety and Security Activity's point of contact for this manual is Margaret Hayes (N522), DSN 354-5634, commercial (301) 744-5634, or email: margaret.hayes1@navy.mil.

LAURA M. DESIMONE
By direction

Distribution:
Explosives Safety Technical Manual (ESTM) CD-ROM
Distribution List

FIRST REVISION

TECHNICAL MANUAL

EXPLOSIVES SAFETY ACCIDENTS AND LESSONS LEARNED

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15 SEPTEMBER 2009

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LIST OF EFFECTIVE PAGES

The total number of pages in this manual 148. They are all Revision One pages. The date of issue for all pages in this manual is 15 September 2009.

FOREWORD

1. NAVSEA SW020-AD-SAF-010 combines the former NAVSEA OP 3347, Second Revision, "United States Navy Ordnance Safety Precautions" of 1 Jul 68 and NAVORD OP 1014, Third Revision, "Ordnance Safety Precautions, Their Origin and Necessity" of 15 Aug 72. Both NAVSEA OP 3347 and NAVSEA OP 1014 are canceled.

2. This publication is not intended to supersede, contravene, or modify any Federal, state, municipal, or local laws and their supplements. If any provision of this publication appears to conflict with any other published regulation, this fact should be reported in detail to the Naval Ordnance Safety and Security Activity (NOSSA) (N5).

3. Changes to this manual will be issued as required. Comments or suggestions relative to material to be included in such changes should be forwarded as specified in chapter 1.

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CHAPTER 1

INTRODUCTION

1-1. PURPOSE. This manual establishes the origin and need for safety precautions for operations involving Navy and Marine Corps ammunition, explosives and related hazardous materials. Mishaps which have occurred aboard ship and at ordnance handling activities identified past shortcomings in explosive safety procedures. Such accidents and incidents warranted immediate establishment of specific operating procedures and safety requirements. In conjunction with NAVSEA OP 4, "Ammunition Afloat" and NAVSEA OP 5 Volume 1, "Ammunition Ashore," this manual provides examples of historical mishaps that illustrate the need for explosives safety precautions. The illustrations and case histories describe events that result from non-compliance with stated safety precautions.

1-2. SCOPE. This manual is intended for all Navy and Marine Corps personnel to emphasize ordnance safety precautions and further accident prevention programs where military and/or civilian personnel are stationed or employed and ordnance equipment, ammunition and explosives are used and/ or stored. These safety precautions apply to explosive and non-explosive ordnance material and equipment located ashore and afloat in facilities and units of the U.S. Navy and Marine Corps. The term ammunition as used in this manual refers to all types of non-nuclear items of ammunition used in naval service designed to be fired from guns, tubes, or launchers; dropped from ships or aircraft; placed in static position by personnel; or fired by individual troops ashore. It includes all such items which contain explosives, incendiary or pyrotechnic material, chemical agents, propellants of all types, and combinations of these. Illustrations and case histories in this manual are from actual accidents which have occurred.

1-3. GENERIC CLASSES OF MISHAPS. During their life cycle, explosive substances may be exposed to conditions which can cause them to become unserviceable or to react and cause damage to the immediate area. Many explosive related accidents or incidents do not result in the mass detonation, deflagration or burning of the item. In many instances an expensive ordnance item, or its required container, is rendered unusable for combat or training. In addition, the time, effort and expense of proper disposal of the item is incurred. Some of the more prevalent situations include:

1-3.1. ROUGH HANDLING.

a. Dropping of an item, during handling, beyond a specified threshold distance

b. Puncture of the protective case or the item by a fork or a forklift

c. Rough handling which results in dents, cuts, bends, or other deformity

d. Impact due to the fork of a forklift

e. The impact of a bullet or piece of shrapnel

f. The impact from the dropping the explosive item

g. The impact from the dropping of another item on the explosive item

h. Friction due to rubbing or dragging

i. Energy from the detonation of an adjacent explosive

1-3.2. IMPROPER PROCEDURES.

a. Electrical discharge generated by a moving vehicle

b. Electrical discharge due to an improper tool

c. Static electricity discharge due to improper grounding

d. Static electrical charge due to movement of explosive components

e. Static electrical charge due to dragging

f. Exposure to high powered Radio Frequency (RF) fields

g. Heat and friction due to operations in areas containing explosive dust

h. Static electrical discharge from an explosives and ammunition worker in a plant

i. Contamination with chemicals (especially alkalis), foreign materials or other non-explosive components

j. Unauthorized smoking by workers in explosives and ammunition areas

k. Improper handling at very low temperature

l. Static charge generated by the motion of granular or powdered explosives

1-3.3. EXCESS EXPOSURE.

a. Heat generated by a fire

b. Self heating due to a combination of improper storage, poor ventilation and high temperature

c. Exposure to unauthorized “open flames”

d. Exposure of items to conditions which cause corrosion and deterioration

1-3.4. NATURAL EVENTS.

a. Heat generated by a lightning strike

b. Prolonged storage at very high or very low temperatures

c. High solar radiation

1-3.5. BYPRODUCTS OR RESIDUE.

a. Of explosive dusts, vapors and fumes

b. Of solid and liquid propellants

c. Of pyrotechnics

d. Leakage and exudate of explosive byproducts

1-4. LESSONS LEARNED. All explosive incidents and accidents are to be reported as described in paragraph 2-2, which includes establishing an explanation as to the cause of the mishap. The reason for such an effort is so that a lesson may be derived from past experience, thereby attempting to eliminate the potential for a repeat mishap. Some tragedies may never be fully explained. Due to the unpredictable nature of explosives and the constant potential for mishap, those personnel performing explosives operations must be ever vigilant of established safety precautions and standard operating procedures.

MISHAP 1-1: In April 1989, an explosion occurred in Turret 2 on the battleship U.S.S. *Iowa* (BB-61). Bag charges which had been loaded into the 16-inch, 50-caliber center gun of the turret were ignited prematurely with the breech still open, producing violent blast effects, severe heat, and extremely toxic gases throughout the turret from the gun rooms down to the powder handling platform at the turret's base. All 47 men in the turret were killed.

In the years that followed, several comprehensive investigations explored the many possible factors which may have lead to this disaster. However, although a variety of scenarios for the incident were explored, they remained unproven for lack of evidence, partially due to the violence of the explosion and fire. Because of this, it may be difficult to ever fully resolve the many unknowns and develop a clear and unambiguous explanation of the events that occurred onboard the U.S.S. *Iowa*.

1-5. ORGANIZATION AND USE OF THIS MANUAL. This manual consists of ordnance precautions for the following areas:

a. General ammunition and explosives safety

b. Classifying, marking and identifying

c. Handling

d. Storage/stowage

e. Preparation for shipping and ammunition in transit

f. Checkout and testing

g. Prefiring, firing and postfiring

h. Ordnance maintenance, repair, modification and rework

i. Demilitarization and disposal

Throughout the manual, specific explosives safety precautions are given, then are exemplified by either a recent or historical explosives mishap and the lesson learned. The mishap, marked within the text by this symbol: annotates the need for strict compliance with safety precautions for each area.

1-6. INDEX OF MISHAPS. A list of the mishaps described in this manual is provided in appendix A. Each mishap is electronically linked to its location within the manual.

1-7. DEFINITIONS AND ABBREVIATIONS. Definitions and abbreviations applicable to this manual are listed in a separate file on this CD-ROM.

1-8. REFERENCE DOCUMENTS. A list of documents containing all types of information and data that are applicable to and referenced throughout this publication is presented in a separate file on this CD-ROM. These documents, together with station instructions and notices, technical publications, and Standard Operating Procedures (SOP's) shall be maintained in appropriate libraries as a collection of current information pertaining to storage of ammunition and explosives. These documents are essential for complete understanding of the safety regulations contained in this manual.

1-9. REPORTING DEFICIENCIES IN MANUAL. Ships, training activities, supply points, depots, Naval shipyards, and supervisors of shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA technical manuals. All errors, omissions, discrepancies, and suggestions for improvements to NAVSEA technical manuals shall be reported to Commander, Naval Surface Warfare Center Port Hueneme Division (NSWC/PHD) (Code 312), 4363 Missile Way, Port Hueneme, CA 93043-4307 on NAVSEA Technical Manual Deficiency/Evaluation Report (TMDER), Form NAVSEA 4160/1. A copy of Form NAVSEA 4160/1 is included at the end of this manual. For activities with internet access, this form may also be completed and processed using NSWC/PHD website: https://nsdsa2.phdnswc.navy.mil. To expedite a response, also send as an email to jeri.dimaggio@navy.mil. All feedback comments shall be thoroughly investigated and originators will be advised of their outcome. If you prefer to submit a TMDER using a word file, click here.

TMDER

1-10. DATE OF PUBLICATION. The date of publication of this technical manual, and of revisions and changes thereto, as shown on the title page, is the estimated date the publication is to be distributed. The manual, revision, or change is however effective upon receipt, regardless of the date shown on the title page.

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CHAPTER 2

AMMUNITION AND EXPLOSIVES SAFETY PRECAUTIONS

2-1. ORDNANCE ACCIDENTS/INCIDENTS. Complete understanding and strict adherence to specified safety regulations are necessary to avoid unsafe acts and conditions that cause preventable accidents. Repeated work is likely to become routine and lead to carelessness. Therefore, constant alertness on the part of the employee and close supervision by the supervisor must be maintained to prevent accidents in ordnance operations. As ordnance is designed to kill and destroy, it is dangerous and shall be treated so at all times. Accidents and incidents are brought about, for the most part, by the failure of personnel to know and strictly observe existing safety precautions. The leading causes of explosives mishap reports (EMR's) and conventional ordnance discrepancy reports (CODR's) are the following:

a. Lack of training

b. Improper procedures or failure to follow procedures

c. Improper handling

d. Lack of proper attention

e. Inattention to detail

f. Complacency

Figure 2-1 illustrates an actual situation where a cutting torch was used to cut an access opening through a bulkhead of a ship into an ammunition magazine in order to more readily remove the ammunition it contained. While no accident occurred, such an act is in gross violation of safety precautions and safety regulations and a perfect example of lack of knowledge and carelessness.

2-2. ACCIDENT INVESTIGATION AND REPORTING. All accidents, incidents, or explosive mishaps that involve ammunition or explosives shall be investigated and reported in accordance with OPNAVINST 5102.1 (series) and OPNAVINST 3100.6 (series), if applicable, or MCO 5102 (series) for Marine Corps activities. An investigation shall be conducted to determine cause and resulting losses, and to formulate corrective measures to prevent recurrences. Information obtained by the investigation shall be reported using the format contained in OPNAVINST 5102.1 (series) or MCO 5102 (series) for Marine Corps activities. Fires at shore activities and injuries or deaths associated with these fires shall be reported in accordance with OPNAVINST 5102.1 (series).

FIGURE 2-1. An Unauthorized Short Cut to Offloading Ammunition

2-3. STANDARD OPERATING PROCEDURES. A common cause of shipboard incidents was not having the evolution checklist on board; that is, written procedures were not available. The Standard Operating Procedure (SOP) is the required document by which activities integrate ordnance processing tasks for the workers conducting the process. The Commanding Officer is responsible for developing, validating, approving, reviewing and using SOP's for processing ordnance at the activity or aboard ship. Each process shall comply with the technical requirements, explosive safety standards, personnel qualification and certification requirements, Navy Occupational Safety and Health (NAVOSH) standards, federal, state and local environmental protection requirements and security and physical security directives. Existing and potential hazards inherent in processing ordnance or ordnance components must be clearly identified and minimized. Where necessary, emergency response, evacuation and contingency plans associated with ordnance processing must be developed, implemented and rehearsed.

MISHAP 2-1: The petty officer in charge of four ordnancemen organized them into two-man teams and assigned "release and control checks" to each team. They carried their checklists to the line area and started work on the dailies. Five aircraft checked out properly.

The teams took a break for a quick cup of coffee before finishing up the remaining aircraft. When they finished their coffee, however, they left the checklists behind in the shop. The teams proceeded to check the remaining aircraft with what they thought was the proper sequence of steps: station select; master arm on; pickle; pull pin and ... Bang! The aft end of the fully loaded drop tank fell to the deck. The bomb rack safety pin had been partially pulled, allowing the cartridge-activated devices (CADs) to fire and release the aft hooks. "Who was supposed to dearm the aircraft?" and "I thought it was done already!" were comments overheard.

Two AE's had been working by the main mount on a gripe. The falling tank narrowly missed them. There were no personnel casualties. Material damage amounted to $4,500.

This episode is a typical example of complacency and lack of supervision. Proper supervision and the applicable checklists are mandatory for conducting a safe ordnance evolution, no matter how routine the task.

MISHAP 2-2: An AO2 was directed to take his crew to the ready service locker area and build up some Mk 76 Mod 6 practice bombs for the day's flight schedule. When he arrived at the build-up area, an AO3 team member lined up a number of practice bombs on a utility trailer. This would make it easier to insert the Mk 4 Mod 3 signal cartridge, the firing pin assemblies (strikers), and the securing cotter pins. One practice bomb seemed to have some rust in the nose of the cartridge cavity; this prevented the cartridge and firing pin assembly from seating properly. The AO3 could not insert the cotter pin through the bomb body because the firing pin assembly wouldn't clear the holes.

The next step should have been to remove the firing pin assembly and the cartridge, then use a bore gauge to check for proper clearance. The AO3 decided to try to seat these items, however, by tapping them into place with a No. 2 Phillips screwdriver and using a "MER Tool" as a hammer. As he pounded away, the cartridge exploded.

The explosion broke the screwdriver into three pieces and caused severe injury to the petty officer's left hand, amputating his left ring finger at the first joint. He also suffered a fractured little finger and multiple tendon damage to the same hand.

Investigations revealed that the injured man had experienced a similar problem with a practice bomb the day before and had used the same method to solve it. He had gotten away with it then and gained confidence that this short cut would work again.

Never deviate from prescribed procedures for handling ordnance. Corrosion in the cartridge cavity has been a chronic problem ever since the Navy started using practice bombs. A bore gauge was developed to keep people from having to guess if the cartridge will seat.

MISHAP 2-3: In January 1962, at a naval ordnance station, an explosion occurred during an attempt to shut down a chemical distillation process involving dinitrofluorethane (DAPHNE). An exothermic reaction developed during the distillation process and the pot temperature increased over the bath temperature. When this was noted, the chemical engineer immediately started shutting down the distillation by adding cold water from the condenser into the bath. He then started to reduce the vacuum by purging. This led to the admission of air before the flask was sufficiently cool, resulting in an explosion between the air and the products of the chemical reaction. The compound involved was dinitrofluorethane. One civil service employee was killed and two others injured. There was major material damage to the building and its contained equipment. Figure 2-2 illustrates damage to the building in which the explosion occurred.

The cause of the accident was given as personnel error involving failure to follow Standard Operating Procedures (SOP's) in regard to shutdown of the process in progress. This is another instance where a fatal accident resulted by failure to comply with specific procedures and regulations.

2-4. RESPONSIBILITY FOR SAFETY. Explosives safety shall be implemented and maintained at Navy and Marine Corps activities by those parties described in detail in NAVSEA OP 5 Volume 1 for Navy and Marine Corps activities ashore and NAVSEA OP 4 for units afloat. Since operating personnel are the first lines of defense in identifying workplace hazards when involved in ammunition and explosives evolutions, they shall read, understand, and strictly observe all safety standards, requirements, and precautions applicable to their work or duty.

MISHAP 2-4: In January 1993, a BM3 relieved the Petty Officer of the Watch and took custody of the .45 caliber pistol. The pistol was unloaded at the time of watch turnover, but the BM3 later loaded the pistol with one magazine containing five rounds without the knowledge or orders of anyone else. He did not realize a round had chambered. He noticed that the weapon was cocked and while he attempted to release the hammer, the weapon discharged through the holster. The round passed through the BM3's foot, fracturing two bones. Surgery was performed at a local hospital.

The BM3 stated that he loaded his weapon due to the "terrorist threat". There was no terrorist threat, nor was he told that there was one when he assumed the watch. He exceeded the limits of his authority when he decided to load his weapon. The BM3 was qualified as Petty Officer of the Watch and qualified in small arms (including the .45 caliber pistol), but stated that he didn't feel he was "trained as well as he should have been" in the use of his weapon.

Frequent reviews of the rules governing authority to load weapons and the use of deadly force prevents misunderstandings on the part of armed personnel on the limits of their authority to act without direction in the use of their weapons. Persons in leadership positions should be alert for signs of reticence or unfamiliarity on the part of any subordinate.

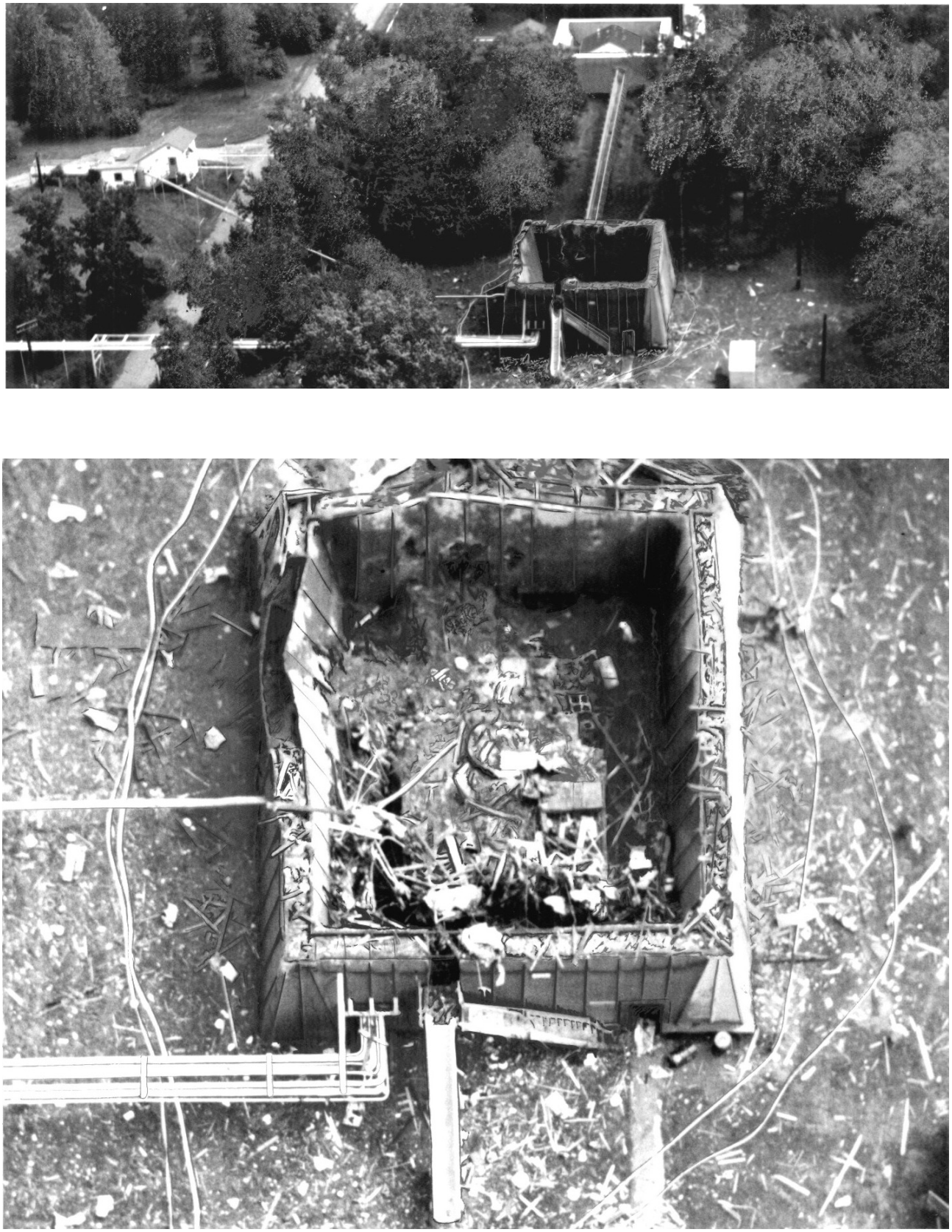


FIGURE 2-2. Results of an Accident Which Occurred During a Chemical Distillation Process

2-5. PRINCIPLES OF OPERATIONAL RISK MANAGEMENT (ORM). Hazards can be minimized in seemingly mundane tasks by applying the five steps of operational risk management prior to commencing work. Navy ship and shore personnel deal with unique hazards and risks, especially in the realm of explosives ordnance where exercising good judgment is crucial to safe and effective operations. Using the ORM technique as established by OPNAVINST 3500.39/MCO 3500.27 (series) is especially useful in high-risk environments. The five steps involved in ORM are as follows:

a. Identify hazards. A hazard can injure or kill people or make them sick, damage or destroy equipment and property, or keep them from completing the mission.

b. Assess hazards. Examine each hazard in terms of probability and severity to determine what the level of risk is when exposed to the hazard.

c. Make risk decisions. After assessing each hazard, develop one or more controls to either eliminate the hazard or reduce the risk of a mishap. When developing controls, consider the reason for the hazard, not just the hazard itself. Once a control has been developed, determine if the risk is justified.

d. Implement controls. Develop a process to do the job correctly and safely.

e. Supervise. Monitor the effectiveness of the controls and watch for changes. A situation can change quickly; be ready to adapt safety measures to fit the current circumstances.

The five steps of ORM can be memorized using the first letter of each step: I AM IS.

2-6. QUALIFICATION/CERTIFICATION. The Qualification/Certification Program was established in the late 1960's by the Chief of Naval Operations to establish specific processes to be followed when performing tasks involving ammunition and explosives. Research continues to show that the majority of explosive mishaps are caused by personnel error, resulting from inadequate training, insufficient supervision, lack of or inadequate Standard Operating Procedures (SOPs), complacency, and/or a failure to follow the governing technical directives. All Department of the Navy (DON) personnel that handle or physically interact with ammunition and explosives shall be qualified in accordance with OPNAVINST 8020.14/MCO 8020.11 (series).

MISHAP 2-5: On the morning of October 27, 1966, aboard the U.S.S. *Oriskany*, two nonrated men were assigned to restow unexpended Mk 24 Mod 3 flares in A-107-M (magazine). One man was tossing flares to the other man who stowed them in the magazine. At 7:18 a.m., a flare which had apparently not been safed, was dropped and its safety lanyard inadvertently pulled, initiating the flare. One of the men picked up the flare, placed it inside the magazine and then closed and partially dogged the hatch. The burning flare ignited other flares in the magazine, creating an intense fire. The magazine sprinkler system activated, but the water had little effect in extinguishing the burning flares which were composed of magnesium and sodium nitrate.

Shortly after, an explosion occurred in the flare locker and blew open the door sending fire and smoke into Hangar Bay 1 and the passageway in the vicinity of the flare locker. This initial explosion also forced fire, smoke and magnesium cinders through the flare locker ventilation system into the forward officer's living quarters on the main, second and 01 decks.

A second explosion occurred in the flare locker, spreading fire and smoke throughout the entire hangar deck and the forward portion of the ship. Immediately after the second explosion, personnel started moving the A-4 aircraft loaded with bombs from Hangar Bay 1 to Hangar Bay 2 and then to the flight deck. Ordnance was jettisoned from both hanger deck and the flight deck.

A third explosion about 10 minutes later of a LOX cart located on the port side of Hangar Bay 1 spread the fire to two helicopters which were then jettisoned.

Many personnel were unable to escape their spaces due to lack of familiarity with planned escape routes. Rescue teams who were experienced in the use of Oxygen Breathing Apparatus (OBA) were sent into smoke-filled areas to rescue personnel and to fight the fire. Many personnel who had not been trained in the use of OBA donned OBAs and proceeded to smoke-filled areas and experienced considerable difficulty.

This incident resulted in 44 deaths. All died from asphyxiation except for one who died from burns and injuries. There were six serious and 150 minor injuries. The total estimated cost of repairs/replacement to the ship, aircraft, helicopters, ordnance, supplies and equipment was $7,600,000. See figure 2-3.

Following this catastrophic ordnance incident that resulted in a significant loss of life and major ship damage, the Flag Board of Inquiry concluded that the accident was attributed to a lack of training, direct supervision, and methods used for assessing and determining personnel qualifications prior to being authorized to handle ammunition and explosives. One outcome of the investigation was to institute the Qualification/Certification Program to prevent similar accidents.

MISHAP 2-6: The frigate had completed overhaul and the ASROC system had been out of operation for one year. After it became operational, the ship's force had rigged it once. That rigging was accomplished by the ASROC handling team. During this incident, three seaman and a BM2 were attempting to rig the rammer rail to the loader crane when the rammer rail fell and struck a seaman in the chest, causing a fatal injury.

The BM2 and the deceased seaman were not part of the ASROC division or the ASROC handling team. The two ASROC division seamen involved were not PQS qualified and had never rigged the rammer rail, although both had observed the evolution on at least one occasion.

Personnel should not engage in any ordnance handling or maintenance operation unless they are fully trained and certified.

2-6.1. EXPLOSIVES SAFETY TRAINING PROGRAM. All personnel required to handle ammunition or explosives must attend appropriate explosives safety courses listed in NAVSEA OP 5 Volume 1. Personnel in these positions have daily contact with ammunition and explosives through research, development, testing, production, handling, transportation, and disposal operations. The commanding officer will establish a program to ensure personnel in these positions possess sufficient experience and education in explosives safety. Periodic drills shall be conducted to provide realistic training for operation of ordnance equipment, and to note or eliminate any unsafe practices.

FIGURE 2-3. "U.S.S. *Oriskany*, 27 October 1966

MISHAP 2-7: In March 1994, while conducting night perimeter defense training, a Chief Gunner's Mate (GMC) was positioning trip flares. He was thoroughly experienced with this type of flare which is routinely used for similar training events. During positioning, the latching mechanism on the flare was apparently tripped, resulting in ignition when the GMC released his grip on it. He was treated for minor burns.

Personnel should be frequently trained in the handling of ordnance and should periodically review weapon system and safety precautions, regardless of years of experience.

2-6.2. PERSONNEL PROTECTION. Personal protective equipment (PPE) consists of garments and devices necessary to protect individuals against hazards inherent in the performance of specific jobs. A comprehensive study of the working conditions for each operation should be performed to determine what type of PPE is required. The requirements for PPE are defined in OPNAVINST 5100.19 (series) and OPNAVINST 5100.23 (series). See also NAVSEA OP 5 Volume 1.

MISHAP 2-8: A 6-year summary of mishap reports submitted between the years 1990-1996 resulting from fuel spills aboard ship indicates the need for PPE aboard ship. Over that period, 111 sailors got fuel in their eyes. Regulations require users to wear chemical-splash safety goggles with no vents. Reports noted that goggles were available at the scene but sailors weren't wearing them.

Twenty-seven people got fuel on their skin or were burned. In some cases, the victims didn't wear the required protective gloves (made from rubber, plastic, or other impervious materials). In other cases, the victims failed to immediately remove their fuel soaked clothing.

Eleven sailors inhaled fuel vapor, and two others were found unconscious from fuel exposure. Respiratory-protection requirements for hazardous materials operations vary widely. They are specifically outlined on the material safety data sheet (MSDS) for that operation.

Specific kinds of PPE should be established on the basis of a comprehensive hazard assessment of the working conditions for each operation. Standard Operating Procedures (SOP's) must include requirements for PPE. All surface ships are required to develop procedures for responding to hazardous material spills, including on-the-job training in the proper use of PPE.

2-7. FIRE PREVENTION AND PROTECTION. Fire is a great hazard to life and property, especially when ammunition and explosives are involved. Fire prevention, protection and emergency planning regulations are described in NAVSEA OP 5 Volume 1 and NAVSEA OP 4. In addition, the following paragraphs emphasize the importance of adhering to established fire precautions.

2-7.1. EMERGENCY WITHDRAWAL DISTANCES. Emergency withdrawal distances for personnel are intended for application in emergency situations only. Emergency withdrawal distances are developed using fire involvement and on whether or not the explosive hazard classification, fire division, and quantity of explosives are known. More specific information is provided in NAVSEA OP 5.

MISHAP 2-9: In 1971, a tractor-trailer was enroute from a naval ammunition depot to a naval base when an automobile crossed the center line of the two-lane road and collided head-on with the truck. The driver of the automobile was killed instantly in the collision. A fire started immediately and engulfed the truck in flames. Within 5 to 10 minutes, a wrecker and fire truck arrived on the scene and the firecrew proceeded to extinguish the flames. A small crowd had gathered to observe the activity. Overheated by the fire, the cargo of the truck exploded. The blast killed two firemen, the wrecker driver and two bystanders who had moved in close to watch. Thirty-three other people were injured by the blast. Property damage, including structural damage to nearby buildings, trucks and cars, exceeded $1 million. The explosive cargo was completely destroyed.

The primary lesson learned was in firefighting procedures. Firefighters and other emergency-response personnel must know the safety precautions to be used in the event of a fire involving explosive and other hazardous materials. The five deaths in this mishap could have been prevented if the public had been kept at 2,000 feet or more and the firefighters at 1,200 feet. This distance for firefighters is necessary to fight secondary fires resulting from additional explosions.

2-7.2. SMOKING. Smoking shall be prohibited on any vessel handling, loading, or unloading explosives at loading piers or in magazines, buildings, railcars, motor vehicles, on piers or wharves. It is also prohibited in any other area of conveyance containing or in the vicinity of ammunition, explosives, and other hazardous materials, or where operations that involve these materials are conducted. "No Smoking" signs shall be conspicuously displayed in all areas where smoking is prohibited. Exceptions may be authorized by the commanding officer for designated locations, at specified times and under specified conditions. Smoking is prohibited in those areas described in NAVSEA OP 5 Volume 1 and NAVSEA OP 4.

MISHAP 2-10: In 1994, ammunition was being transferred between two destroyers. Work was suspended during the evening meal, the smoking lamp was lit on both ships and no cargo light was rigged. Before work was resumed, someone threw a cigarette onto a number of tetratol demolition packs stacked in an unlighted space on the deck. A fierce ammunition fire involving both ships occurred during which a number of personnel jumped overboard. No explosion occurred and the fires were extinguished with no casualties occurring on board. However, five of the personnel who jumped overboard drowned.

Shipboard smoking shall be in designated areas only as outlined in NAVSEA OP 4. Suitable metal receptacles are provided for cigarette butt disposal. No cigarette disposal is permitted in places where there is a risk of igniting combustible material.

2-7.3.EXHAUST FROM STARTER UNITS. Fire precautionary measures shall take into account the danger of hot exhaust from engines and starter units, which may reach high temperatures and ignite sensitive weapons.

MISHAP 2-11: In January 1969, the aircraft carrier U.S.S. *Enterprise* was operating in company with two destroyers approximately 70 miles southwest of Oahu, Hawaii, undergoing an Operation Readiness Inspection. In preparation for the second aircraft launch of the day, an explosion occurred which ultimately resulted in 27 deaths, 344 injured, loss of 15 aircraft, and damages of $50 million. It is almost certain that initial explosion and fire were caused by high order detonation of one or more fuzed Mk 32 ZUNI warheads in a LAU-10 pod on an F-4 aircraft. The exhaust from an aircraft engine starter unit blew directly onto a pod containing four ZUNI rockets. Heat caused at least one warhead to detonate. A fire then ignited from JP-5 jet fuel spilled from aircraft fuel tanks ruptured by the explosion. The fire, in turn, cooked off 500-pound Mk 82 bombs about 3 minutes after the initial explosion. Shaped charges blew a total of eight holes through the FLY-3 area of the flight deck, allowing burning fuel to invade the lower decks. In all, there were 18 munitions explosions. Figure 2-4 shows various views of this disaster.

The cause of the accident was design of the aircraft starting tractor and failure of those on the flight deck to recognize the seriousness of the problem, and then to act promptly and decisively. The design of the aircraft made it physically possible and even likely that the extremely hot (590 °F at 2 feet from the duct) exhaust gases would eventually be in contact with sensitive weapons. To preclude repetition of this accident, a requirement has been established to maintain a minimum distance of 8 feet between the exhaust of jet starting units and any part of an aircraft. Jet starting unit hoses have been lengthened to a minimum of 30 feet.

2-8. ORDNANCE ELECTRICAL SAFETY. The use of electrical power on, in, or near explosive ordnance materials always presents a threat. Shorts, grounds, arcing, faulty circuitry, and buildup of static electrical charges can create situations where the possibility of explosion, fires, electrical shock, or combinations of these hazards exists.

Fire on the flight deck, U.S.S. Enterprise (CVA(N)65).

Fire Damage aboard the U.S.S. Enterprise (CVA(N)65).

FIGURE 2-4. Fire Onboard the Aircraft Carrier U.S.S. *Enterprise*, January 1969 (Sheet 1 of 4)

Hole in deck from bomb cookoff, flight deck, aft.

Damage to the flight deck, aft.

FIGURE 2-4. Fire Onboard the Aircraft Carrier U.S.S. *Enterprise*, January 1969 (Sheet 2 of 4)

Damage to the flight deck, aft.

FIGURE 2-4. Fire Onboard the Aircraft Carrier U.S.S. *Enterprise*, January 1969 (Sheet 3 of 4)

Views of Fire Involving Planes and Ordnance

FIGURE 2-4. Fire Onboard the Aircraft Carrier U.S.S. *Enterprise*, January 1969 (Sheet 4 of 4)

2-8.1. HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO) CONSIDERATIONS. The presence of strong fluctuating fields of electromagnetic radiation can induce current surges in electroexplosive devices (EED's) sufficient to cause explosion. NAVSEA OP 3565/ NAVAIR 16-1-529 Volume 2 provides technical guidance for operating requirements to ensure safety from the HERO standpoint, and prescribes operating procedures and precautions necessary to prevent accidental initiation of ammunition and electroexplosive devices in ordnance in the presence of an electromagnetic radiation environment during handling, loading and storage/stowage.

MISHAP 2-12: In September 1970, in a Marine fighter attack squadron, three personnel were killed and an aircraft was destroyed when external fuel tanks were explosively jettisoned during refueling operations. An F-4B aircraft was being cold-refueled. When external electrical power was applied, both external fuel tanks were jettisoned by explosive cartridges. Residual fuel from the left tank stand pipe was ignited. Maintenance personnel attempted to extinguish the fire with a roll-around extinguisher. The first extinguisher failed to function and the fire was out of control before an additional one could be brought into play. The fire was being brought under control about 30 minutes after it started when a SPARROW missile warhead on the aircraft exploded. Figure 2-5 illustrates the type of disastrous fire which results from an accident of this nature. Three personnel were killed, eight were seriously injured, and five received minor injuries. One F-4B aircraft was totally destroyed.

The cause for this accident was listed as suspected stray voltage in tank jettison circuits. The fueling of armed aircraft is a risky procedure. In this case, the risk was compounded by personnel errors, as the wing tank safety pins were not installed and extinguishers were faulty and failed when needed.

MISHAP 2-13: On July 29, 1967, the U.S.S. *Forrestal* was operating in the Gulf of Tonkin and was in the process of launching strike aircraft. A ZUNI rocket which was loaded on an F-4B aircraft inadvertently fired and struck another aircraft approximately 100 feet away, rupturing a 400-gallon fuel tank and igniting the JP5 fuel beneath the aircraft. The flow of the flaming fuel, burning rocket propellant, and wind across the flight deck created a large area of flame and intense heat in an extremely short time. The first major explosion occurred 94 seconds after the rocket fired. It spread the fire to the group of loaded aircraft on the starboard side aft of number 4 elevator. The second explosion was even more violent, hurling bodies and debris up the box and spreading the fire to the five F-4 and RA-5C aircraft on the stbd side aft of the island. These two detonations decimated the fire fighters, riddled and threw back the hoses, and terminated the initial frontal assault on the fire. The sequence of major explosions continued with violent detonations for about 5 minutes after the initiation of the fire.

During this early phase, aircraft were moved forward and disarmed on the bow and ordnance located on the starboard side of the island originally intended for the next air strike was jettisoned. Similar jettisoning was in progress on the hangar deck and strikedown of ordnance to the magazines on the second deck assembly areas was begun.

After the major explosions ceased, firefighting quickly became effective despite continuing explosions of minor ordnance, internal fuel tanks, and ejection seats. The fire on the flight deck was then controlled and extinguished without serious difficulty.

As far as can be determined, the U.S.S. *Forrestal* was subjected to high order detonations of one 500-pound bomb, one 750-pound bomb, and seven 1,000-pound bombs. Also 40,000 gallons of jet fuel from aircraft spotted on the flight deck was ignited and contributed to the damage. This disaster resulted in 134 deaths, 343 injured, loss of over 50 aircraft, and $74 million in damages. The firing of the ZUNI rocket was probably caused by stray voltage initiating the rocket firing circuit when the umbilical cable was plugged in. Figure 2-6 shows scenes from this disaster.

The major action resulting from this accident, as well as the U.S.S. *Enterprise* accident (Mishap 2-11) was an increased concern and study of the cook-off characteristics of aircraft munitions. They started development of elastomeric explosive systems which are designed to be more resistant to cook-off (longer time to reaction) and react less violently in cook-off situations (burst the warhead case and burn rather than detonate). The Insensitive Munitions (IM) programs of today are the result of this and the U.S.S. *Enterprise* accidents.

FIGURE 2-5. Fire Among Armed Aircraft at an Air Station Ashore

HERO has been implicated or suspected in numerous ordnance mishaps including the disastrous explosion and fire on the U.S.S. Forrestal (CVA 59) in 1967.

Aircraft Burned in a Carrier Fire.

FIGURE 2-6. Fire Onboard the Attack Aircraft Carrier U.S.S. *Forrestal* (CVA-59), Gulf of Tonkin, July 1967 (Sheet 1 of 2)

Streams of water from a destroyer play on the U.S.S. Forrestal (CVA-59) to help extinguish a raging deck fire.

FIGURE 2-6. Fire Onboard the Attack Aircraft Carrier U.S.S. *Forrestal* (CVA-59), Gulf of Tonkin, July 1967 (Sheet 2 of 2)

2-8.2. STATIC ELECTRICITY. Under certain conditions of storage it is possible for static electrical charges of considerable magnitude to accumulate on the surface of ammunition items. These can be of sufficient power to draw a strong electrical arc when approached by a conductive object differing in charge. Such a condition can be dangerous where sensitive explosive devices are concerned. Established rules on grounding for both the stored materials and for personnel entering the area must be observed if hazards from this source are to be avoided. Under certain atmospheric conditions which are conducive to the buildup of such charges, such as severe electrical storms, it may be prudent to suspend all operations involving ammunition until the condition subsides. See NAVSEA OP 5 Volume 1 and NAVSEA OP 4 for the appropriate treatment of static electricity.

MISHAP 2-14: In January 1994, during a Phase B aircraft inspection, aircraft fire bottle leads were disconnected to check for voltage during the operational check. The lead was 1/2 inch from the airframe and the CAD detonated. There was no visible arc to the CAD. All notes and cautions were complied with. Suspect high humidity was a significant factor in arcing.

Certain materials such as metallic powders, pyrotechnic mixtures and some explosives cannot be exposed to air with 50 percent or more relative humidity. Under these conditions, spontaneous ignition or detonation can occur.

MISHAP 2-15: In February 1998, operators in Building 1026 at NSWC Indian Head, Maryland, were remotely adding ground RDX to a mixer when a detonation occurred. Damages totaled $2.2 million, not including replacement cost of Building 1026.

The probable cause of the incident was an electrostatic discharge which initiated a vapor/liquid fire, initiating the RDX. The electrostatic discharge was most likely a cone discharge from the accumulation of RDX in the mixer bowl. Processes such as propellant mixing that involve process ingredients contacting, sliding along, or impacting a surface should address the hazard of triboelectric charging. See NAVSEA OP 5 Volume 1.

2-8.3. GROUNDING. An adequate ground is one which provides a continuous conductive electrical path from a person, metal structure of an aircraft or other vehicle or the metal case or frame of the weapon to the metal structure of the ship. The adequacy of ground paths must be verified by continuity and resistance checks and approved by the engineering officer or engineering maintenance officer before being placed into use. For further information on grounding requirements, refer to NAVSEA OP 4 (afloat) and NAVSEA OP 5 (ashore).

MISHAP 2-16: Saudi fuel personnel failed to ground an F15C Aircraft prior to refueling. Results are shown in figure 2-7.

Grounding of aircraft prior to ordnance evolutions is required by ordnance loading manuals/weapons checklists and SOP's. If the aircraft had been properly grounded, this mishap may not have happened.

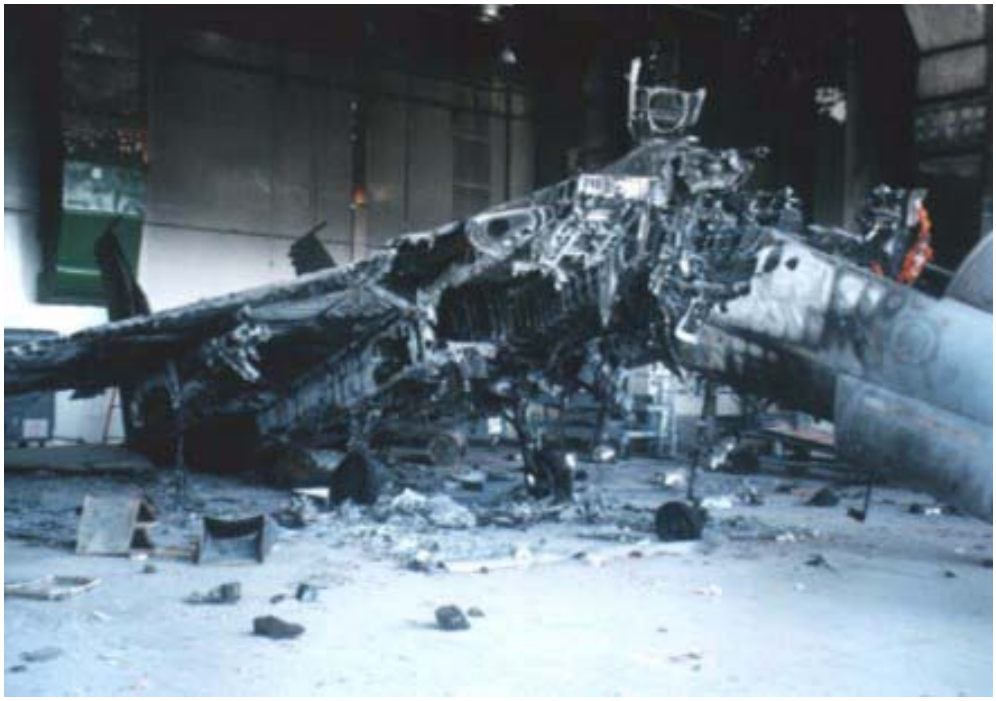


FIGURE 2-7. This was all that was left of an F15C aircraft after grounding procedures were ignored prior to refueling.

2-8.4. ELECTRICAL EQUIPMENT. The electrical requirements of the National Electrical Code (NEC), National Fire Protection Association (NFPA) 70, and supplemented by NAVSEA OP 5 Volume 1, are the minimum acceptable for electrical equipment used or installed in hazardous (classified) locations or explosive areas at Navy and Marine Corps shore activities.

2-8.4.1. Use. No work on electrical equipment is to be performed in the presence of explosive ordnance. In addition, the covers of switches, circuit breakers, etc., shall be kept securely closed while powder and other explosives are exposed in the vicinity; circuit breakers which have opened shall not be closed again until the cause of the overload has been corrected. Repairs made to the electrical service for magazines shall be done in accordance with NAVSEA OP 5 Volume 1.

MISHAP 2-17: In September 1964, a petty officer and striker were working in a magazine on the trolly indicator lighting system close to a fully assembled 2.75-inch rocket. The motor was ignited and burned. A total of 65 such rockets were on board at the time of the accident. The blast from the burning motor escaped through an overhead scuttle into the mess deck. Eight men received burns of a non-critical nature, but sufficient to hospitalize them for up to 30 days. Bulkheads and overhead in the magazine were charred as was the mess deck above, and minor damage to electrical circuits in the immediate vicinity occurred.

No work on electrical equipment should be performed in the presence of explosive ordnance, especially electrically-fired ordnance. Either nonsparking tools should have been used in this case, or the explosives removed.

2-9. WEAPON INSPECTION AND TURNOVER. When relieving a watch, the off-going sentry shall download the weapon and both the off-going and on-coming sentries verify that the weapon is empty and the required number of rounds are accounted for. The on-coming sentry shall reload the weapon to then be placed in its holder. Continued training as described in OPNAVINST 3591.1 for firearms use and safety is essential.

MISHAP 2-18: In March 1994, a STG2 was relieving a BM2 as the main gate sentry. The STG2 stuck the barrel of the shotgun into the clearing barrel and started to unload it. He had difficulty unloading the magazine and thought all four rounds had been extracted. The STG2 then stuck his finger into the chamber, did not feel a round and pumped the action forward. He then pulled the trigger to dry fire the gun and it fired into the clearing barrel, exiting through the right side. The blast penetrated 1/8-inch sheet metal, 3/8-inch plywood supporting the clearing barrel, and the glass window of the sliding door, completely shattering the window.

MISHAP 2-19: In February 1994, a duty armorer was directed to inventory the brow sentry's .45 caliber weapon and magazine clips and replace the sentry's soiled holster and web belt with clean material. The brow sentry removed the web belt, with the pistol in the holster, and handed the entire assembly to the duty armorer. At the time of transfer, there was a magazine installed in the weapon and two magazines attached to the web belt. The armorer removed the weapon from the holster and pulled the slide back to ensure the weapon was safe with no rounds chambered in the magazine. The armorer did not look for the loaded magazine installed in the weapon during this inspection. Following the serial number verification, the armorer handed the weapon back to the sentry with the slide in the aft position. The sentry accepted the weapon and looked in the chamber to verify the weapon was safe with no rounds in the chamber. The sentry did not look for the loaded magazine in the weapon. The sentry released the slide, thus chambering a round unknowingly. The sentry pointed the weapon at the deck and pulled the trigger to release the cocked hammer. A round was fired into the asphalt pavement of the pier and then ricocheted off the pavement. The round was never found, even after a thorough search was conducted.

Activities are responsible for generating individual procedures for clearing and turning in a firearm. Watchstanders shall be trained and certified in such procedures. NTRP 3-07.2.2 provides procedures for loading and unloading force protection small arms and other service weapons. Clearing barrel procedures are described in chapter 1 of NTRP 3-07.2.2.

2-10. MACHINERY AND TOOLS. Machinery and tools can introduce hazards where they are misused, are not working properly, or otherwise fail in their function.

MISHAP 2-20: In May 1994, an ordnance technician was building up chaff buckets. During the installation of a CCU 63/B, he noticed the CAD electrodes were slightly bent. He attempted to straighten the electrodes with a pair of needlenose pliers, at which time the cartridge initiated in his hand. He received lacerations to his left hand.

This accident was caused by using the wrong type of tool for the job.

2-10.1. USE OF AUTHORIZED TOOLS. Only those tools which are authorized for use in operations involving ammunition and explosives shall be used in accordance with the Standard Operating Procedure (SOP) and NAVSEA Technical Manuals. Supervisors are responsible for ensuring that tools are authorized and used in the manner specified for the operation being conducted. See NAVSEA OP 5 Volume 1, paragraphs 1-4.5.1(k) and 9-2.9.

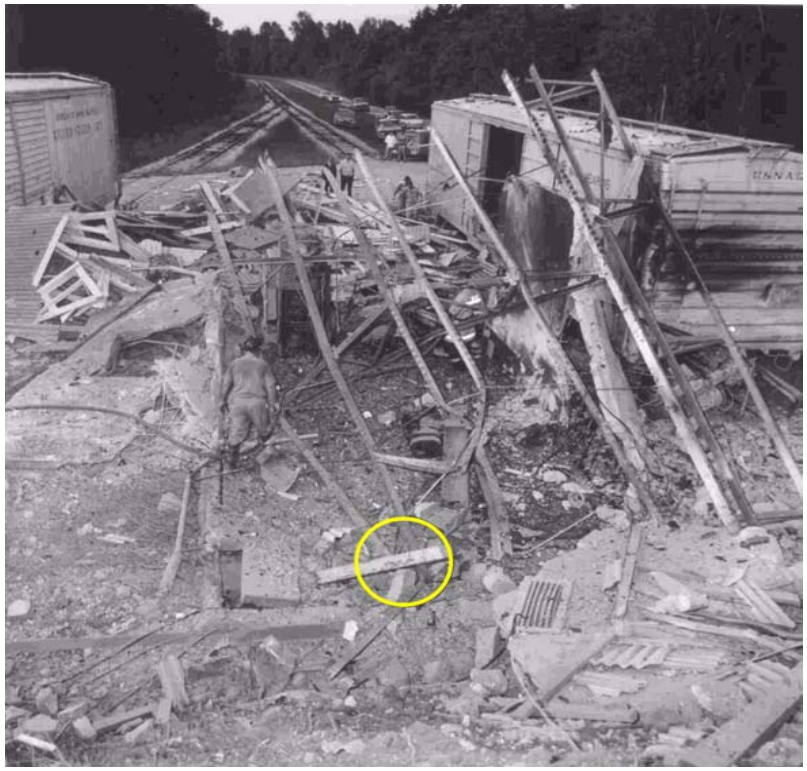
MISHAP 2-21: During a 16/50 Caliber High Capacity Projectile renovation procedure conducted at NSWC Crane Building 71 in August 1968, a fuze was installed using an air impact wrench that had sufficient revolutions per minute capability to arm the fuze. The centrifugal force caused the fuze to be armed, and the projectile exploded, resulting in three fatalities. See figure 2-8.

This procedure was to be performed manually, without the use of an air gun. Apparent cause of the accident was that personnel fitted the wrench with a drill to speed up the rate of production. This was without authorization. Use of the drill actually armed the fuze, unknowingly to operators. Additionally, explosive material may have been in the threads of the fuze hole, thereby causing the fuze to fire as a result of pressure and friction. Accident is attributed to improper use of tools, as well as failure to follow SOP. This particular operation was to be redesigned to require remote removal of tracer and base fuze, vice manual removal of tracer with impact wrench.

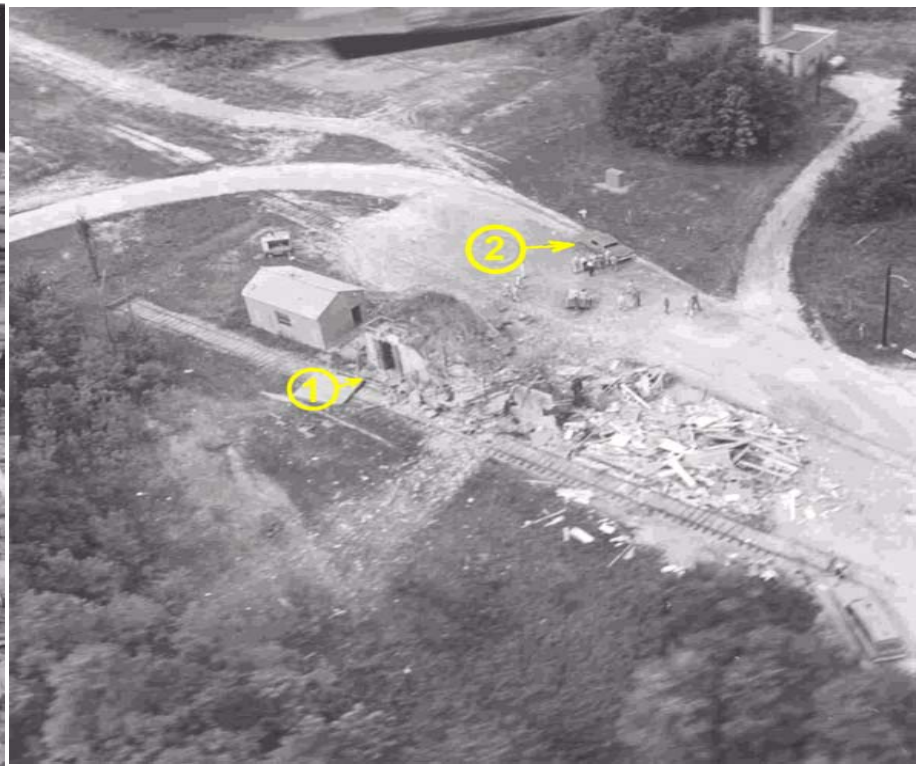
2-10.2. EQUIPMENT MALFUNCTION/FAILURE. Operation of tools and equipment shall cease immediately on evidence of malfunction. A check shall be made to determine the cause and the corrective action to be taken. The tool/equipment shall remain out of service until it is determined to be safe for further operation.

MISHAP 2-22: In 1992, during FXP drill, originator loaded Mk 31 tool set with .50 caliber cartridge. Each time items were initiated, they would sustain bursting damage. The resulting swelling, cracking, and breaking would jam the cartridge in the tool, resulting in wasted time clearing the tool set. This could lead to endangerment of personnel on actual EOD operations.

When an item malfunctions or operates in an unexplained manner, immediate notification of supervisory personnel is necessary to prevent accidental discharge or further mishap. Ensure handling and tool clearing SOP's are adequate and that personnel are familiar with them. Adequate hazard awareness training shall be provided.



The circled area (bottom center) is the point of detonation



Aerial view of the Building 71-13 area the morning following the explosion. The boxcars that had been present at the time of the explosion have been removed. Arrow #1 points to the defuzing cell and arrow #2 points to a vehicle.

FIGURE 2-8. Fuze Setting Accident Caused by Improper Use of Tools

2-11. ENVIRONMENTAL CONSIDERATIONS. The environment in which ammunition is stored/stowed and handled will affect the stability of the ammunition and, at extreme levels, can make its use dangerous. Of primary concern in the storage/stowage environment are the factors of temperature, humidity, electromagnetic radiation (see paragraph 2-8.1) and conditions conducive to the buildup of strong electrostatic charges (see paragraph 2-8.2). Factors which can add to the hazards of handling include excessive heat or overexposure of ammunition components to the direct rays of the sun; excessive cold, snow and freezing temperatures, which can greatly increase the risk of personnel injury by slipping and sliding and can increase the risk of equipment failures or malfunction; and heavy seas, as personnel and ammunition may be tossed around and handling equipment may be subjected to excessive strain under load as the ship alternately dips and rises to the sea. Other outside forces that can bring about hazardous conditions to ammunition in storage include fires, nearby explosions, storms, earthquakes and human incursion.

2-11.1. HAZARDOUS WEATHER CONDITIONS. Ammunition evolutions involving direct contact with ammunition components shall be curtailed during atmospheric disturbances such as thunderstorms which approach to within a 5-mile radius of the evolutions or high winds. Operations shall not be resumed until less hazardous conditions prevail. Operations during electrical storms are discussed in detail in NAVSEA OP 5 Volume 1 and NAVSEA OP 4.

MISHAP 2-23: During heavy seas in October 1995, a ship was returning to port from a major ordnance crossdeck with two carriers. While removing ammunition from the flight deck, a multi-side loader picked up a missile container and turned port at the same time the ship rolled to port. Due to the forklift turning and the ship rolling, the container slid off the forktruck and flipped top down on flight deck, approximately 3 feet. The container took most of the impact on the four metal stand arms protruding from the container. The container was properly tagged and turned over to the Weapons Station for proper disposition.

When handling in moderate to heavy seas and forced to use multi-side loaders, operators should turn in the opposite direction of the ship rolling to prevent lifts from sliding off.

MISHAP 2-24: During a VERTREP operation in November 1993, and while the ship was maneuvering in large swells, the ship took a violent roll to port causing a stack of two missile containers on a weapons carrier, positioned fore and aft, to fall over. One of the four stacking legs of the upper missile container landed on and punctured an adjacent CNU-491/E Container, damaging the nose cone of one of the air launched decoys inside. The CNU-491/E Container shifted position, following the impact of the missile containers, pinning one crewmember against another CNU-491/E Container. A second crewmember fell on the flight deck while trying to avoid the sliding containers.

Alterations of the ship's course in rough seas can quickly and drastically change the motion of the ship, endangering personnel and equipment not prepared for the changes. While cargo handling operations are in progress at sea, an announcement should be made over the ship's 1MC circuit that the ship will be maneuvering and that heavy rolling is possible. All cargo and handling gear shall be properly secured or positioned as to best prevent shifting.

MISHAP 2-25: On July 10, 1926 at 1715 hours, a severe electrical storm struck the southwest end of NAD Lake Denmark. Immediately thereafter smoke issued from Temporary Magazine 8. Depot personnel responded to the fire call, rigged hoselines, and had one stream of water on the fire. At 1720 hours, a detonation occurred. Within 5 minutes of this blast, Temporary Store House 9 with 1.6 million pounds of bulk TNT also detonated. The third explosion involved 180,000 pounds in Shell Store House 22. There were a number of minor explosions. With few exceptions, all structures within 3,000 feet of Store Houses 8 and 9 were destroyed. See figure 2-9. Structures in the area between 3,000 and 5,600 feet were severely damaged with the exception of earth covered magazines located between 2,200 and 4,000 feet which were undamaged. There were 21 fatalities, and 51 injured. The monetary loss to the Navy alone was $46 million. The primary cause is listed as lightning, complicated by overloaded magazines.

As a result of a full scale Congressional investigation, Congress directed the establishment of the Department of Defense Explosives Safety Board (DDESB). The Board was directed to survey the storage of Army and Navy supplies of ammunition and components with special reference to those supplies located in such proximity to populous communities and industrial areas as to constitute a menance to life and property. As the basic standards of safety, the Board adopted the laws of the State of New Jersey which incorporate the American Table of Distances, and the concept of quantity-distance was established for Navy use. See NAVSEA OP 5 Volume 1.

U.S. Army Photograph - Picatinny Arsenal

An explosion caused by lightening rocked Picatinny, July 10, 1926. This was the view of Picatinny as seen from Lake Hopatcong on that day.

U.S. Army Photograph - Picatinny Arsenal

FIGURE 2-9. Disaster at NAD Lake Denmark, July 1926 (Sheet 1 of 3)

U.S. Army Photograph - Picatinny Arsenal

View of the remains of the buildings at the Main Gate which is where the Navy Hill Gate is today.

U.S. Army Photograph - Picatinny Arsenal

Picatinny General Storehouse after the Navy Hill explosion.

FIGURE 2-9. Disaster at NAD Lake Denmark, July 1926 (Sheet 2 of 3)

U.S. Army Photograph - Picatinny Arsenal

Explosion victims were evacuated to Morristown where they were taken either to the U.S. Hotel above or the National Guard Armory.

FIGURE 2-9. Disaster at NAD Lake Denmark, July 1926 (Sheet 3 of 3)

2-12. AMMUNITION ACCOUNTING AND CONTROL. Improper accounting and control of ammunition can lead to serious injuries or even death. Accurate ammunition records and a vigorous surveillance program are required to ensure that ammunition in storage does not exceed its recommended shelf life and to detect at an early stage any ammunition which shows signs of having been subjected to adverse storage conditions.

MISHAP 2-26: In April 1966, a fatal accident occurred at a naval station when a fragmentation hand grenade accidentally detonated. A civil service employee found the grenade in some weeds and picked it up. He pulled the safety pin whereupon it exploded, killing him instantly.

MISHAP 2-27: The ship's marine detachment had been permanently deactivated in February 1994. During disposal/distribution of equipment, a bag of tools for Mk 79 Grenade Launcher maintenance was transferred to the ship's armory. A TM2 assigned to the armory was preparing for a PMS spot check. Upon examining the bag of tools, the TM2 found the M212 practice grenade. The frangible nose cap and marker powder were missing from the grenade. Reading "practice" on the grenade and finding it in a maintenance bag with the nose cap missing led the TM2 to believe that it was a dummy grenade. Desiring to examine the firing mechanism of the M79, the TM2 loaded the practice grenade, pulled the trigger and discharged the M79 into the armory overhead.

An investigation revealed that the practice grenade was last held by the Marine detachment and was returned from a range exercise in an unserviceable condition. It was placed in the tool kit because it had already been listed as expended on the range.

Ammunition taken out of storage or used for training should be fully accounted for at the end of the procedure or training to make sure no stray pieces are left behind.

2-13. INERT/DUMMY AMMUNITION. Inert/dummy ammunition does not contain any explosive material. Only inert/dummy ammunition shall be permitted for classroom training, displays (public or otherwise), museum displays, public functions, and patriotic occasions. Inert ammunition used for these purposes shall not contain other hazardous items such as batteries of any type, high pressure vehicles, or other devices such as spring high tension assemblies which may injure personnel.

MISHAP 2-28: In July 1993, hostage survival was being taught to Command auxiliary security force members as part of the semi-annual command authorized training requirement. In order to inject realism into the training, six "terrorists" wearing masks and carrying weapons loaded with unauthorized blank ammunition entered the classroom while class was in session. During the ensuing confusion caused by shooting, discharging of firearms and students being forced to lie on the deck, one of the "terrorists", his vision partially obscured by the pantyhose covering his face, collided with either a desk or podium, causing him to bend forward, lowering the shotgun barrel which discharged into the victim.

Blank rounds for this training should not have been used. Unauthorized ammunition should never be used for any type of training.

CHAPTER 3

CLASSIFYING, MARKING AND IDENTIFYING AMMUNITION

3-1. METHODS OF CLASSIFYING AND IDENTIFYING. Ammunition is classified by hazard Class/Division (C/D) and compatibility group. The DOD uses the UNO classification system for dangerous materials to identify the hazardous characteristics of ammunition and explosives. The UNO classification system contains nine hazard classes, based on the chemical and physical characteristics of material and its reaction under various test conditions. A compatibility group accompanies the hazard class to complete the hazard classification designation. Ammunition and explosives are assigned to a compatibility group when they can be stored and transported together without significantly increasing either the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident. For further information on ordnance classification, see NAVSEAINST 8020.8 (series) and NAVSEA SW020-AC-SAF-010.

3-1.1. Ammunition is most readily identified by size, shape, and weight. Specific characteristics of ammunition are further identified by painting, marking, lettering, or combinations of these methods. NAVSEA SW010-AF-ORD-010 provides color-coding and marking information for most conventional ammunition, ammunition components and ammunition containers in current Navy and Marine Corps inventory.

3-1.2. Mislabeling of ordnance classification or means of identification can result in serious injury or fatality.

3-2. PERSONNEL RESPONSIBILITIES. Prior to using any ammunition, note any unusual appearance. Bring concerns to the attention of a supervisor or ordnance expert. Do not assume that the ammunition was verified by content at the point of origin. Mislabeling does occur.

MISHAP 3-1: During an ammunition onload at a weapons station in August 1994, a box clearly labeled “dummy ammo NALC A929 lot no. LC-88J273-031” was received. The box contained 20mm CIWS ammo with blue tips. The blue tips were unusual in color, but believed to be a new type of Teflon coated dummy round the techs had heard was in development. At approximately 0600, the CIWS tech uploaded 800 brass inert CIWS rounds and 100 blue tipped rounds. The blue tipped rounds were uploaded in groups of 10 every 90 rounds in order to ease verification of magnetic pickup and round counter operation. Following upload, post-teardown maintenance check was in progress when ten blue tipped CIWS rounds fired during the PSOT 14 section of the maintenance check. This check had been conducted previously, several times in port, without incident because the blue rounds had been loaded at the end of the ammo holding system and did not fire because they did not cycle up to the gun. At time of firing, CIWS was at zero degrees elevation with an approximate range of 350 yards. The ship was in open water which resulted in no injuries to personnel, damage to the ship or its contents. The blue tipped rounds were subsequently identified as live training rounds and reclassified.

MISHAP 3-2: During a routine inspection in July 1991 of empty wooden containers, four boxes were found to contain one booster each. All four boxes were marked "certified empty."

3-2.1. CONTAINER MARKING (LABELS/PLACARDS). An external container marking is required by the DOT to identify the hazardous nature of the contents for transportation and emergency response purposes. Each hazardous material shipment must be labeled and placarded as described in NAVSEA SW020-AG-SAF-010, paragraphs 3-5 and 4-6.

3-2.1.1. Empty Containers. Empty ordnance containers require inspection and must meet the requirements of NAVSUP P-805/P-807. Marking of empty ordnance containers must include the removal/obliteration of all previous markings indicating the presence of hazardous materials such as loading dates, lot numbers, serial numbers, maintenance due dates (MDD's), and Department of Transportation (DOT) markings, etc. Empty markings must be applied by stenciling, labeling or by attaching a material condition code tag. See NAVSEA OP 5 Volume 1 for empty container certification requirements, and NAVSEA OP 4 for requirements for the return of empty containers under combat and non-combat conditions.

MISHAP 3-3: In July 1991, workers inspecting containers believed to be empty discovered a live WALLEYE weapon in a damaged container. This and several other containers were received in a shipment that was manifested as empty. This container was still marked and labeled correctly as to its content. The markings had not been painted out nor was the container certified as being empty. At some point before the weapons station received this container, it had been damaged and someone had written the word "bad" on the cover. Other containers in this same shipment were still marked and labeled as live weapons; however a 100 percent inspection of all other containers proved them to be empty.

Empty shipping containers shall be certified and marked as empty.

3-3. METHODS OF IDENTIFYING AMMUNITION

3-3.1. COLOR CODING. MIL-STD-709C establishes standard colors to designate the primary hazard of ammunition items.

3-3.2. ABBREVIATIONS AND SYMBOLS. Abbreviations and symbols used in marking and lettering ammunition, components, and ammunition containers are listed in NAVSEA SW010-AF-ORD-010, appendix A. Colored marking symbols and their corresponding meanings are listed in NAVSEA SW010-AF-ORD-010, table 1-2. Most chemical filler ammunition, ammunition components, and ammunition containers are identified by bands that are color coded in accordance with NAVSEA SW010-AF-ORD-010, table 1-1.

3-3.3. UNIDENTIFIED EXPLOSIVES. The handling or disposition of ammunition, explosives, or similarly hazardous materials shall not be undertaken unless the items are specifically identifiable and their characteristics known.

MISHAP 3-4: In early 2008, a 2.75-inch rocket on display for two years at a veterans' museum in Maryland was discovered to be live. The ordnance was the type used on helicopter gun ships during the Vietnam conflict, and had been donated to the museum by a local Vietnam veteran. Local technicians removed the rocket and rendered it safe. Figure 3-1 shows the live ordnance as displayed.

Unidentified ordnance that is not known with certainty to present an explosion hazard is considered Material Potentially Presenting an Explosive Hazard (MPPEH). MPPEH must be assumed to present an explosion hazard until it is visually inspected and/or processed, and certified safe. NAVSEA OP 5 Volume 1, establishes criteria for managing and processing MPPEH. Documentation is key to the safe management of MPPEH. Documentation allows certification, chain of custody, and explosives safety status to be tracked and known at all times.

At no time should unidentified ordnance be used as display, paper weights, door stops, etc. Inert ordnance must be labeled with the worlds "INERT" and have an inert certification serial number issued by the Safety Department or activity Explosive Ordnance Disposal unit. See NAVSEA OP 5 Volume 1 for inert ordnance labeling and management requirements. Labeling as "INERT" and applying the serial number shall be done using a permanent method such as metal stamping or engraving, to preclude future loss of identity.

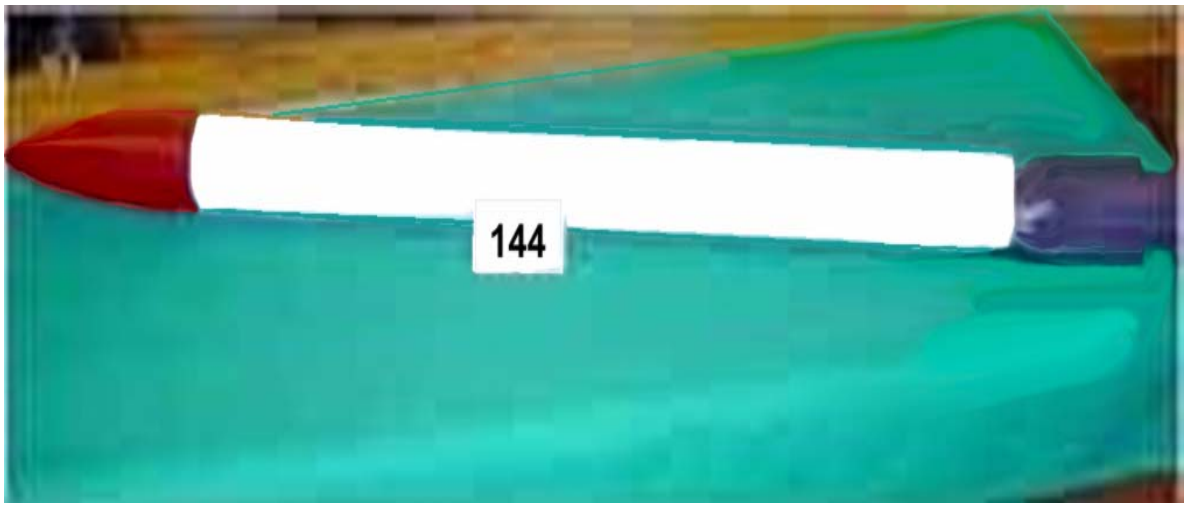


FIGURE 3-1. Unidentified 2.75" Rocket on Display

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CHAPTER 4

AMMUNITION HANDLING PRECAUTIONS

4-1. INTRODUCTION. Any time ammunition is being directly manipulated by man or machine between points of storage, between storage and points of loading for launching or firing, or between points of loading for launching or firing back to storage, it is in the process of being handled. Ammunition handling is one of the more hazardous of the various activities which has caused, and continues to cause, accidents. The utmost care and discretion shall be exercised by everyone involved in the handling of all explosives, ammunition, ammunition components, and other hazardous materials. These items shall be protected from shock or friction, abrasive or spark-producing substances, inclement weather or direct sunlight. They shall not be thrown, dropped, dragged or tumbled over floors or other containers. Care should be taken to avoid obliterating or defacing identification markings. A more descript listing of precautions may be found in NAVSEA OP 5 Volume 1.

4-1.1. SAFETY PROCEDURES. Every weapons handing evolution requires coordination and communication with others. All personnel involved in an evolution must be aware of what will happen at each stage. Only approved equipment and fully qualified personnel shall be used. As handling occurs at many points in the life cycle of ammunition, safety is a continuous requirement in any evolution involving ammunition or elements thereof.

MISHAP 4-1: A routine weapons handling operation required that two missiles be moved from an ordnance rework shop to the loading platform for transfer to a flatbed truck. The forklift operator and truck driver briefly discussed the details of the move. It was late and the driver was anxious to get the job done. The first missile loaded successfully. When the forklift approached with the second missile, the driver looked out the back of his cab and watched the forklift operator lower the missile into the bed of the truck. He started the truck, let the engine warm up for a few seconds, and started to pull away from the loading platform. The forklift operator shouted,"Hey, Hold it!", but it was too late. The missile fell nose first to the ground (see figure 4-1). The forklift operator had been attempting to reposition the missile since it had not positioned correctly the first time. Initial inspections revealed that the radome was broken. The missile was disassembled so that all internal components could be checked for possible shock damage.

Communicate and conduct explosives handling operations with safety first. Procedures shall not be rushed.

FIGURE 4-1. Ordnance Damaged Through Improper Handling

4-2. DROPPED OR ROUGHLY-HANDLED AMMUNITION. Ammunition which has been dropped or subjected to rough handling shall not be fired or assembled for firing, but shall be returned to an ammunition activity. There are no specific rules to cover dropped or roughly handled ammunition since so many factors such as height of drop, impact attitude, temperature, past history of unit and fragility of the unit play an important part in the disposition decision. Any evidence that explosives or ammunition have been handled roughly or explosive material exposed shall be reported promptly to the responsible officer or supervisor. Units that have been dropped or roughly handled and whose capability to perform as designed is suspect shall be disposed of in accordance with current instructions.

MISHAP 4-2: On July 17, 1944 at Naval Magazine, Port Chicago, California, cargo of ammunition, bombs, and smokeless powder was being loaded from railroad cars on the pier into the hold of the steamship S.S. *E. A. Bryan*, starboard side to the pier. The S.S. *Quinault Victory* was lying starboard side to the opposite side of the pier and was empty. At 10 p.m. the first explosion occurred, followed in a few seconds by a second

more powerful explosion. Both ships, as well as the pier, were blown apart. The explosion created a 25-foot tidal wave in the bay and destroyed most buildings on the Naval Magazine. Fragments were thrown up to 13,000 feet. The explosions caused 320 deaths and 390 injured. Total damage was estimated to be about $12.5 million including over $9 million to U.S. Government property.

Figure 4-2 shows the damage resulting from the explosion. The accident and resulting damage was extensively studied. The cause of the initial explosion was never established, but it was surmised that it was due to dropping a Torpex-2 loaded weapon.

The studies resulting from this accident were used to learn more of the necessary quantity-distance criteria for explosive handling operations. After the incident, HBX and H-6 explosives were developed that incorporated wax and other chemicals to desensitize the explosive and hot melt liners were introduced for lining bombs and warheads to give some thermal protection and eliminate potential pinch points from cracks or fissures in the bomb or warhead case. Later, plastic-bonded explosives were developed for increased thermal protection and fragment impact resistance.

MISHAP 4-3: In January 1994, following preparations for testing, a sample round was being removed from the orderly rack and dropped approximately 37 inches to a conductive mat on the lab floor. The fuze was on safe. The fuze was then taken into the prep cell. Upon starting to remove the welsh plug, the firing pin dropped, inadvertently firing the M47 detonator. The fuze was on safe and still functioned. It was suspected the fuze was damaged internally when dropped.

MISHAP 4-4: In September 1944, a violent blast wiped out Naval Ammunition Depot Hastings, Nevada. The Chief of the Bureau of Ordnance stated that the explosion resulted from “accidentally dropping or otherwise roughly handling a depth bomb.” Eye witness accounts reported a depth bomb, being transported on a standard two-wheeled stevedore truck, fell from the truck and exploded. The case history of the event states that the cause was impact of a Torpex depth bomb against the corner of a railcar door while unloading. One end of the depot became enveloped in flames. Fire spread to loaded charges in the building, but enough time elapsed to allow most of the personnel to escape before a huge blast involving 719 tons of Torpex depth bombs took place, blowing up the depot and its adjacent facilities. At the time of the accident there were 12 loaded railcars and two empties on the tracks. Massive earthen barricades, 950 feet long and 75 feet wide at the base (20 feet high) enclosed the sides of the area along the rails. The barricades proved ineffective in alleviating either the blast or the missiles which reacted in that direction. However, some of the operators survived directly behind the barricades. Ten persons were killed and 56 injured. Missiles flew great distances. Concrete and railcar debris fell within 1,000 feet for the most part, but chunks of concrete weighing 500 pounds were thrown a mile. One large piece of concrete reached 7,300 feet. The crater was 525 feet long, 140 feet wide and 30 feet deep. The depot was totally destroyed. Figure 4-3 shows a before and after scene of such an accident.

View looking north toward pier.

Looking southwest, showing collapsed Building A-14 (garage) in the center.

FIGURE 4-2. NAVMAG Port Chicago Disaster, July 1944 (Sheet 1 of 3)

View looking NE at railway station.

Looking west at Bldgs. E67, E66 and E72.

FIGURE 4-2. NAVMAG Port Chicago Disaster, July 1944 (Sheet 2 of 3)

View looking south from ship pier.

View looking north from BM138.

FIGURE 4-2. NAVMAG Port Chicago Disaster, July 1944 (Sheet 3 of 3)

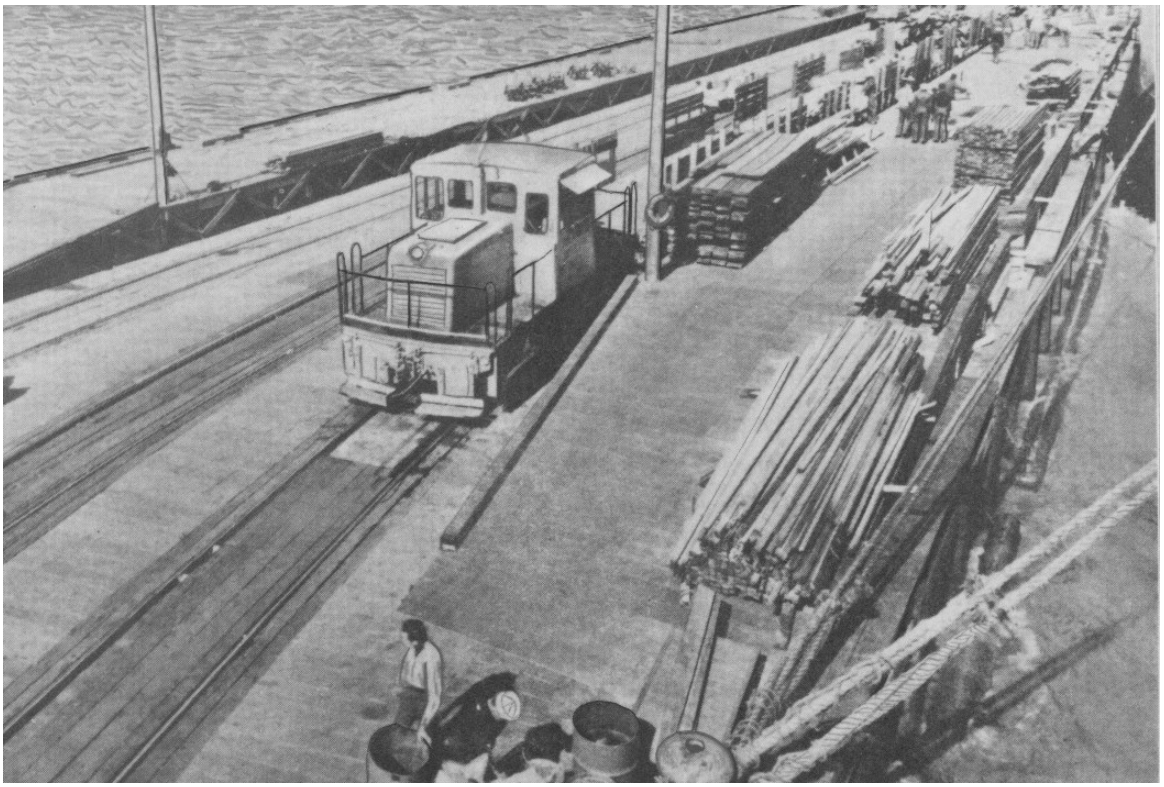

FIGURE 4-3. Before and After Views of an Ammunition Pier Explosion

MISHAP 4-5: In 1945, personnel loading an ammunition barge with bombs were carelessly tossing the bombs a distance of up to 7 feet from the jetty onto the barge. The barge had about 1,300 bombs on it. An explosion occurred followed by several additional blasts. Twenty-eight persons were killed and another 16 were injured. Material damage was heavy.

MISHAP 4-6: On April 30, 1946, a destroyer escort, U.S.S. *Solar*, was offloading ammunition at Naval Ammunition Depot Earle. The forward ammunition handling party was passing hedgehog charges from the magazines to a location inside the 3-inch gun shield on deck. The charges were being placed in rows of 15 each. At 1120, a low order detonation occurred near the gun shield. Apparently, it was caused by dropping or otherwise mishandling one of the charges. The explosion ripped open the deck below the gun. Fire was spread by burning Torpex explosives. Several charges fell through the deck into the crew's quarters and exploded. The fire blazed through the sail and paint lockers until it reached the upper hedgehog magazine. A gunner's mate who was there when the first explosions occurred left the magazine without turning on the sprinklers, and left the magazine hatch cover open which allowed the fire to enter the magazine. About 250 hedgehogs detonated in a powerful explosion.

Seven Sailors were killed and over 160 injured. Damage to the ship was estimated at $4,000,000. $200,000 damage was done to the pier. The ship's first deck, main deck, and superstructure from the bow to amidships had blown upward and were folded back into the deckhouse. Damage was so severe, it was recommended that the ship be sold for scrap or towed to sea and sunk. Figure 4-4 shows damage to the ship.

MISHAP 4-7: On November 10, 1944, a newly commissioned ship, the U.S.S. *Mt. Hood*, was being loaded with 500-pound bombs and aerial depth bombs into the No. 3 hold. An explosion occurred in the vicinity of the No. 3 hold. Smoke and flames rose to masthead height and men were seen running aft. A few seconds later, a second and more violent explosion took place. The entire ship was obscured by smoke and flames. Shells, rockets and fragments were hurled to a radius of a full mile, blasting and splattering a total of 36 ships in the area. When the smoke finally cleared, only tiny bits of debris indicated where the ship had been. Figure 4-5 shows the explosion of the ammunition ship. Figure 4-6 shows fragment damage to a ship nearby when the ammunition ship exploded. No trace was found of the 295 men known to have been aboard. The blast and shell fragments killed 51 men on surrounding ships and over 400 others were injured. Divers sent down at the anchorage later found a crater 300 feet long, 50 feet wide, and 30 feet deep blasted out of solid coral.

With no survivors aboard, there was no direct evidence as to what caused the explosion. Investigations concluded that the most likely force to have caused the explosion was a load of ammunition set off by dropping into, or by striking, the hatch of the No. 3 or No. 4 hold.

FIGURE 4-4. An Explosion Due to Mishandling of Ammunition; U.S.S. *Solar* Before and After 30 April 1946

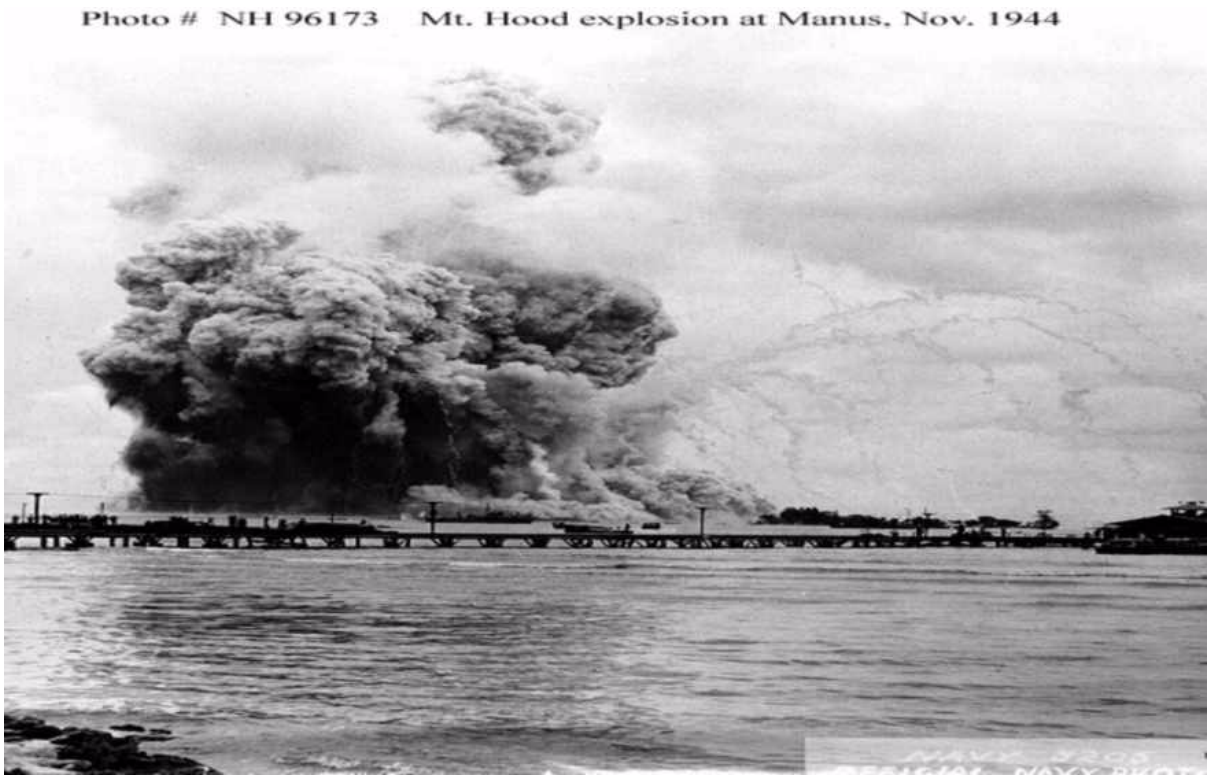

FIGURE 4-5. Explosion of U.S.S. *Mt. Hood*

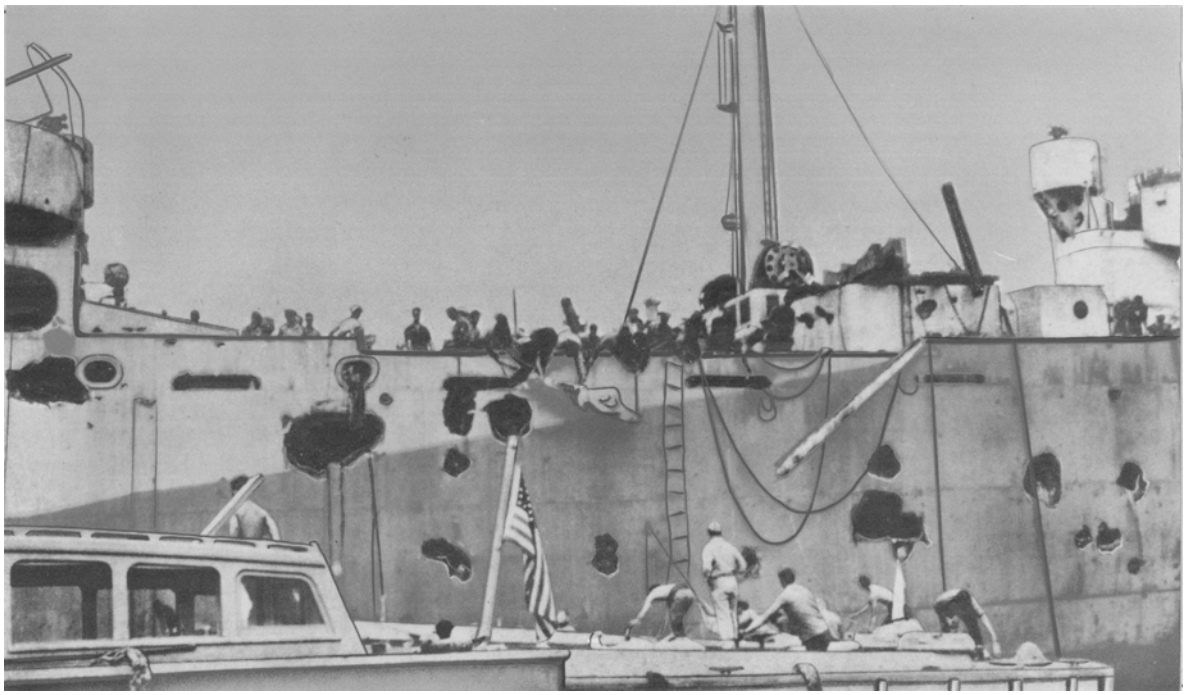

FIGURE 4-6. Fragment Damage to the U.S.S. *Mindanao* as a result of the U.S.S. *Mt. Hood* Explosion

4-3. SPOTTERS. A spotter or safety watch is sometimes necessary to facilitate a safe operating environment. Standard Operating Procedures (SOP's) shall incorporate the designation of spotter(s) by supervisors or work leaders.

MISHAP 4-8: In November 1994, as a Navy civilian forklift operator was removing a unit of cluster bombs from the second level storage area of the No. 3 hold, the load caught the unit on the left side as he began to back out. This caused the unit on the left to slip off the stack and fall about 4 feet to the deck, damaging the side and corner of the Mk 427-0 shipping containers. No spotter was used.

MISHAP 4-9: In January 1996, an ordnance employee was hit on his hard hat with a loaded missile container as he bent over strapping other loaded missile containers down onto a flatbed railcar at Pier B. Apparently, the forklift operator did not see the employee when he was moving a loaded missile container to be spotted at the designated crane lifting station. The spotter was not properly assigned during this particular evolution. The ordnance employee complained of a sore neck and back and went to the naval hospital for treatment. He lost 6 work days.

No matter how well or how often a task is performed, never take something for granted. Use a spotter or ask for help if necessary.

4-4. TAMPERING. Any tampering with ammunition, ammunition components, and explosives is prohibited by NAVSEA OP 5 Volume 1. Unauthorized assembly of explosive components into inert ammunition items is prohibited. The handling of ammunition or explosives during manufacture or processing and their removal from the operating line is prohibited unless authorized by the supervisor. Excluded from this requirement is the handling and removal of normal samples required for quality control and other inspection requirements. For regulations on the use of explosives or pyrotechnic devices for displays, demonstrations or similar purpose, refer to NAVSEA OP 5 Volume 1.

MISHAP 4-10: In September 1960, a group of enlisted men were performing routine maintenance and cleanup work at a naval air facility. Two of the men went to a nearby dump and, while there, picked up a device of some type. It was brought back to the pool area and given to one of the men having an ordnance background who identified the device as a fuze. Assuming the fuze to be inert, the man proceeded to remove the arming vane. He then tapped the fuze against the table top and the fuze exploded. The man lost his hand and three other men received minor injuries.

4-5. ORDNANCE HANDLING EQUIPMENT (OHE). Ordnance handling equipment (OHE) is used to carry, lift, transport, or transfer explosives or inert loaded ammunition items. It includes beams, carriers, dollies, slings, strongbacks, cargo nets, bands, and other equipment that provides interface between the item being handled and the prime handling equipment. For instructions on selecting and safely operating OHE, refer to NAVSEA OP 5 Volume 1. NAVSEA OP 2173 describes the handling equipment approved for use with ammunition and explosives.

MISHAP 4-11: In 1992, production personnel were in the process of installing a TARTAR LAU HARPOON Guided Missile into a Mk 532 Mod 0 Shipping and Storage Container. A Mk 34 Mod 0 Lifting Beam was installed on the missile in preparation for lifting the missile off of the handling dolly. As the missile was being positioned over the container, the missile fell approximately 4 feet to the floor. When the missile fell, it struck one of the workers involved in the canning operation on the right knee and ankle. The operation was suspended and appropriate personnel were notified. The injured worker was examined by station medical personnel and transported to the Branch Medical Clinic. EOD personnel inspected the missile and determined that the sustainer section was leaking JP10 fuel. EOD personnel placed the missile in a test cell where they transferred the fuel from the sustainer section into a drum and disassembled the missile.

The direct cause of this incident was that the production operator was faulty on securing the missile for movement. In addition, the locking/safety pin was incorrectly positioned on the beam. As a result, a warning was immediately stenciled on the lifting beam. A change was written to HARPOON missile maintenance, and instructions were given to all operators.

4-6. INDUSTRIAL MATERIALS HANDLING EQUIPMENT (MHE). Accidents involving the handling of explosives with forklifts are considered a primary cause of ordnance mishaps on ship and shore. Some of these mishaps could be prevented if supervisors would ensure that forklift operators adhere to the following:

a. Attend the mandatory course (MHE Operator Course), required by NAVSEA OP 5, before they handle any ordnance.

b. Have adequate vision of all items in the handling area. If vision is obstructed, ensure that a safety observer is provided prior to any handling evolution.

c. Are qualified to operate the forklift and are certified to handle the ordnance.

d. Ensure loads are properly stacked or positioned prior to movement.

e. Ensure correct amount of safeties and spotters are present during all handling evolutions.

Safety regulations and precautions for the use of MHE for handling ammunition and explosives in specific locations are specified in NAVSEA SW023-AH-WHM-010. Operators shall be properly trained in the operations to be performed, shall be aware of the hazards involved with MHE usage, shall be certified in accordance with OPNAVINST 8023.24 (series) and shall observe the safety precautions described in NAVSEA SW023-AH-WHM-010.

MISHAP 4-12: In October 1970, while fire bombs were being loaded into a USNS' hold, the fork of a forklift truck punctured one of the bombs causing a leak (see figure 4-7). The bomb in question was the center bomb in a three-high tier of bombs. After completion of work on the day of the mishap, the supervisor was advised that a strong odor of gasoline was coming from the hold. He took no action to investigate this report and ordered the hold closed until morning. The next morning, flammable material was found on the deck. The bomb, a 750-pound fire bomb, was subsequently removed from the hold without incident. No personnel casualties resulted.

Use of a fork stop is required when handling fire bombs; see NAVSUP Publication 538. Gross negligence on the part of the supervisor could have resulted in disastrous results.

MISHAP 4-13: In November 1994, wharf personnel were offloading ordnance from a flatbed trainer received from the magazine and staging the ordnance on the wharf in preparation for loading onboard a ship. While offloading a trailer loaded with unitized HARM missiles (two containers banded together), the explosive forklift driver was trying to clear the trailer and lower the containers. He noticed he was getting too close to an empty flatbed trailer that was parked nearby and applied his brakes, causing the containers on the forklift to slide forward. The rear of the forklift came up off the ground and the containers slid off and fell. One end of the container caught upon the rub rails of the trailer while the other end hit the ground. This caused the entire unit load to drop approximately 2 feet. No damage to the missiles was found.

All ordnance evolutions shall be planned before being executed.

MISHAP 4-14: In July 1996, an MHE operator was assigned the task of retrieving specific HARPOON missiles from a magazine. The missiles were stored in Mk 607 shipping and storage containers. In order to gain access to the specific missiles, the MHE operator had to remove other HARPOON missiles from the magazine that were not to be shipped. The missiles that were to be shipped were loaded without incident on commercial trucks. After loading the trucks, the MHE operator started to restow the HARPOON missiles that had been placed temporarily on the loading platform of the magazine. Using a swing-mast type forklift truck, the operator would pick up a single container, swing the container parallel to the direction of travel and back into the magazine. Once inside the magazine, he would swing the container back to the front of the forklift truck and then stack the containers four-high. As he attempted to swing the last container to the front of the forklift, the container slid off the forklift tines and fell. The forward end of the container landed on the top container of a 2-high stack. Upon impact, the metal framework of the dropped container punctured a hole in the top of the other container. The aft end, which fell approximately 6 feet, struck the magazine floor. The container that was struck incurred a 7" by 10" hole in the top of the container. EOD personnel discovered a dent in the top of the guidance section of the same missile. A spotter was used for this operation.

Spotters must position themselves such that they have a clear view of the operator; a clear view of the load being handled and any obstructions to be avoided; and an unobstructed path to exit the area in case the load shifts, falls or other emergencies.

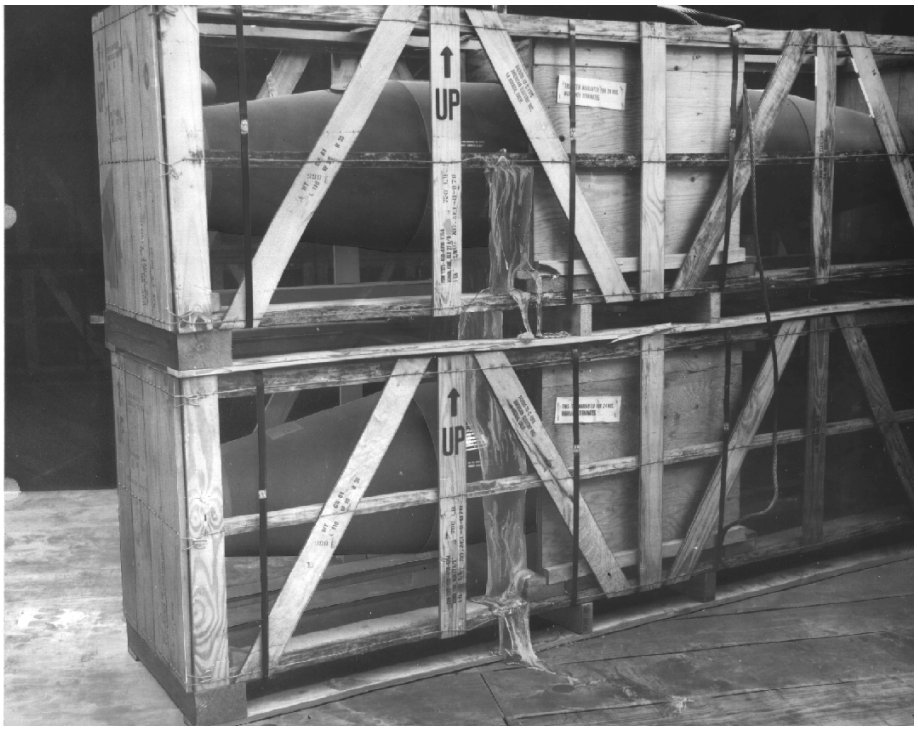

FIGURE 4-7. Leaky Fire Bomb Damaged During Handling

MISHAP 4-15: During handling operations in 1992, a forklift operator caused three torpedo containers (strapped together) to fall 6 feet and land on their sides on the dock. Since these containers were strapped together, the top container was most vulnerable and sustained two small dents in its top. The operator was attempting to move the stack of torpedo containers from in front of another stack positioned tight behind it. He did not have a spotter nor was he using a spacer. Consequently, the forklift tines went through the forklift tine pockets of the first stack and continued partially into the pocket of the second stack. When lifting pressure was applied, the second stack fell over. The top container's holddown strap had a broken weld and its locking device was broken.

Forklift forks must be sufficiently inserted into the forklift pockets of the container and the mast must be tilted backward to stabilize the container. Spotters must assist in all MHE requirements, whenever possible.

MISHAP 4-16: In March 2002, during truck loading operations at a magazine, a forklift loaded with a Mk 65 Mine was exiting the magazine and approaching the outside loading dock. The driver inadvertently depressed the accelerator pedal when he had intended to depress the brake. The forklift with the Mk 65 Mine skidded off the dock and came to rest with the fork tines imbedded in the asphalt, and resting on the base off its main mast, with its rear wheels still resting on the dock, as shown in figure 4-8. EOD was notified and performed a visual screening of the mine case, declaring it "safe and undamaged." The mine case was returned to stock. Forklift truck gear sustained minor damage during removal, rendering it unserviceable.

The forklift involved in this incident was borrowed from another command and was an older style with foot and gas pedals located very close to one another. Explosive drivers should thoroughly familiarize themselves with each forklift prior to operating it with an explosive load. Handling docks should have stop guards installed to prevent forklifts from moving past the end of the dock.

FIGURE 4-8. Forklift Loaded With Mk 65 Mine Slides Off Loading Dock

4-6.1. MAINTENANCE, INSPECTION AND TEST OF INDUSTRIAL MATERIALS HANDLING EQUIPMENT. Maintenance, inspection and testing are crucial elements involved in the safe operation of industrial materials handling equipment. They will improve the overall condition of the equipment and lesson the possibility of accidents. Requirements can be found in NAVSEA SW023-AH-WHM-010.

MISHAP 4-17: In October 1994, a Navy civilian equipment operator was preparing to load a 20-foot container on a chassis using a Clark 50,000-pound capacity rough terrain container handler. The operator started the engine and waited approximately 4 minutes until a light came on indicating that enough air pressure had built up for his brakes to be operational. The operator then proceeded toward the containers, stacked two high by three deep, to pick up the container he needed. When he was within about 20 feet of the container, he applied both the left and right brake and received no response. He then tried to put the Clark in reverse before he contacted the containers, but to no avail. The Clark hit the stack, the container fell approximately 15 feet, hitting a guard rail and landed upside down sustaining damage to the right side and top. EOD examined the material and deemed it safe to be moved to segregation for further inspection. No damage was found.

During the inspection process of the Clark container handler after the mishap, a white tag was found around the steering column stating, “Use right brake only”. The tag had slipped down and was not visible to the operator. Further investigation revealed that the air hose to the left brake had been disconnected by a Public Works mechanic who had informed the equipment operator’s supervisor of this situation. Both individuals decided that the Clark could be operated safety with only the right brake as long as all of the operators were aware of the situation. The Clark was placed back in service while awaiting parts for the brake system. Unfortunately, not all of the appropriate personnel received this information.

No matter how well an operator feels he knows the equipment, pre-operational checks must be conducted. Rather than putting the Clark back into service at a time when it was not fully functional, the supervisor should have thought of other alternatives such as renting another Clark container handler or using cranes. Also, mechanics who service materials handling equipment that will be used in explosive evolutions must never return that equipment to service until such time as it is fully operational.

4-7. WEIGHT HANDLING EQUIPMENT (WHE) (CRANES, LIFTS, HOISTS). WHE is used in conjunction with OHE described in paragraph 4-5 to lift ammunition, explosives and ordnance. All WHE used for handling ammunition, explosives or ordnance shall be maintained, inspected, tested, certified, repaired and altered in accordance with NAVFAC P-307. All WHE shall be operated in accordance with NAVFAC P-307, with the exceptions listed in NAVSEA OP 5 Volume 1 for lifting ammunition and explosives with WHE. Crane operators shall not engage in any movement of cranes without receiving an approved hand or voice signal from the rigger. When moving any type of crane, even with an empty hook, be alert for obstructions. Ensure the ground the crane will travel over is reasonably smooth and level and can support the machine. Inspect all rigging gear prior to use including inspection date (if so marked) and rated capacity. Crane teams and crane operators shall understand the definition of a crane accident and report all accidents in accordance with NAVFAC P-307.

MISHAP 4-18: In November 1993, a 90-ton crane crew was assigned to load one manlift to the flight deck and one manlift to the stern gate of a ship. The first manlift was successfully lifted to the flight deck. While waiting for the second manlift to be positioned and the stern gate lowered, the crane operator discussed the lift with one of his crew as he knew it was a critical lift and verified the load weight. He told his crew member to keep the counterweight of the load towards the crane during the lift and to stand on the outriggers and advise him if the crane got light. The crane operator raised the manlift to clear an adjacent brow stand and mooring lines on the pier and swing towards the ship. As the load approached the ship, the manlift basket struck the upper stern gate which was in the raised position, bending a light on the basket. At about the same time, witnesses noticed the front crane outriggers rock up. The crane continued to raise, “stood up” on an adjacent rail stop and flipped over into approximately 55 feet of water. As the load fell, one of the tires struck the edge of the stern gate. At some point during the crane’s descent, the crane operator extracted himself or was ejected from the cab and made his way to the surface. He was in the water approximately 15 minutes.

His injuries included three breaks to the right arm and wrist, dislocation of the left hip, broken right thigh, broken ribs, punctured right lung, broken nose and numerous cuts and bruises. Permanent partial disability was likely. The estimate for material property damage to the crane, pier and manlift and the cost for recovery, salvage and clean up was up to $1 million.

Proper supervision, job preplanning and development of SOP's are a must for work in high risk environments. In this particular case, the direct cause of the mishap was operator failure to determine the actual radius and boom angle necessary prior to making the lift. Had he done this, he would have found the load exceeded the rated capacity of the crane for the required boom configuration.

MISHAP 4-19: In 1997, before lifting a scrap hull section, riggers estimated the load in the low 30,000-pound range. Rigging gear capacity was 79,920 pounds. After three lifts, the actual weight of the load was determined to be 82,900 pounds, an 18 percent overload.

A review of recent overload accidents showed that weight estimates were off by an average of 80 percent; that is, actual weights were 80 percent higher than estimated. Training in the proper estimation of weight is essential to safe and proper weight handling. When load weights must be estimated, follow the rules of NAVFAC P-307, paragraph 10.5.

MISHAP 4-20: In 1996, a contractor tipped over a mobile crane while placing an aerial work platform vehicle into a drydock. The intended set down location was obstructed. While booming out to clear the obstruction, the crane tipped forward. After the load impacted the ground, the crane tipped backward, breaking the rigging gear and damaging the crane.

The vast majority of crane accidents are the result of personnel error and can be avoided. While the rigger-in-charge has overall control of the operation including ensuring the crane operating envelope remains clear of all obstructions, team members shall work together to ensure the safety of crane operations. Everyone on the crane team shall be responsible for recognizing potential problems and making all team members aware of them.

4-7.1. CROSSDECKING. When crossdecking ordnance, a crane is usually used to transfer limited amounts of ordnance from one vessel to another. A degree of risk is inherent in any ordnance evolution, and the degree of risk increases as the number of components in an operation increase. Such is the case in crossdecking.

MISHAP 4-21: In September 2000, a crossdecking event took place between a barge crane and a Vertical Launching System (VLS) combatant. During an onload of VLS ancillary equipment, a sailor's hand was injured when a wire rope pendant sling parted. The sailor was fortunate in that parted slings can potentially cut a person in half.

VLS ancillary equipment, due to its relatively small size compared to the length of the launcher cell it goes into, has a tendency to get cocked and hung up in the launcher cell. This operation must be done in accordance with the proper procedures with extra care taken to keep the equipment steady and free to move through the cell. This potential to hang up in the VLS cell is compounded greatly when relative motion between the ship and crane is increased. As a result, the Naval Ordnance Safety and Security Activity (NOSSA) letter 8020 Serial N7121/ 1006 of 29 September 2000 limits at-anchorage loading and offloading of VLS ancillary equipment to use of the ships VLS strikedown crane, only. If the VLS strikedown crane is unavailable, the ship must go pier side and use a pier side crane.

4-8. FREIGHT/WEAPONS ELEVATORS AND AMMUNITION HOISTS. Elevators are fixed shipboard systems designed and authorized to vertically move ammunition and explosives between decks. Shipboard hoists are fixed or portable systems designed and authorized to move ammunition and explosives within the ship's structure. NAVSEA OP 4, paragraphs 3-8.1 and 3-9.4.2 provide safety requirements for freight/weapons elevators and ammunition hoists, respectively.

MISHAP 4-22: A sailor was assigned to help two civilian technical representatives from the weapons-elevator support unit to survey the material condition of the elevators. The elevator door had to stay open so that the operator and observer outside could talk to the contractor's representatives on the elevator car during the survey. In an effort to find the proximity switch which when flagged would override the "door closed" logic, the sailor laid down on the deck outside the elevator and leaned into the shaft, over the top of the lower door and under the raised ramp. As he placed the flag on this switch, the door started closing, fatally crushing his head and torso between its outer side and the ramp's inner side.

All elevator operation, maintenance, inspection and testing shall be in accordance with NSTM S9086-ZN-STM-010/CH-772. Elevators shall be securely blocked before any personnel goes under them. If the elevator is operational, personnel shall never reach into, or place any part of their bodies within, the shaft.

MISHAP 4-23: A fireman and an MM3 were helping an MM2 do monthly elevator-PMS checks onboard an AE. The checks involved cleaning and oiling the guide rails. The MM3 went to the elevator-machinery room and de-energized the elevator. He then manually and slowly released the brake, lowering the elevator platform by gravity, with the MM2 and fireman aboard. These two Sailors oiled the rails during the descent. When the elevator reached the bottom, the MM3 re-energized it so the MM2 and fireman could ride it back to the main deck. All three Sailors knew this action violated procedures, but they didn't want to use the ladders that were available. One time, no one was around when the elevator reached the bottom of the hold, so the MM2 decided to dispatch the elevator himself. To accomplish this dangerous feat, he first pushed the dispatch button, then sprinted toward the only opening, the door farthest from the controls. Leaping for the moving platform, the MM2 landed on his hands and knees,

with his legs hanging over the edge. Unfortunately, he didn't have time left to pull them in. The top of the opening caught one of his ankles and dragged his body between the platform and the trunk, killing him instantly.

Elevators shall not carry passengers unless authorized for passenger use, such as medical emergencies or during maintenance. No one shall get on or off an elevator while it is in motion.

4-8.1. SAFETY MARGINS. Safety margins shall be painted on ordnance elevator platforms to ensure that loads do not overhang the platform prior to closing doors or hatches. Refer to NAVSEA OP 4 for specific details on elevator safety margin markings.

MISHAP 4-24: In March 1996, ammunition was placed on an elevator for transfer to the 01 level. One corner of the ammunition pallet was extended across the yellow hazard line. This was not noticed by the forklift driver, elevator operator, or the safety observer. When the elevator was sent to the 01 level, the corner of the pallet was caught on the ships structure, denting or scarring seventeen powder cans. The elevator operator on the 01 level heard the noise and pressed the emergency stop button. The elevator was jogged back down to third deck and the ammunition was safed by EOD personnel.

All ammunition and cargo placed on elevators for transfer should have their position verified by the safety observer and the elevator operator.

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CHAPTER 5

AMMUNITION STORAGE/STOWAGE PRECAUTIONS

5-1. INTRODUCTION. The term storage includes ammunition maintained in any semi-permanent storage condition at any location. It includes ammunition at regular depots in the continental U.S.; at overseas bases; and in advanced base type storage or open storage in direct support of operations involving combat ashore and afloat. Of particular concern are open ammunition storage areas ashore which are frequently vulnerable and subject to major disaster unless effective measures for their security against fire can be provided. The term "stowage" refers to ammunition maintained in magazines aboard ship. These magazines are designated with specific reference to the purpose intended.

5-2. STORAGE/STOWAGE COMPATIBILITY. The highest degree of safety in ammunition and explosives storage could be assured if each item or division were stored separately. However, this ideal storage is generally not feasible. A proper balance of safety and other factors frequently requires mixing of several types of ammunition and explosives in storage.

5-2.1. STORAGE IN MAGAZINES. Ammunition and explosives may not be stored together with dissimilar materials or items that present positive hazards to the munitions. Examples are mixed storage of ammunition and explosives with flammable or combustible materials, acids, or corrosives. Different types of ammunition and explosives designated by item and division may be mixed in storage provided they are compatible. Ammunition and explosives are assigned to a storage compatibility group (SCG) when they can be stored together without increasing significantly either the probability of an accident or, for a given quantity, the magnitude of the effects of an accident. Considerations contributing to SCG's and further details on compatibility can be found in NAVSEA OP 5 Volume 1.

MISHAP 5-1: Standard and developmental explosives stored in a magazine detonated. The magazine was destroyed, and there were numerous broken windows, doors and holed roofs on surrounding explosives operating buildings. There were also numerous broken windows in the surrounding civilian community. The debris ignited several vegetation fires in the explosives magazine area which were extinguished.

Compatibility must be considered before different items are stored together, especially where developmental items are concerned.

MISHAP 5-2: On August 1, 1994, at the Naval Surface Warfare Center, Indian Head, Maryland, an above ground magazine was destroyed in a major incident caused by an autocatalytic chemical reaction (self ignition) of either bulk propellants having low stabilizer content or an exothermic chemical reaction involving the reaction of two incompatible materials being stored in close proximity. Inventory records showed the magazine contained 98,000 pounds of energetic materials with at least 4,600 pounds being hazard class 1.1 (mass detonating). The magazine was sited for materials that have a hazard classification of 1.3 (mass fire hazard). See figure 5-1.

Some roofing material debris was thrown beyond the perimeter fence and onto private property. There was also widespread window damage reaching beyond 1,500 feet.

This incident was preventable. SOP's were in place at the time of the incident for the receipt, storage, segregation, issuing, handling, and disposal of energetic materials. At the time of the incident, the material suspected of self ignition had been tested and designated for removal from the magazine for disposal. These actions were not completed within the timeframe specified by local SOP. By not fully carrying out the actions defined under local procedures, an unintended risk factor was introduced which likely contributed to the fire in Magazine 518. As a result of this mishap, a requirement for separate storage of laboratory samples was added to NAVSEA OP 5 Volume 1.

FIGURE 5-1. Magazine 518 Before and After

5-2.2. SHIPBOARD STOWAGE. Insofar as practicable, magazines are designated to hold a single type of ammunition. Where space limitations are such that separate stowage is impossible, stowage of more than one type is authorized in accordance with permissible stowages contained in NAVSEA OP 4, or as otherwise authorized by NAVSEASYSCOM. Ammunition shall be stowed so that the oldest ammunition will be most accessible and used first.

MISHAP 5-3: On April 16, 1947, a disaster occurred in the harbor of Texas City, Texas, where three ships and one barge were moored. In her hold, the French S.S. *Grand Camp* had 961.3 tons of ammonium nitrate and 2,000 tons of bulk sulfur. The S.S. *Wilson B. Keene* was not loaded and was undergoing repairs. The barge *Longhorne II* was loaded with sulfuric acid. Next to the harbor were steel frame and reinforced concrete pier warehouses housing bagged flour and 1,000 tons of ammonium nitrate. Also in close proximity to the waterfront was the Monsanto Chemical Plant which was manufacturing styrene plastics. The Monsanto plant contained large high-temperature chemical processing equipment, storage tanks of benzene and liquid styrene, and 12 rail tank cars. Also near the waterfront were oil storage facilities of several petroleum companies. See figure 5-2.

At the close of operations the previous day, a draft of bags of ammonium nitrate had been left in the square of the hatch. At the start of operations at 8:20 a.m., on April 16, stevedores arriving in the hold of the S.S. *Grand Camp* noticed smoke coming up between the ammonium nitrate bags and the hull. After attempting to extinguish the fire using a hand fire extinguisher, they observed flames coming from the bottom of the ammonium nitrate pile at several places. With the fire beyond their control, the stevedores left the ships hold and closed the hatch at 8:40 a.m. Steam was reported to have been turned into the hold by the ship's crew. When the fire progressed, a public alarm was turned in by a whistle and the longshoremen left the scene. The volunteer fire department units from Texas City had two streams of water on the burning ship when it exploded at 9:14 a.m. Almost the entire fire department was lost in the explosion. A crowd of onlookers, not realizing the potential for explosion, had gathered to watch the bright orange color coming out of the black smoke. A great column of smoke shot up an estimated 2,000 feet, followed in about 10 seconds by another, and even more violent shockwave. The air blast from the explosion virtually demolished the plastics building and powerhouse of the Monsanto Chemical Plant, overturned tank cars, and blew the styrene storage tanks out of their earthen berms. A miniature tidal wave, caused by water displaced from the bay at the explosion rushed over the docks and continued 150 feet inland.

Rescue efforts continued throughout the night, including a vain attempt to tow the burning S.S. *High Flyer* out of the ruined harbor. At 1 a.m. on April 17, everyone was ordered away from the area, and the S.S. *High Flyer* exploded at 1:10 a.m., taking with her the S.S. *Wilson B. Keene*. This blast destroyed a concrete warehouse and a grain elevator and triggered even more fires.

The sulfuric acid barge, the *Longhorne II*, was washed inland over 100 feet, passing over a railroad track bed 3-feet high, coming to rest with damage to the barge.

This disaster resulted in 634 deaths, 3,000 injured and damages to facilities estimated at $50 million. The cause is believed to have been due to burning of ammonium nitrate and paper bags impregnated with this material under confined conditions in the ship's hold. The source of the initial fire has not been determined. It was observed that the ammonium nitrate was a mixture of 1/2 white crystals of angular shape and 1/2 buff-rounds particles. A strong odor of ammonium was noticed. To prevent caking, the ammonium nitrate was coated with an organic material designated as Type B wax. Historical records of previous industrial explosions of ammonium nitrate indicate that either a very strong initiating charge or contamination by an oxidizer material such as organic material or sulfur is necessary for detonation of ammonium nitrate. Other suspected contributing factors were residue oil in the holds mixing with ammonium nitrate, creating ammonium nitrate/fuel oil (ANFO), a sensitive explosive, or spontaneous combustion of paper, oil and other organic materials, or salt water reactions.

The lesson to be learned is that compatibility of any component is critical in preserving insensitiveness.

5-3. AMMUNITION AGE AND SHELF LIFE CONSIDERATIONS. For every item of ammunition there is a stated shelf life within which the item should perform as intended providing it has been stored under acceptable environmental conditions. Estimated shelf life is based on normal expected environmental conditions. Storage under adverse environmental conditions can materially reduce the expected shelf life. As it is difficult to determine how much reduction has occurred, it is general practice to withdraw from service items so exposed. Excessive age will affect ammunition in a variety of ways, depending on the type of ammunition and the details of its storage. Accurate ammunition records and a vigorous surveillance program are required to ensure that ammunition in storage does not exceed its recommended shelf life and to detect at an early stage any ammunition which shows signs of having been subjected to adverse storage conditions.

Photo courtesy of Moore Memorial Public Library, Texas City

Photo courtesy of Moore Memorial Public Library, Texas City

The Grandcamp's propeller shaft was flung far from where the ship was berthed. Pieces of the ship, some ablaze, were transformed into deadly missiles. The powerful explosion hurled the Grandcamp's 1.5-ton anchor 2 miles.

FIGURE 5-2. Texas City Port Disaster, April 16, 1947 (Sheet 1 of 3)

Photo courtesy of Moore Memorial Public Library, Texas City

The tidal wave produced by the explosion sent this 150-foot, 30-ton barge 100 feet inland. The surge of water also killed a number of people who survived the initial blast, drowning them as they lay trapped in rubble or unconscious.

Photo courtesy of Moore Memorial Public Library, Texas City

The Grandcamp explosion triggered a series of blasts at Texas City chemical plants. Thick clouds of black smoke vaulted skyward. Fires burned out of control for days.

FIGURE 5-2. Texas City Port Disaster, April 16, 1947 (Sheet 2 of 3)

Photo courtesy of Moore Memorial Public Library, Texas City

Wood-frame houses in Texas City were crumpled by the powerful blast. For miles around, windows shattered in homes and businesses. Some survivors decided to move out of Texas City, but most stayed to rebuild.

Photo courtesy of Moore Memorial Public Library, Texas City

The freighter Wilson B. Keene was alongside the High Flyer, which blew up in the wee morning hours. Like the Grandcamp, the high-flyer was loaded with ammonium nitrate.

FIGURE 5-2. Texas City Port Disaster, April 16, 1947 (Sheet 3 of 3)

NOTE

Shelf life should not be confused with ammunition service life. Service life is a general term referring to the average or mean time within which the ammunition item should perform as intended. Service life is based on the ammunition's performance, and is not assigned to all ammunition. See NAVSUP P-805.

MISHAP 5-4: During a weekend at Lone Star Army Ammunition Plant, a service magazine containing benite (1,820 pounds) and black powder (244 pounds) exploded. The explosives had been stored there for more than a year. The magazine was heated and temperatures were possibly as high as 130-160° Fahrenheit during that time period. Damage was limited to the magazine and an adjoining ramp that ran from the magazine to an operating building.

Deterioration of the explosives was determined to be the cause of the explosion. Magazine and magazine areas shall be periodically inspected for contents identification, condition, arrangement, and segregation. Inspection requirements are listed in NAVSEA OP 5 Volume 1.

MISHAP 5-5: At Lake City Army Ammunition Plant, a magazine containing 2,240 pounds of IMR 4903 propellant burned. The propellant apparently deteriorated, resulting in auto-ignition. The fire started in the container of the propellant and spread to other containers. Damage was limited to the magazine and its contents.

Stored propellant shall be periodically inspected for stability.

MISHAP 5-6: At the Sierra Army Depot, BLU-82/U bombs at an outdoor storage site detonated high order. The explosion was believed to be due to deterioration of the explosive filler, resulting in temperatures and pressure increases. There was damage to the administrative area (broken windows), several magazines (cracked concrete, damaged doors) and off-base buildings (broken windows, damaged wells and pipes, a collapsed ceiling and one building collapsed).

Ammunition and explosives outside of magazines or environmentally controlled buildings are susceptible to conditions and temperatures that can affect their performance and safe handling. For any ammunition or explosives which remain outside of magazines or explosive operating buildings longer than 24 hours, follow the procedures given in NAVSEA OP 5 Volume 1.

5-4. RESEARCH, DEVELOPMENT, TEST AND EVALUATION (RDT&E). The compatibility group of experimental energetic materials under development may not be known. Storage configurations for up to 25 grams of energetic material per container are allowed ashore provided the total magazine limit does not exceed 1,000 pounds net explosive weight (NEW). Each container shall be capable of fully containing any possible reaction of the contents. Each container design or type must be approved by NOSSA (N5). Storage configurations and duration of storage in these configurations will be approved by line management and the local safety office, however, the inventory in such a magazine will be reviewed

and justified on an annual basis. See NAVSEA OP 5 Volume 1. Direction concerning the removal of energetic materials from operating buildings at the end of the workday are provided in NAVSEA OP 5, paragraphs 4-1.7.5 and 11-6.3. Afloat, experimental explosives or ammunition containing experimental explosives shall be separately stowed from all other explosives.

MISHAP 5-7: On June 28, 1992, at the Naval Surface Warfare Center Detachment White Oak, Maryland, near simultaneous explosions occurred within an earth-covered magazine. The second explosion completely destroyed the magazine. Damage to the local civilian community was limited to broken windows from the overpressures. Minor damage was also done to windows and buildings located on the facility grounds. No personnel injuries occurred and all damage from debris was within station boundaries. See figure 5-3.

The magazine contained several formulations of a new type of explosive being researched. A reconstruction of the magazine inventory revealed the magazine contained approximately 5,000 pounds of explosives, well within the 7,000 pounds it was certified to contain. Investigations showed processing procedural errors and inadequate attention to the storage of unstable explosive products led to the explosions.

Unstable materials shall not be stored in the same magazine as Code A material. Incompatible materials shall not be stored together, and accurate magazine inventories shall be conducted.

MISHAP 5-8: Process development personnel were in the second of several 5-pound mixes to characterize the effect of Hivelite 498 on double base gun propellant burning rates. (Hivelite is a proprietary name for a family of boron-hydride chemical compounds used as either a fuel or a burning rate modifier.) The propellant had been successfully mixed and extruded and the strand was being cut in a large arms cutter. Attendant personnel noticed flames behind the fire screen, separating the cutter from the container holding the cut propellant, and exited the bay as the automatic sprinkler activated. An informal engineering investigation found no defects in the cutter and operating personnel were following the approved operating procedure for this job. Tests conducted on the uncut propellant from this mix showed medium sensitivity to initiation from impact and low sensitivity to friction and electrostatic energy.

The engineering investigation concluded the fire was caused by a chemical incompatibility between Hivelite and nitrocellulose and other nitrate esters. This conclusion is based on the lack of equipment and procedural defects and reports in the literature concerning chemical incompatibility.

Additional efforts shall be conducted to understand the nature of the incompatibility between nitrate esters and Hivelite. Further, there is a need for additional one-pint or smaller sub-scale mixes to define the initiation mechanism, which was not inferred from impact friction, and electrostatic sensitivity testing. Additional protection shall be provided to the operator responsible for processing of Hivelite formulations.

FIGURE 5-3. NAVSURFWARCEN Indian Head White Oak Detachment Magazine Before and After Explosion

5-5. TEMPORARY OPEN STORAGE. Open storage sites are to be used only with the approval and direction of NOSSA (N5). Refer to NAVSEA OP 5 Volume 1 for requirements to obtain open storage approval. In addition, existing regulations concerning quantity-distance, piling, dunnaging, identification, and inspection for aboveground magazines shall apply to open storage areas. Refer to NAVSEA OP 5 Volume 1, paragraphs 11-5 and 11-6.2 for open storage regulations.

a. The following precautions shall be observed when ammunition has been removed from magazines for firing or ready service:

(1) During firing, no ammunition other than that immediately required shall be permitted outside of the magazine.

(2) When cartridges or other explosives are outside the magazine, each flame-proof compartment or space which forms a stage of the ammunition train, including the magazines and gun compartments in or out of turrets, shall, wherever practicable, be kept closed except when passage of ammunition requires it to be open. Where practicable, no flame-proof stage of the ammunition train shall be open to both the preceding and the following stages at the same time.

MISHAP 5-9: In June 1966, at a naval air station in the Philippines, a number of ejector racks containing photoflash cartridges exploded while awaiting loading on aircraft for night operations. The loaded ejector racks had been withdrawn from their ready service magazines and temporarily stored in an open end quonset hut near the aircraft line in preparation for aircraft loading. The resultant explosion injured 11 men and damaged the quonset hut in which the ammunition was stored.

The cause of the accident is not known, however, sensitive ammunition was outside of its original containers and temporarily stored near the flight line. The ordnance was drawn from the magazine before it was required for loading, necessitating temporary storage in an unsatisfactory area where too many personnel were nearby.

5-6. AMMUNITION SUPPLY POINT (ASP) OPEN STORAGE. In advanced base areas or under field conditions, the risk of grass fire could result in loss of the entire stock due to explosion. Vegetation near open storage facilities created in support of combat operations or field training exercises shall be controlled to the extent described in NAVSEA OP 5 Volume 3. Figure 5-4 illustrates the devastation that can occur as a result of explosions in a large open area ammunition storage site.

FIGURE 5-4. Results of a Major Explosion in a Forward Area Ammunition Storage Site

MISHAP 5-10: In April 1969, a grass fire that originated outside an Ammunition Supply Point (ASP) spread into the area initiating fires and explosions which resulted in complete loss of the ASP. For a number of months prior to the accident, small fires had been observed in a civilian area across a road along the boundary of the ASP. Such a fire was in progress on the day of the accident. A variety of air and ground types of ammunition were present in the area, including a variety of dry wooden ammunition boxes. The fire became unmanageable and spread, eventually covering the entire ASP area and destroying the complete stock of ammunition on hand. This accident caused the deaths of two men and wounded 78. The value of the ammunition destroyed was estimated at more than $97 million dollars with total losses of almost $105 million.

The accident could have been prevented by proper housekeeping and foreseeing and taking remedial action before the fact to correct deficiencies.

5-7. PILING/STACKING. Safe stacking starts with a safe base. If the floor or yard surface is uneven, check to see if it can be leveled, or if a better site can be used. Crosstie (interlock) the pile and use dunnage or timber when necessary to keep the stack from shifting. Ensure that barrels or other round objects that can roll are secure. Never stack broken containers. If containers are damaged, material must be repackaged before it is stacked.

5-7.1. STACKING HEIGHT. Stacking height depends on the floor load limit, the type of material, the strength of containers, and the requirements of fire protection. There must be at least 18 inches between the top of the stack and the sprinkler heads. If the material can burn easily, allow at least 36 inches. Where they are available, stacking height requirements for individual items are listed in NAVSEA SW020-AC-SAF-010. Never store things close to open light bulbs, or hot pipes. See NAVSEA OP 5.

5-7.2. STACKING IN AISLES. Nothing shall be stacked in aisles where it can interfere with the movement of power trucks and fire equipment, or personnel walking by. See NAVSEA OP 5.

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CHAPTER 6

PREPARATION FOR SHIPPING AND AMMUNITION IN TRANSIT

6-1. INTRODUCTION. A common cause of accidents to ammunition in transit is due to the movement and vibrations of the transporting vehicle or vehicles. These can vary from a mild continuous vibration or rocking movement to violent jarring and shock. In addition, the civilian population near, through, or over which ammunition is transported has become increasingly aware of their stake in ammunition and explosives movements. Therefore, safety rules and regulations formulated for this purpose must be adequate and complied with at all times to prevent accidents and protect the public.

6-2. SCOPE. Transportation of ammunition as discussed herein applies to ammunition in transit between two points, origin and destination. It is not intended to cover ammunition carried as regular allowance by Navy ships for use in their assigned combat or training missions. Such ammunition is considered to be in storage.

6-3. GENERAL LOADING REGULATIONS

6-3.1. GENERAL. Since loading and unloading operations involve handling of ammunition and explosives, the general handling regulations described in chapter 4 shall be observed. Particular importance is given to the requirement for the use of approved and tested handling equipment and for properly trained and supervised personnel. In addition to the general handling regulations, the general safety regulations in chapter 2 shall be followed. Also refer to NAVSEA OP 5 Volume 1 for general loading regulations.

6-3.2. PROCEDURES AND INSPECTIONS. Procedures and inspections pertaining to ammunition and explosives loading and shipment are given in NAVSEA SW020-AG-SAF-010 and NAVSEA SW020-AF-HBK-010. Topics covered in these publications include preparation and retention of loading records, pre-loading inspection of equipment and material to be loaded, inspection prior to offloading, damaged shipments, cargo compatibility, and conveyance storage time. Additional requirements for damaged ammunition, empty containers and spent rounds, opening or repairing containers, loading and bracing ammunition, pneumatic nailers and battery powered tools are to be found in NAVSEA OP 5 Volume 1.

MISHAP 6-1: On September 9, 1992, a fatal accident occurred at Lexington-Bluegrass Army Depot, Kentucky, involving M206 Countermeasure Flares during blocking and bracing of a shipment in a commercial trailer. Evidence and testing indicated that initiation of the flares was caused by a nail from a pneumatic nailer penetrating an approved shipping container, striking a flare. Two blocker/bracer workers were notified by their supervisor that they were to block and brace a vanload of M206 Flares and a vanload of 2.75-inch rockets. The two workers examined the load and agreed to “track” the load by nailing two 2- by 4-inch boards along the sides of the pallets to prevent

shifting during transport. They decided to use an air compressor and pneumatic nail guns to do the nailing. After some difficulty (approximately 5 minutes), Worker 1 finally started the air compressor motor. Worker 2 entered the van with a pneumatic nail gun and began, at the rear of the van, nailing the tracking boards in place. Worker 1 began work in the other van which contained the rockets. Worker 2's work was being observed by the driver of the vehicle. Driver was standing at the rear of the van looking through the rear van doors. Worker 2 completed tracking two parallel rows of pallets in the rear of the van, and began tracking another row of pallets near the center of the van, blocking the aisle made by the two rear parallel rows of pallets. As Worker 2 was observed to continue the tracking of the pallets, the driver heard the ignition of a flare and saw fire developing in the immediate area where Worker 2 was working. Driver was knocked down by the blast but was not injured. The driver and Worker 1 who exited the other van when he heard the blast, ran for help. The Lexington Bluegrass Army Depot fire department extinguished the flames, and rescue workers located Worker 2's body at the left front corner of the van.

While blocking and bracing a load of pyrotechnics, worker used equipment for the task which was not authorized by the SOP. As the work progressed, a steel nail from the pneumatic nail gun was discharged into a wooden box of M206 Flares, igniting them. The resultant massive fire destroyed the transport van and fatally injured the worker.

Immediately following this incident, use of pneumatic power nailers within 50 feet of explosives was prohibited until criteria could be developed for determining which items and operations were safe for use of power nailers. This criteria was built into SOP's for all operations involving the nailers. Further, although it did not contribute to the cause of this accident, the placement of the ammunition pallets within the van by the loading team did not provide an unobstructed path to the exit, which was required by the SOP safety notes. Procedures for the loading of ammunition, which provide for unobstructed exits were reviewed, revised as necessary, and enforced.

6-4. PREPARATION FOR SHIPMENT. Requirements for the preparation of ammunition and explosives for shipment as described in NAVSEA SW020-AG-SAF-010 shall apply. That manual presents detailed requirements for packing, marking, and labeling of ammunition and explosives and discusses the shipping documents required for moving this material.

MISHAP 6-2: In June 1991, a crew of three qualified/certified individuals was assigned to transfer and transport retrograde ammunition/explosives from one magazine area to another for temporary storage preparatory to EOD disposal. A certified flatbed, railed truck was being used to transport the materials; building separation was about 2 miles. A standard procedure was followed. The incident occurred with the ninth load being transported. The last container loaded on this trip was a wooden crate containing nine canisters of Mk 33 Mod 0 Safety and Arming Devices. The crate was not properly tied down. The truck made a very sharp left turn and apparently the crate jumped the rear rail, fell 6 to 8 feet to asphalt pavement, and rolled about 8 feet into the grass. No one noticed the missing crate during unloading. The crate was found the next day by a security patrol.

The safety investigation revealed that the transfer and transport of retrograde ammunition and explosives was not performed in accordance with NAVSEA OP 5 Volume 1, NAVSEA SW023-AG-WHM-010 or NAVSEA SW020-AG-SAF-010. The vehicle required proper blocking, bracing, or strapping of the loaded pallets during on-station movement. A local policy relative to these procedures must be established and posted in each explosives transport vehicle. Netting must also be used to keep light load position as required. Inventory checks are mandatory during both loading and unloading.

MISHAP 6-3: In November 1995, ordnance personnel received one box of multi-pack explosive dynamite for disposition consisting of water gel, nitroglycerin, and ammonium nitrate. The material was packaged together with different United Nations (UN) markings, incorrect DOT markings and labeling. Due to the sensitivity of the items, EOD was contacted to inspect and unpack suspect material. EOD unpacked the dynamite and found it to be leaking an exudate which they identified as nitroglycerine. EOD took the suspect dynamite with them for disposal.

A thorough inspection of all explosives prior to shipment and upon receipt is a must. If suspect material is found, it shall be disposed of through proper channels at that time. All activities shall complete a thorough inventory to determine that there are no suspect materials such as described. Activities storing this type of dynamite shall refer to NAVSEA OP 5 Volume 1, paragraph 10-7.14.3 and 11-8.15.9. All ordnance personnel must be aware of the rules for storage of commercial dynamite. If suspect dynamite is found, EOD must be notified for dynamite disposal. Receipt inspection of incoming explosives is a must.

6-4.1. BLOCKING AND BRACING. As ships sometimes encounter heavy seas, cargo must be secured by blocking and bracing in order to prevent displacement during rolling and pitching. Military Sealift Command (MSC) TW023-AB-WHS-010, chapter 5 refers. The following two mishaps were caused by incorrect blocking and bracing.

MISHAP 6-4: An AE was involved in a rearming evolution while in heavy seas. The ship was fully loaded to support a major underway replenishment at sea (UNREP) and cargo hold space was at a premium. The hazards of storing containers fore and aft rather than port to starboard had been discussed but were deemed unavoidable. Six exercise weapons in Mk 183 Containers were stacked fore and aft on the second deck of cargo hold No. 4. Handling personnel had already broken out two of the six stowed weapons when the ship took a hard roll to starboard and the two top containers began to fall.

The uppermost container rolled off the stack and across the top of a forktruck, striking an SN ammunition handler. The man flipped over the elevator safety net and fell about 40 feet to the bottom of the elevator shaft. The container stopped momentarily on top of the forklift truck while the ship rolled to port, and attempts were made to secure it in place. The ship again rolled to starboard, however, and the container rolled into the elevator shaft. It was stopped by the elevator buffer spring mounts which kept the container from landing on the SN lying at the bottom of the shaft.

The man suffered only minor abrasions and a broken left arm.

Cargo stowed in the manner described may well have been justified, but the mishap report made no mention of any method used to secure the containers for a rolling and pitching ship.

MISHAP 6-5: On December 26, 1969, about 1,200 miles from Midway Island in the Pacific Ocean, bombs exploded in the hold of the S.S. *Badger State*, blowing a 12- by 8-foot hole in the hull just above the waterline. The *Badger State* was carrying 8,900 bombs and rockets for the U.S. Air Force from Bangor Naval Ammunition Depot to DaNang, South Vietnam. During a storm in the North Pacific Ocean, the cargo of military explosives onboard broke loose. For over a week, the bombs, some of them 2,000-pound bombs, not having been loaded properly, rolled back and forth with each motion of the ship. They slammed against one another and the inside of hull. Many bombs were out of their cases. The crew attempted to jam all types of items between the bombs in an effort to stop the rolling: mattresses, lifejackets, chairs, even frozen meat. Eventually the constant battering punched holes in the hull and in a tween-deck hatch, which covered the opening between different levels in the cargo hold. Bombs fell through from one level to the next. The ultimate explosion which opened a hole in the starboard side, started minor fires and caused other structural damage. The vessel was ordered abandoned. Waves were 30 feet high, rain was heavy, and winds were over 40 knots. Thirty-five of the crew of 40 were lowered to the water in the starboard lifeboat. As it drifted aft, a 2,000-pound bomb fell into the boat from the hole blown in the side of the ship, causing the lifeboat to capsize. A Greek freighter, *Khian Star*, came to the rescue, but 26 of the crew were washed away by giant waves and the attack of albatrosses. Fourteen survived. After 10 days of fires and explosions, the S.S. *Badger State* finally sank on 5 January 1970.

The investigations concluded that the major cause was failure of the blocking and bracing to restrain the bomb pallets.

As a result of this tragedy, modern-day metal dunnaging systems were developed. Techniques for blocking and bracing of cargo were developed which would be adequate to restrain cargoes in heavy weather conditions. Detailed unit loading documents were written, providing specific procedures for securing fleet-issue loads.

6-5. AMMUNITION IN TRANSIT. The transportation of ammunition as it is discussed in this manual applies to transit between two points, origin and destination. It is not intended to cover ammunition carried as regular allowance by Navy ships for use in their assigned combat or training missions. Such ammunition is considered to be in storage, or in use. The most prevalent cause of accidents to ammunition in transit is related to the movement and vibrations of the transporting vehicle or vehicles. Accidents to a carrier are also great cause for concern.

MISHAP 6-6: Probably the most tragic accident involving ammunition in transit occurred in 1917 in the port city of Halifax, Nova Scotia, when a ship that was loaded with high explosives collided with another ship while entering the port. One of the vessels, the French ship *Blanc*, carried 7,000 tons of picric acid, an extremely sensitive primary explosive, and a deck cargo of gasoline. While entering port, she collided with the Belgian steam IMO resulting in damage that opened her hold and ignited her gasoline deck cargo. Blazing gasoline spilled into her hold through the openings caused by the collision and ignited the high explosive cargo. The crew, expecting the ship to explode, abandoned her to drift in the channel. The *Blanc* burned for several hours; during which she was boarded by a fire fighting party from a British warship in the harbor. Tug boats were sent to attempt to get her out of the channel. The *Blanc* eventually drifted against the piers alongside the channel and detonated in a terrific blast of high explosive force which engulfed the major part of the city and harbor. The explosion of the *Blanc* in Halifax harbor must rank as one of the largest which has ever occurred. It was also one of the most devastating. Approximately one half of the city was leveled. A number of nearby ships were completely demolished and the tidal wave which resulted carried other ships ashore leaving them stranded inland far above high water. Over 5 million pounds of explosives were involved in the blast. Over 1,800 people were killed and thousands injured.

6-5.1. RAIL TRANSPORT. Trains are subject to derailment or collisions in which severe damage with possible fires and explosions can result. In addition, ammunition in rail transit may be subjected to severe jostling where switching and shunting are required enroute. As rail shipments pass through or in close proximity to heavily populated and industrial areas, safety is of utmost importance and pre-loading and loaded railcar inspections must be conducted. Railroads within a Navy or Marine Corps shore establishment shall be operated in accordance with the requirements of NAVSEA OP 5 Volume 1.

MISHAP 6-7: In May 1967 at a naval weapons station, aerial bombs were being transferred from a railroad boxcar to a commercial ship for further transport. A forklift operator was lifting two palletized bombs when one detonated low order. At the time of the low order detonation, there was an additional 1,500,000 pounds of explosives on the pier and aboard the vessel being loaded. The boxcar caught on fire but was quickly extinguished. Pieces of the bomb, its filler and section of the boxcar were spread over a wide area. Minor injuries were sustained by the forklift operator. The boxcar was totally destroyed. See figure 6-1. Minor damage also occurred to the forklift and adjacent equipment.

No cause for this mishap was determined. Conceivably, the bomb that detonated was highly unstable in some manner, and required only the degree of shock induced by normal handling to produce a low order detonation. The results were surprisingly minor in nature. Had the bomb detonated high order, it is quite possible that the pier, ships, and surrounding area would have been demolished.

6-5.1.1. Railcar Spotting. When single railcars are spotted, the handbrakes shall be set and the wheels chocked with two chocks. See NAVSEA OP 5 Volume 1.

MISHAP 6-8: In August 1970, at a naval weapons station, a railcar loaded with 8-inch projectiles derailed after traveling 2-1/2 miles. The train crew had cut the car off on the main line in order to spot a second car at a magazine. The conductor climbed to the top of the car to set the brakes. As he began to dismount, the car began to roll downgrade on the main line. The conductor again ascended the ladder to set the brakes. He had trouble setting the brakes, but continued to try as the car gained momentum on the downgrade. After traveling 2-1/2 miles, the car failed to negotiate an S-curve and left the tracks, tipping over on its right side. The conductor suffered two broken legs, a severe concussion, and partial blindness. Damage to the car involved both trucks torn away, holes punched in the roof of the car, and the airbrake tank torn off. Figure 6-2 illustrates. Damage to the projectiles was unknown, but all were turned in for x-ray examination.

In this instance, personnel error resulted in failure to chock the wheels of the railcar prior to cutting loose from remaining cars.

6-5.1.2. Railcar Inspection. Refer to NAVSEA SW020-AF-HBK-010 for inspection criteria of railcars used on-station. 49 CFR prescribes safety standards for railcars transporting Class/Division 1.1 and 1.2 explosives off-station.

MISHAP 6-9: In June 1919, a Western Railroad train, transporting M117 (Air Force) 750-pound bombs from the Cornhusker Army Ammunition Plant, NE was in transit when an explosion occurred. The bombs were loaded with 350 pounds of Minol-2 and 2-3 pounds of Tritonal. There was no fatalities, but two individuals were injured. Three box cars were destroyed and one moderately damaged.

The explosion was caused by cook off of the bombs resulting from a fire in one of the box cars which had been started by red hot brake shoes on the cars' undercarriage. This accident illustrates the need for constant surveillance of railcar equipment carrying hazardous cargo. Compliance with all railcar inspection requirements by commercial carriers is necessary, as underscored by this incident.

MISHAP 6-10: On April 28, 1973, a Southern Pacific train, which included 21 DODX railcars, enroute to Port Chicago, California (now Concord) was stationary in the Roseville, California Antelope Railyard when a series of explosions began which lasted about 32 hours and involved 18 of the 21 cars. (See figures 6-3 and 6-4.) The 18 cars carried a total of 4,368 bombs. The explosions and hot shrapnel caused fires in a nearby town which destroyed eight buildings. The explosions measured 1.5 on the Richter scale.

FIGURE 6-1. Low Order Explosion of a Bomb in a Freight Car

FIGURE 6-2. Runaway Carload of Ammunition Derailed

There were no fatalities, but 48 people were injured and there was extensive damage in the nearby town. Eight buildings burned to the ground; about 600 railcars were destroyed or damaged. Property damage was estimated in the millions of dollars and the federal government paid $5,500,000 of a total $19,000,000 as a result of legal judgments.

Investigations revealed that enroute to the railyard, the train stopped three times for emergency repairs. A witness to the passing train saw a DODX car with red hot brake shoes, red hot wheels, and an intermittent flame shooting out of the wheel area. The cars sat in the railyard for about an hour before the first explosion occurred. The explosions spread fire in both directions along the train. The cause of the explosions was believed to be cook-off of a Mk 81 bomb by a fire in a railcar which had been burning for over 3 hours. The fire was believed to have resulted from overheated brake shoes and wheels which ignited fuel oil leaking from a tank car in the train.

Railcars shall be equipped with high friction composition brake shoes and metal sub-floors or spark shields. Further, railcars shall be equipped with roller bearings which replace journal boxes and are in condition for service. These safety standards eliminated potential fire hazards resulting from overheated friction journal bearings, brake shoes and combustible material underneath railcars. Careful and thorough inspection shall be carried out in accordance with NAVSEA SW020-AF-HBK-010.

FIGURE 6-3. Multiple Railcar Explosion Near Roseville, California, 1973

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FIGURE 6-4. Debris from 18 Boxcars of Bombs Detonating

6-5.2. MOTOR VEHICLE TRANSPORT. Motor vehicle transport of ammunition and explosives is subject to accidents similar to railway trains; i.e., collisions and leaving the road. In addition, motor vehicle transport is subjected to increased risks posed by other drivers and unfavorable weather conditions. Therefore, it is imperative that safety regulations as outlined in NAVSEA OP 5 Volume 1 be observed.

MISHAP 6-11: In October 1971, a semi-trailer loaded with 144 rounds of high explosive projectiles was engaged in an interbase transfer operation. The load was palletized on 24 skids with 6 rounds per skid. Due to the high density of the cargo, the load was not dunnaged or tied down in any manner. The vehicle was traveling at an excessive rate of speed when it entered a curve in the road which was lightly covered with loose gravel. The physical forces encountered in the turn caused the undunnaged load to shift. This action, coupled with excessive speed and lack of traction caused by accumulated loose gravel, resulted in the trailer overturning. No personnel casualties were incurred. The semi-trailer was bent out of shape and six rounds sustained damage to their rotating bands.

A combination of excessive speed, poor road maintenance and violation of regulations requiring dunnage caused this accident. Loads must be inspected prior to transport to ensure they are secure and truck drivers must maintain safe rates of speed when transporting ammunition and explosives. Figure 6-5 shows the overturned truck.

MISHAP 6-12: On July 27, 1971, at a naval magazine in the Philippines, a tractor trailer carrying 575 aircraft parachute flares caught fire and burned enroute from the magazine to the pier area. See figure 6-6. At the time of the accident, the vehicle went onto a slight downgrade at approximately 15 miles per hour. At this point, the cap on one of the flares popped off deploying its parachute which actuated the ignition assembly. The fire soon spread throughout the entire trailer load. Upon ignition of the flare, the driver stopped the vehicle, disengaged the cab, and went for help. No personnel casualties resulted. The entire load of flares and the flatbed trailer were destroyed.

An informal investigation as to the cause of the accident determined that a serious hazard existed where the cap popped off of the flare under certain circumstances. This mishap emphasizes the need for the driver to be familiar with the hazardous nature of his load and to be prepared for unforeseen occurrences.

MISHAP 6-13: On April 13, 1983, as four commercial tractor-trailers were traveling west on an interstate highway carrying TALOS rocket motors, one of them had a blowout on the right front steering axle tire. As the truck veered off the road to the right, the front axle and other parts of the truck began coming apart. The front axle traveled under the truck, rupturing the fuel tank. This caused diesel fuel to be exposed to high temperature exhaust, ignite and set the tractor-trailer on fire. The driver was able to escape, but the alternate driver could not. Flames spread to the cargo and caused it to ignite. The explosions gave off a great amount of heat and flame and resulted in the total destruction of the tractor-trailer and its cargo. The alternate driver died as a result of the accident.

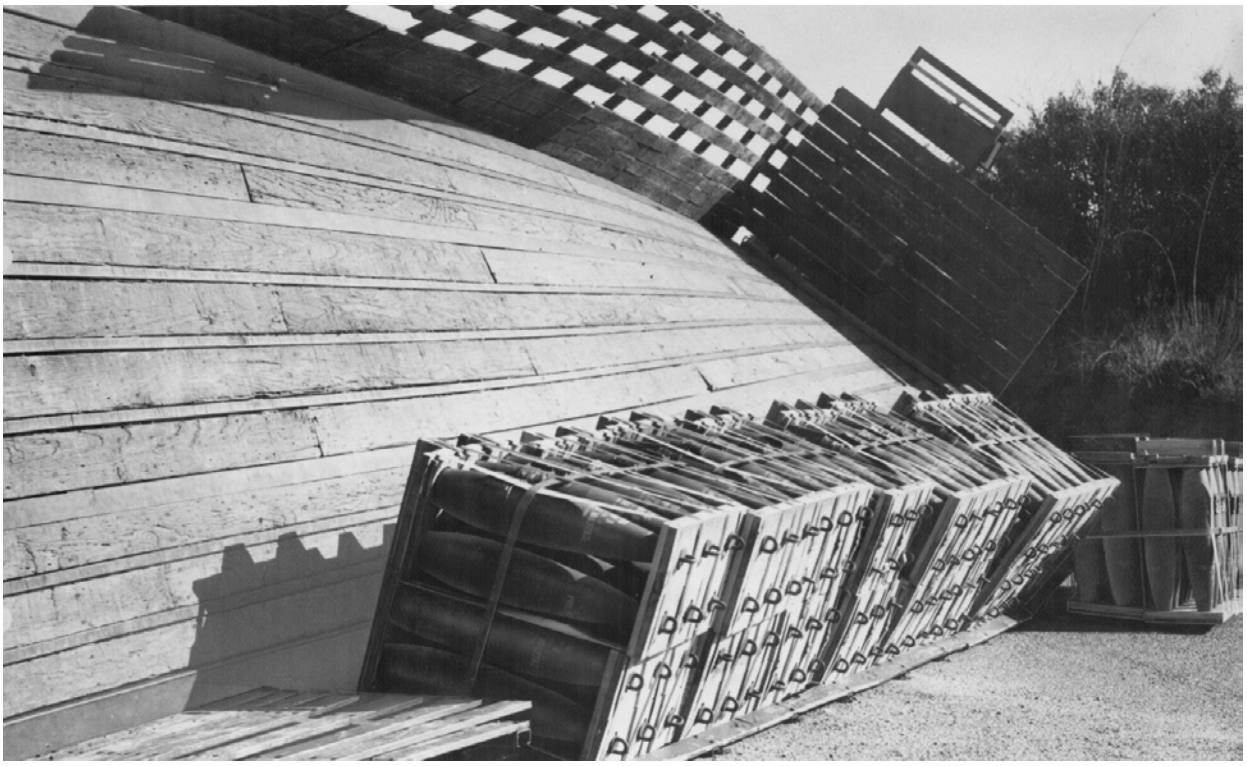

FIGURE 6-5. Truckload of Ammunition Overturned

The Department of Transportation mandates that all motor vehicles which transport military ammunition, explosives, and related hazardous materials shall undergo the vehicle inspections outlined in NAVSEA SW020-AF-HBK-010. These regulations apply to military or civil service employees as well as to drivers of a contract trucking company.

FIGURE 6-6. Trailer Load of Flares Burned

6-6. AIRCRAFT LOADING/DOWNLOADING. The hazards encountered in preparation of aircraft for firing and launching of ammunition consist of those operations involving final preparations for loading guns and missile launchers, for preparing loaded aircraft for launching, and ammunition firing and launching. An especially hazardous situation exists aboard aircraft carriers in this phase of operations with armed aircraft on deck and a variety of complex operations simultaneously in progress to conduct preflight checks and finalize readiness. All evolutions and precautions involving aviation ordnance shall be in accordance with the provisions of this manual, NAVSEA OP 4 or NAVSEA OP 5 Volume 1, and NAVSEA OP 3565/NAVAIR 16-1-529 Volume 2, supplemented by requirements contained in the NWP 3.04.1M “Shipboard Helicopter Procedures for Air-Capable Ships” as appropriate and the special requirements of the Airborne Weapons/Stores Manual for the particular aircraft involved.

MISHAP 6-14: In April 1994, during weapon downloading, Step 10 of the weapon downloading checklist was not performed. The arming cable to the thermal battery was left connected to the aircraft. After rack release, the computer control group thermal battery pin safety wire broke. The thermal battery pin was withdrawn by the arming cable, initiating the thermal battery.

This mishap illustrates what can happen when downloading procedures are not followed.

MISHAP 6-15: In May 1964, a SIDEWINDER missile was accidentally jettisoned during aircraft takeoff. The missile traveled 6,000 feet, struck a tree, and disintegrated without detonation of the warhead. No damage other than the loss of the missile occurred.

The cause of the accident was improper checkout and setup of cockpit switches in that the jettison switch was improperly set to jettison on takeoff. Preflight checks had not been properly and completely carried out.

6-6.1. THINGS FALLING OFF AIRCRAFT (TFOA). Things Falling Off Aircraft (TFOA) is an ongoing problem in the aviation community. TFOA includes ordnance and ordnance equipment such as cartridge chamber assemblies, ejector foot pads off bomb racks, access doors, fairings, wing pylons, missile launchers, etc. The most frequently identified flying objects from military aircraft are ALE-chaff buckets, which have turned up in unintended places such as backyards, beaches, parks, farmlands, and rooftops. TFOA from any altitude can cause serious property damage and/or injury or death to military personnel as well as civilians. TFOA pose an unacceptable hazard to both people and property.

6-6.1.1. The fundamental causes of TFOA are material failure and personnel error, or a combination of both, which is why an active ordnance shop TFOA prevention program is a must. TFOA can be controlled by the following:

a. Training;

b. Following proper procedures;

c. Inspecting weapons prior to loading, post-loading, and arming/disarming.

6-6.1.2. Ordnance TFOA may never be completely eliminated, but following Standard Operating Procedures (SOP's), Airborne Weapons/Stores Loading Manual and Airborne Weapons/Stores Loading Checklist will reduce the number of incidents.

CHAPTER 7

CHECKOUT AND TESTING PRECAUTIONS

7-1. INTRODUCTION. The hazards encountered in the testing and checkout of ordnance are those associated with the handling and subjection of the weapon or its component to electric power, electronic signals, and pneumatic or hydraulic pressure in the process of testing. Checkout of components is not permitted unless NAVSEASYSCOM has specifically authorized that the component be checked. Only authorized procedures and equipment are to be used when performing a test. Testing of assembled missiles or missile components in a magazine is prohibited. Tests are to be performed in predesignated areas only.

7-2. HAZARDOUS ASPECTS OF CHECKOUT AND TESTING. The basic elements which, alone or in combination with one another, can produce accidents during checkout and testing are discussed in the following paragraphs.

7-2.1. ELECTRICAL POWER. Electrical power must be applied to many ordnance items during testing, either directly or through various electrical instruments and test sets. The application of electrical power can introduce the hazard of explosive component initiation in the event of electrical circuit defects in the item being tested. Further, it is essential that the meters and test sets being used are functioning properly and the power actually being introduced is within the limits specified for the particular tests.

7-2.2. ELECTROEXPLOSIVE DEVICES. Electroexplosive devices present in components under test are always a source of hazard. It is essential that their safety system be operating properly and in the condition specified for the particular test, that their shielding or electromagnetic filter protection be present and operating properly, and that they be returned to a safe condition if they have been manipulated to any degree in accordance with testing procedures.

7-2.3. HYDRAULIC POWER SYSTEMS. Where high pressure hydraulic systems are used in testing and checkout, extreme care must be exercised during their connection or disconnection. Likewise, pressures applied must be maintained within the limits specified in the test and checkout procedures.

7-2.4. HIGH PRESSURE GASES. High pressure gases can be extremely hazardous where flexible lines are used. Extreme care must be exercised in making disconnections so as not to uncouple a charged high pressure line. Pressures must be kept within prescribed limits and high pressure gas sources must never be pointed toward anyone. High pressure flasks can rupture with the violence of an explosion where fragments are concerned and high pressure lines can whip with great force when they burst.

7-2.5. ORDNANCE/SHIP/LAUNCHER INTERFACE. A series of interface problems exists aboard ship between the ordnance to be tested and the ship. It is the latter which provides the electrical power and in many cases the high pressure gases and hydraulic power systems required. In addition, the ordnance being tested will eventually interface with some type of launching vehicle such as a gun, missile launcher, or an aircraft. Where testing occurs on or in the launching vehicle, additional hazards are imposed through a combination of the hazards presented by the ordnance and the launching vehicle. An aircraft gun system is a case in point.

MISHAP 7-1: In June 1968 aboard a guided missile destroyer, shipboard personnel were conducting daily launching system operability tests. A TARTAR missile was accidentally fired and destructed 4 seconds after firing. There were no personnel casualties and no material damage beyond the loss of the one missile.

The cause of the accident was given as "improper performance of launcher operator and violations of safety precautions." The majority of accidents concerning test and checkout were caused by errors on the part of people. In practically all cases, the accident would not have occurred had the prescribed checklists been followed and existing safety precautions observed.

7-2.6. ORDNANCE/AIRCRAFT INTERFACE. When complex weapons are attached to aircraft and connected into their extremely intricate electrical systems, a situation exists wherein the slightest error in procedures or judgment can cause an accident. The situation is further compounded by the fact that it is at this point where personnel interface; that is, ordnancemen arming the aircraft simultaneously as electronics technicians are checking out aircraft electrical circuits in the cockpit. In practically all cases, the use of proper procedures and the observance of applicable safety precautions can prevent these types of accidents.

MISHAP 7-2: In June of 1965, an armament system check was being conducted on an aircraft aboard a carrier by an ordnanceman who neglected to ensure that the aircraft was completely disarmed. As the checkout proceeded, the ordnanceman asked a nonrated man in the cockpit to ready the gun switches and pull the trigger. A 20mm gun fired, expending five rounds of ammunition which struck a man nearby and another aircraft on the deck. The man hit was severely injured and the one aircraft extensively damaged.

Procedures for checkout of specific weapons and systems were not followed in this situation. Personnel conducting check of aircraft armament system must first establish with certainty that the aircraft is disarmed.

7-2.7. CONCURRENT OPERATIONS. Concurrent operations are constantly in progress aboard ship and the majority of these will have no impact on testing. However, such operations in or adjacent to an ordnance testing area should be curtailed to the barest essentials. They can be the source of additional hazards at worst, and distracting at best. Operations which pass through the test area should be avoided if possible.

MISHAP 7-3: In August 1964, onboard an aircraft carrier, a missile head was lost overboard from a missile launcher due to interference by nets rigged for flight deck personnel safety during aircraft launching operations. At the same time as operations for launching of aircraft were being conducted, the missile launcher was being exercised with a missile in place. During these operations, when the missile launcher synchronized with the fire control director, the missile struck the personnel safety net and broke in two whereupon the missile head fell overboard and was lost. No personnel injuries occurred. Material damage was confined to the missile involved.

The cause of the accident appeared to stem from failure to establish effective safety watches while exercising missile launchers, especially while concurrent operations were being conducted.

7-3. SYSTEM CONDITION. Naval guns and their related mounts and equipment are powerful machines whose improper operation can result in serious accidents related to checkout and testing. Precautions should be taken to establish known and proper status of the equipment before beginning tests and checkout.

MISHAP 7-4: In August 1950, a Gunner's Mate was fatally injured when he was testing primers in a 3-inch automatic twin gun mount aboard a destroyer. He inserted a short shell case containing the primer and ordered the loader motor energized. Since the gun control switch was on 'BOTH" and the other gun had previously cycled, the loader mechanism cycled; the flexible end of the pivoted chute liner struck the man's head, dislocating and fracturing the cervical vertebra. The man was instantly killed.

The cause of the accident was personnel error in that the man apparently did not know the condition of the mount as it existed, or he momentarily forgot that the other gun had already cycled. This accident points up the extreme importance of knowing beforehand the complete status of equipment and of personally checking to verify system condition before beginning work on the system.

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CHAPTER 8

NAVY GUN ACCIDENTS

8-1. INTRODUCTION. The hazards to be considered in this chapter are those that are associated with the firing, launching, disarming, and unloading of explosive ordnance and Naval gun/weapon systems. Operating these weapon systems involve complicated procedures which must proceed like clockwork.

MISHAP 8-1: In February 1844, the U.S.S. *Princeton* arrived in Washington, DC, and during the next several weeks, she made trial trips down the Potomac River, firing her two 12-inch guns, one of which was called the PEACEMAKER. The PEACEMAKER had been proof fired five times beginning with 14 pounds of powder and going up to 45 pounds. On February 29, the U.S.S. *Princeton* made a final trip down the Potomac with approximately 200 distinguished guests onboard, including President Tyler and his Cabinet. Against the better judgment of the captain of the ship, the PEACEMAKER was fired in a demonstration for the presidential group. On the third firing of the day, the gun barrel burst, killing Honorable Abel P. Upshur, Secretary of State; Thomas Gilmer, Secretary of the Navy; Captain Beverly Kennon, Chief of the Bureau of Construction, Equipment and Repairs; Representative Virgil Maxey of Maryland; Representative David Gardiner of New York; and a servant of the President. The explosion was caused by a serious design flaw of the gun barrel. The PEACEMAKER gun which exploded had retaining bands welded in place, but the sister 12-inch gun, the OREGON, had retaining bands shrunk in place. The shrunk-on bands served as crack arresters while the welded-on bands permitted cracks to enlarge, causing weakening with each firing and ultimately failure.

In addition to giving strong credence to advice previously voiced by the Navy Ordnance Department on welding and weakness, the investigation found that the proof testing of the gun was inadequate to determine life and strength. The tragedy's impact worked against the acceptance of sound technical innovation and may have slowed the acceptance of propeller driver ships, which the U.S.S. *Princeton* was the first. After this accident, procedures were established to:

a. Review and check gun designs for safety considerations;

b. Standardize procurement practices;

c. Require periodic inspection of hardware;

d. Require remote testing of all guns.

8-2. FIRING AND LAUNCHING. The act of firing or launching of weapons is one of the most hazardous operations in which ammunition and weapons can be involved. The various safety systems, ignition and fuzing are being manipulated for final settings; heavy, powerful machinery and ammunition supply systems are operating; many personnel are busy at numerous complicated tasks which must proceed like clockwork; and complete electrical power systems, hydraulic systems, and high pressure gas systems are all operating. A weak link in the chain could spell disaster. It is in the area of firing and launching where resides the greatest amount of historical data covering past accidents of these types. This is due to the serious nature of a number of the early tragedies which occurred to the older, heavy, gun systems in naval service. Although for the most part, these types of systems are no longer in general use, the accidental events gave rise to many of the ordnance safety precautions which exist today.

MISHAP 8-2: The first major accident in the United States Navy which bears upon present safety precautions happened onboard the U.S.S. *Massachusetts* while she was firing target practice off Culebra Island in the West Indies in January 1903. One of the 8-inch guns in her starboard after turret had been loaded and primed, and the firing lanyard had been hooked to the firing lock in preparation for percussion firing. Since electric firing had been ordered for the target practice, the Division Officer attempted to uncock the firing lock. The primer fired and ignited the charge of brown prismatic powder. The entire turret crew of nine men was fatally burned. When the charge was ignited, burning grains of powder, bits of clothing, and pieces of paper were blown through an opening in the floor of the turret down the ammunition tube to the orlop deck (the lowest deck in a ship having four or more decks) 30 feet below, where powder tanks were usually opened to get the charges out. Fortunately no charges were ignited; if this had occurred, the whole ship might possibly have been lost.

MISHAP 8-3: The next disaster occurred onboard the U.S.S. *Missouri* in April 1904 while she was firing target practice off Pensacola, Florida. Although smokeless powder had just been issued to vessels afloat, it was recognized that, when this new type of powder was fired in a gun, a residue of highly flammable gases remained in the bore due to the incomplete supply of oxygen for combustion in the chemical composition of the powder itself. Many cases had already occurred in which those residual gases, heated to a high temperature and needing only additional oxygen for their ignition, had escaped from the breech once it was opened and ignited a short distance to the rear of the breech. Precautionary measures were issued in a special Navy Department order dated October 1903. The officers of the U.S.S. *Missouri* were well aware that flarebacks could occur, although no accident had happened as yet. They were sufficiently on guard and the captain was prepared to stop the practice if flarebacks were noticed. One leader in one of the turrets wore a sponge under his nose so that if a flareback did occur, he would not inhale the gas or flame. During the firing of the third run, the charge of 360 pounds of smokeless powder was ignited burning nearly half the crew. Twenty men in the turret died as a result of their burns. Twelve were also burned to death in the handling room when 720 pounds of powder there was ignited by burning grains which dropped from the turret through an opening between the turret and the handling room.

It was determined that a flameproof subdivision be added to the turret, separating the gun pits from each other and the entire turret from the handling room. Overhead sprinklers were required in magazines in addition to the flooding system. Two additional points were brought out by the testimony in the case. One point was the possibility of inflammable gases remaining in metallic cartridge cases after firing. The other point was the general habit that had developed among the turret personnel to stiffen powder bags by winding tape around them so as to make their loading into the gun easier; the smouldering pieces of this tape in the bore may have been a contributory cause of the accident. Present precautions require that the cartridge cases be free of gases before storage below, and that no additional material may be added to powder bags without authority. After the U.S.S. *Missouri* catastrophe, the safety order regarding flarebacks was reissued in more elaborate form, but was not yet worded as at present. However, the new order required an inspection of the bore after every shot, before the powder charge for the next shot could be brought above the turret floor. It also required that the breech of a turret gun remain closed while powder is exposed in the operation of loading the other gun.

MISHAP 8-4: On June 1, 1943, a destroyer was engaged in director-controlled shore bombardment firing practice. The No. 3 5-inch/38 caliber gun was new, having been installed just the day before. The firing cutout cam was functioning mechanically but not electrically. Apparently, the defect did not show up on the installation test. Before the first salvo of phase three of the practice, the gun had been returned to its ready position at zero train and 5 degrees elevation. The order "load and stand by" was given, but no order was given to train out and match zero readers. Because he received no orders from control, the gun captain of the No. 3 gun did not train out. The buzzer and firing circuits were closed at the director. The point of No. 3 gun had his firing key closed. An Antiaircraft Common (AAC) projectile was fired into the after side of number two stack. It exploded just above the director platform on the stack. Ten men were killed, 19 others were injured. Heavy material damage was done to the ship. See figure 8-1.

Any one of the following precautions might have prevented this accident:

a. A safety observer at the gun.

b. A complete check of the firing cutout mechanism, both mechanical and electrical, before the practice was started.

c. Indoctrination of the gun pointer to keep his firing key open in director fire, except when zero readers were matched or the gun was following in AUTO.

d. A check by control to ensure that guns were trained to a safe bearing before closing the firing key at the director.

e. Indoctrination of the gun captain not to load guns unless trained on a clear bearing.

f. Indoctrination of the gun captain not to permit closing the firing key without first making sure that the gun is pointed away from the ship's structures.

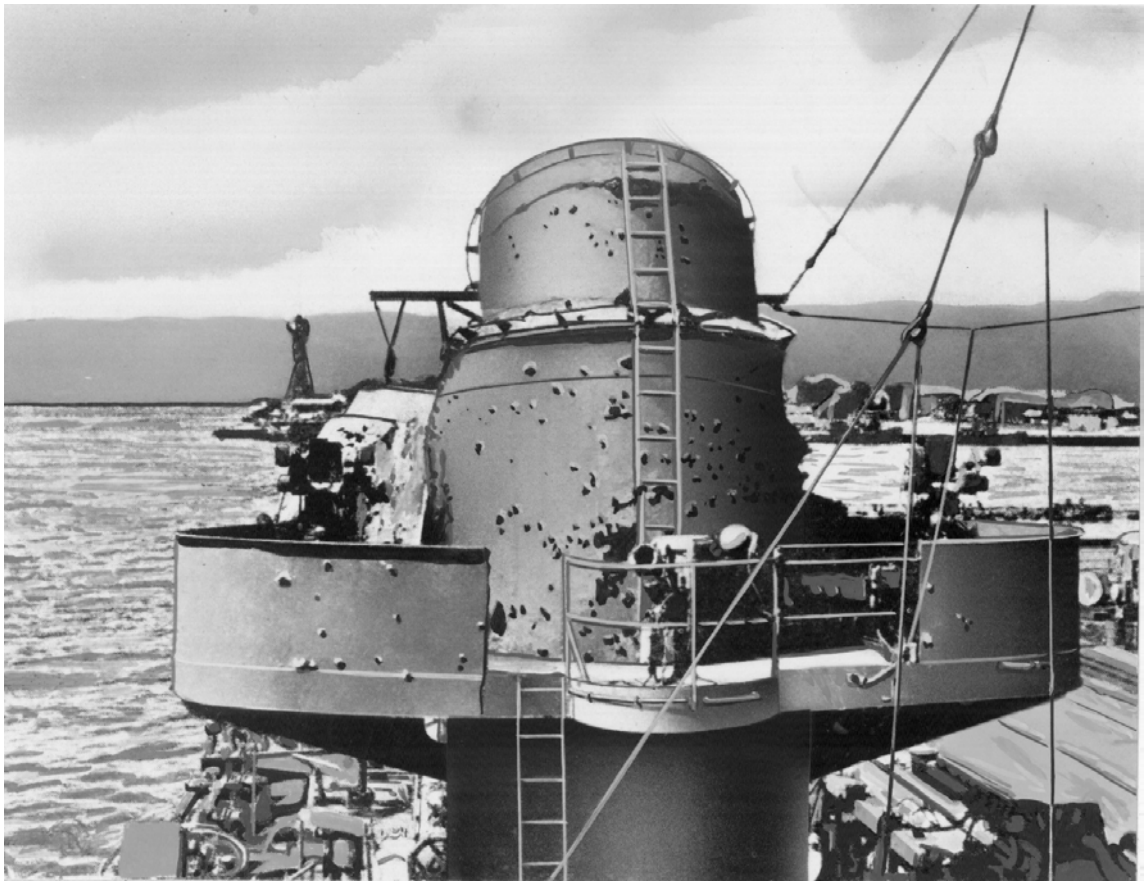

FIGURE 8-1. Ten Men Were Killed When the Ship's Own Gun Fired Into This Stack

8-2.1. HANGFIRES AND MISFIRES. Every misfire shall be treated as an emergency. This shall include water cooling if the misfire procedures so indicate, and shall also apply to firing exercises involving inert loaded projectiles. Always clear a gun using procedures described in NAVSEA SW300-BC-SAF-010.

MISHAP 8-5: During a practice firing ashore, one round exploded in the breech of a 20mm gun injuring two men. The gun had been firing for about 45 minutes when it jammed. A gunner's mate removed the magazine, cocked the gun, and, contrary to instructions, looked into the breech. As he did, a round in the gun breech exploded. Two men were injured, one seriously.

The cause of the accident was the cookoff of a round in the hot gun. The error was in looking into the breech of a hot gun. Injury to the two men would have been avoided had they evacuated the vicinity of the hot gun when it jammed.

8-2.2. IN-BORE DETONATIONS. Many of this type of accident have occurred due to no fault of the gun crew. Moreover, the problem is not limited to the Navy alone; guns and ammunition of Army design, particularly the 155mm gun or howitzer, have had a number of in-bore detonations. This problem has received high priority attention in the Navy and corrective action has been taken which should markedly reduce, if not eliminate the in-bore detonation as a hazard.

MISHAP 8-6: The first shipboard premature detonation of an explosive loaded projectile was in August 1897 on the U.S.S. *Brooklyn*, and since that time over 91 such incidents have occurred. One of the incidents was aboard the Australian vessel *HMAS Brisbane* with a 5-inch 54 caliber gun and projectile purchased from the U.S. Navy. As recently as January 1973 an in-bore explosive occurred aboard the U.S.S. *Henry B. Wilson*. The ordnance involved included 3-inch to 16-inch projectiles loaded with TNT, Composition A-3 and Explosive D. Concern over these explosions and the casualties and damage that they caused have resulted in a number of special boards and investigations.

Between May 1965 and November 1969, there were a total of 14 in-bore premature detonations in Navy 5-inch guns. Of these, six were in-bore detonations of the projectiles that completely severed the gun barrels and eight were low-order type explosions that swelled the barrels. In addition to these, there were numerous out-of-bore premature detonation reported which, for the most part, were blamed on fuze malfunctions. Some of these, however, may have been caused by the same type of ammunition defect as caused the in-bore detonations.

The six in-bore premature detonations, all high-order reactions that demolished the guns occurred between September 1968 and November 1969. Following the November 1969 incident aboard the U.S.S. *Hoel*, the Naval Ordnance Systems Command organized the Ammunition Special Study Group to conduct a complete investigation of these malfunctions.

These incidents resulted in at least 23 deaths and 46 injuries. Each incident ruined the gun barrel involved and the total damage is at least 20 million dollars. The studies and investigations of premature and in-bore explosions have shown that several mechanisms can cause these explosions:

a. Faulty gas check seals on base closures may allow hot gases to pass through the seal and initiate the projectile explosives.

b. Defective fuzes may detonate the explosive in or shortly after leaving the gun barrel.

c. Of the 14 incidents recorded during the 1968 to 1969 period, seven of these were believed due to the defective threads on the auxiliary detonating fuzes.

As a result of the investigations conducted after these incidents, improved procedures were developed to assure positive base gas check seals, to reduce the likelihood of low densities and base gaps in the explosive load, to assure the quality of the base fuze hardware and their installation, and to ensure the high quality of fuze threads.

MISHAP 8-7: While operating off the demilitarized zone (DMZ), U.S.S. *Newport News* experienced an in-bore detonation of an 8-inch High Capacity (HC) projectile in the center gun of Turret 2. The gun was ruptured by the explosion in a manner which permitted much of the released energy, including the propellant charge gases, to vent to the inside of the turret. The initial reaction propagated to the propellant charges in all three hoists, and 9 of 21 were either partially or completely consumed. The left and right powder hoist tubes were ruptured by these secondary reactions, venting propellant gases into all turret levels above the powder handling room.

Twenty men were killed as a result of the explosion and deflagration and 11 men were seriously injured. The middle gun of the turret was destroyed and there was extensive damage to the powder hoists, all three guns, and the interior of the turret.

Based on evidence acquired through the on-site examinations, and supplemented by CONUS investigations, the conclusion was that the in-bore casualty resulted from premature high order detonation of a HC PD projectile almost immediately upon firing, with the projectile at the initial seated position. It was believed that early in the ballistic cycle, the projectile received significant shock loading which either activated a fuze or which initiated the explosive load directly, or the round may have been fired with the entire base fuze missing so that sufficient hot gas could enter the explosive cavity to cause rapid initiation. These hypotheses were examined in detail by CONUS investigators and one by one thoroughly discounted except for the possibility that early shock loads could adversely affect the fuzes. The source of this shock was due to the normally present propelling charge closure plug impact with the projectile base. Laboratory static initiation experiments had established that the extensive gun structure damage produced in the U.S.S. *Newport News* accident could only have resulted from a high order, nose-initiated detonation of the 8-inch HC projectile. This could only have resulted from premature action of the Mk 55 Auxiliary Detonating Fuze (ADF). The critical ADF armed rotor defect most likely derived from misassembly during production operations.

Resulting from investigations taking place after this incident, the critical Mk 55 ADF defects have been eliminated from 8-inch 55 caliber ammunition by revised inspection procedures during manufacture and assembly. The investigation board also recommended that the Mk 55 and similar Mk 54 and Mk 43 ADF's be eliminated from Navy gun ammunition stocks and replaced with the new fuzes such as the Mk 379 and Mk 395 ADF's.

8-2.3. UNFIRED ROUNDS. Immediately following firing, a thorough search shall be made for unfired rounds. If they have not entered the gun mechanism, or have been removed from a cold gun, they shall be placed in a safe condition, returned to their containers, and stowed/stored in the proper magazine. This also applies to flares.

MISHAP 8-8: In August 1994, a white star parachute flare had been armed and placed inside a canvas gear bag which was on the deck of a small boat. An RM inadvertently struck the bag while working on the deck, causing the flare to fire. The resulting minor fire was quickly extinguished with a portable fire extinguisher. Several flares had been stored in the bag during a recent training exercise. All were believed to have been expended during the training evolution. None of the crew recalled arming the flare and then returning it to the bag. An inspection of the boat after the exercise failed to uncover the armed flare.

A thorough inspection after the live firing exercise would have revealed the unsafe condition.

8-3. DISARMING AND UNLOADING. This section discusses disarming and unloading of explosive ordnance and weapons that were loaded and made ready for firing or launching, but for one reason or another, have not been fired or launched. Malfunctioned, misfired, or damaged ordnance will usually present the greatest hazards in unloading or disarming of weapons. Normal safing devices may be unoperable, or, while apparently operating, may in fact not be functioning as designed. The only thing certain about such ordnance is that something is wrong with it.

MISHAP 8-9: In 1945, onboard an LST, a round of ammunition exploded while being unloaded from a hot gun. The gun had fired three magazines during a practice firing when a jam occurred. The crew removed the magazine and a loader inserted the ramrod into the gun barrel to dislodge the cartridge. It slid readily out of the chamber onto the loading tray. Before it could be removed, it exploded. Six men were injured by shrapnel.

The most probable cause of this accident was excessive delay in getting the round out of the hot gun. Investigation revealed that unauthorized spectators, some of whom were injured, were in the vicinity of the gun observing the firing. All personnel not required to be exposed during firing shall remain undercover. While the accident might have been unavoidable, the injuries would certainly have been reduced had applicable safety precautions been observed.

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CHAPTER 9

ORDNANCE MAINTENANCE, REPAIR, MODIFICATION, AND REWORK

9-1. INTRODUCTION. The hazards encountered in the maintenance, repair, modification, and rework of ordnance material, ammunition, and explosive components are mostly faced by personnel at ammunition and weapons activities ashore who have primary responsibility for these operations, especially the more hazardous aspects. While certain support-type ships are equipped to perform more extensive repairs and rework, generally, maintenance operations on units afloat are restricted to minor preservation operations such as repainting and tightening container lids.

9-2. ORDNANCE/WEAPON SYSTEM OVERHAUL AND REPAIR. Personnel error is the greatest and most unpredictable element of hazard which is involved in the maintenance, repair, modification, and rework of explosive ordnance materials. Only by an aggressive training program at all levels, and the most careful and constant attention by a supervisor, can the element of hazard from personnel error be eliminated.

MISHAP 9-1: In 1942, a torpedoman third class aboard a destroyer was assigned to make a monthly overhaul of a torpedo. He had never performed this task before yet no one superior to him or more experienced remained with him to ensure the job was done properly. As a result, the torpedoman failed to follow the checkoff list. He did not close the stop valves, nor did he disconnect and remove the igniter. In fact, he did not remove the torpedo from the tube. At some point, the starter was accidentally tripped and the torpedo made a hot run in the tube. The number two turbine disintegrated, tore through its casing, ruptured the main air line, and caused other damage. High pressure air and flying fragments of metal flew back from the torpedo. The torpedoman was killed instantly.

This is a prime example of letting inexperienced personnel perform complex operations on hazardous weapons without proper supervision.

MISHAP 9-2: In 1944, aboard a destroyer, a depth charge projector was accidentally fired when a torpedoman's mate was attempting to repair a K-gun by replacing its firing mechanism. He had previously performed this task on other K-guns which were not loaded. He incorrectly assumed that the K-gun he was working on was also unloaded. As he was prying with a screwdriver to remove the manual firing latch, the screwdriver slipped and struck the firing pin. The gun fired. Three men, including the torpedoman's mate, were injured by powder burns.

The cause of the accident was personnel error in not checking to determine the true nature of the situation before beginning operations. The accident could have been avoided had proper checks of the gun been made before beginning work. The man was court-martialed and reduced in rating.

MISHAP 9-3: In April 1965, at a naval ammunition depot, a Mk 24 Flare was accidentally fired during rework operations. Holes had been drilled through the flare tube and wood screws were being inserted when ignition of the flare occurred. The pressure buildup caused the flare to blow up. It landed on a truck nearby and ignited 18 other flares. There were no personnel injuries and material damage was minor.

The cause was suspected to be an overlong screw that penetrated into the pyrotechnic contents igniting the flare composition. The accident could probably been avoided had the operator more carefully checked the materials used in the assembly of the flares. Figure 9-1 illustrates the violence of burning pyrotechnic material as firemen move in to extinguish the blaze.

FIGURE 9-1. Firefighters Move in on a Pyrotechnic Fire

MISHAP 9-4: In October 2007, an explosive mishap occurred at Naval Surface Warfare Center Indian Head Division, Building 750 during diamond wire saw operations. The video clip located at the link below shows what happens as a diamond coated wire is being removed from a partially cut Sidewinder rocket motor.

During this operation a diamond coated wire was used to cut through a metal rocket motor case to obtain propellant samples for testing. This work plan called for cutting a SIDEWINDER rocket motor into many 2 inch sections with a diamond wire. After completing each cut the section was removed and the diamond wire was set up to make the next cut. While the clamping used to hold the rocket motor in place during cutting securely held the longer rocket motor, as each cut was made, the motor got smaller and smaller. As is the case when cutting any item, the smaller the rocket motor got, the more difficult it was to hold on to.

At the end of the day, the last small piece was to be cut from the rocket motor. When setting up for this last cut, a decision was made to not separate the previously cut sample, but to leave it in place to help hold the remaining small piece in the clamp, as a means of solving the clamping problem.

Cuts through a SIDEWINDER rocket motor typically take about 30 to 40 minutes to complete. While making this final cut at the end of the day it was determined that the full cut could not completed before quitting time. About two-thirds of the way through, a decision was made to stop cutting, remove the diamond wire and complete this final cut the next day. Removing the diamond wire is a common operation approved by the local operating procedures and is routinely performed in this work area.

During removal operations, the direction of the diamond wire is reversed to remove the wire back through the previously cut slot. Usually the wire retracts smoothly out of the slot in several seconds, but in this case the removal of the wire was taking significantly longer than usual. In the course of the wire removal approximately one pound of composite rocket motor propellant from the SIDEWINDER rocket motor was ignited and consumed by the event. No personnel or equipment damage was sustained.

The investigation team concluded that poor clamping had allowed the previously cut slot to pinch closed. Three times more force is used when removing the wire up through the previously cut slot than during actual cutting operation, so instead of smoothly backing though the previously cut slot, the diamond wire was cutting its way back out at a greater force causing frictional heating and resulting in the event.

Three separate circumstances occurred which contributed to the severity of this mishap. First, operators failed to follow prescribed Standard Operating Procedure when they failed to remove the cut sample at the end of the day. Second, any hazardous procedure which could not be completed by the outgoing work shift should not have been started (see NAVSEA OP 5 Volume 1). Third, the process of removing the wire took an abnormal length of time; operators should have ceased operations immediately in the event of any circumstance on which they were not briefed, did not understand, or which appeared unsafe.

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CHAPTER 10

AMMUNITION DEMILITARIZATION AND DISPOSAL

10-1. INTRODUCTION. Demilitarization is the act of destroying the military offensive or defensive advantages inherent in certain types of equipment or material to prevent further use of this equipment and material for its originally intended military or lethal purpose. It applies to material in unserviceable or serviceable condition that has been screened through the Inventory Control Point and declared surplus or foreign excess.

10-2. METHODS OF DISPOSAL. The disposal of ammunition and explosives may be required because they have become unserviceable due to age, deterioration, damage, obsolescence, overstock or lack of identity. It is the policy of Naval Ordnance Safety and Security Activity (NOSSA) to dispose of these materials using the most economical method consistent with established safety and environmental standards. Methods of disposal include burning, detonation, neutralization, steamout, disassembly, or a combination of these. Disposal by burning and disassembly are illustrated by mishap in this manual. At the present time, disposal operations consist of the following methods: burning, detonating, neutralizing or "bleeding off," as prescribed in NAVSEA OP 5 Volume 1 or in other applicable instructions provided by Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV), Indian Head.

10-2.1. BURNING. When destroying ammunition by burning, there is always a risk that the material being burned may detonate. Quantities to be burned and safe distances for the burning area must be based on this assumption. The burning characteristics of the items to be burned must be known. Burning should not be done under windy conditions; a change in the direction of air movement should always be expected. Again, fully qualified personnel following detailed and specific procedures are required. Black powder is especially hazardous; smokeless powder burns very fast and hot. People have been burned at what they thought was a safe distance. Smoke from burning ammunition can be toxic and can cause severe dermatitis in some individuals. Refer to NAVSEA OP 5 Volume 1 for the types of ammunition and explosives authorized for burning as well as operational requirements.

MISHAP 10-1: In May 1994, test personnel were firing 123 rounds of 81mm cartridges using a standard operating procedure. Three of the samples were fired at charge 0 which required removing the increment charges from the fin assembly. The increment charges that had been removed (12 total) were set aside for disposal. The engineering technician opened three of the increment charges and laid a train of propellant approximately 2 feet. The remaining increment charges were positioned at the end of the propellant train. He wadded paper napkins to light the train. As he lit the propellant, the wind gusted and caused the propellant to flash. The engineering technician sustained burns to his face and hands. He had been wearing prescription safety glasses which protected his eyes from severe injury.

Treatment by burning shall not be undertaken when the wind velocity is in excess of 15 miles per hour, except under circumstances where any interruption of treatment operations would impose an unacceptable hardship or hazard. There shall be instrumentation at the burning ground for measuring wind velocity. See NAVSEA OP 5 Volume 1.

MISHAP 10-2: In July 1988, a SNM had some old black powder (approximately 1 cup) he wanted to dispose of. He placed the powder in a dish on his back and lit the material with a match. The resulting fireball engulfed his head and upper torso, burning off all facial hair and igniting his shirt causing second degree burns to his neck. Luckily, he too had been wearing prescription safety glasses.

Standard operating procedures covering the disposition of items by burning shall be available to and used by personnel conducting such operations. Ammunition and explosives to be burned shall not be carelessly handled.

MISHAP 10-3: In July 1991, an Army unit was using a commercially obtained product as a ground burst projectile simulator. At the conclusion of the exercise, two individuals were instructed to destroy the unused simulators. They proceeded to remove the nose-caps from the projectiles and empty the photoflash powder into a bucket. At the site, most of the bucketful was piled in one place, with some of the powder used to make a trail. One person then lit the train and the entire quantity of photoflash powder instantly deflagrated, inflicting first, second, and third degree burns severe enough to require skin grafts.

Many errors in judgment and procedure are illustrated here. Foremost is the attempt by unqualified personnel to do demilitarization work. Second, disassembly of the items was unauthorized and unnecessary for disposal. Third, powder and speed of combustion were underestimated (black powder, pyrotechnic compositions, and propellant grains and increments will react in a similar fashion).

After this mishap, the following policy was reiterated: unauthorized disassembly of munitions is prohibited and demilitarization work will be done only by qualified persons. Excess ammunition is to be returned to inventory at the conclusion of exercises.

MISHAP 10-4: On January 25, 1971, at McAlester Naval Ammunition Depot, Oklahoma, three operators were killed while preparing obsolete 20mm projectiles for a rotary furnace. During a demil operation in which the 20mm projectiles were removed from an ammunition box and placed on a conveyor belt for feeding into a second building to the demil furnace, an explosion occurred in which an estimated 380 pounds of tetryl detonated. The detonation destroyed the demil building, Building 452 in a radius of 100 feet from the site of the explosion. The building was 200 feet long, 50 feet wide and 15 feet high. See figure 10-1. Missiles as large as 12 to 15 pounds were projected approximately 700 feet from the structure. The accident resulted in three deaths and three injured. Three private automobiles received minor damage.

FIGURE 10-1. Results of a Detonation in a 20mm Demilitarization Line

The explosion most probably started outside of the furnace when the operator who was placing the projectiles onto the belt feed conveyor dropped one or more back into the box or near the box. The explosion was then propagated to the other projectiles and by fragments flying across the conveyor to the other boxes on the east side feed station and on the roller conveyor. It then propagated by shock and fragments along the roller conveyor to the boxes still on the pallet table. Many large pieces of the belt feed conveyor were found to the west of the crater. From the positions of the parts, it was concluded that the explosion started in the two boxes on the east side of the belt feed conveyor.

It was concluded that the explosion did not start by a full or nearly full box falling to the floor from the conveyor, since there was no substantial crate found. Since 10 boxes 30 inches above the floor produced a 6-foot crater, it was reasoned that one box on the floor would have produced a definitely recognizable crater.

The investigation was based on the hypothesis that moisture reaching the detonator caused a reaction between the lead azide initiator and copper detonator cup producing supersensitive copper aside explosive. However, the tests and inspections under such conditions were negative. No fuzed projectiles detonated in any of the drop tests run even though some were dropped above the 40-foot height used in drawing acceptance testing. However, it was demonstrated with certainty that the explosion of one projectile will sympathetically set off a full box.

As a result of this accident, the demil procedure was revised to permit a limited number of rounds exposed to each other during handling. Further, more testing by the Navy did find copper azide corrosion around the detonation cups of some projectiles. One projectile was dropped 4 inches and detonated as a result. The finds of the investigation led to a NAVSEA instruction, eliminating copper in contact with lead azide. This policy began the phasing out of lead azide and the development of new initiating compounds such as DXW-1.

MISHAP 10-5: On June 29, 1964, at Crane Naval Ammunition Depot, a detonation occurred during an attempt to burn out 326 rounds of 75mm HE loaded projectiles. The projectiles had been placed in burning racks and ignited using scrap wood saturated with fuel oil. Two inspections failed to find base detonating fuzes in these rounds. About 10 minutes after the start of the burning operation a major detonation occurred. Three minutes later a series of three further explosions occurred. In all, four double racks of the burning projectiles detonated high-order; the remaining two double racks burned out normally. No personnel casualties occurred. Eight burning racks were destroyed and one fire truck was damaged.

The incident occurred as the result of attempting to burn out the explosive filler of the projectiles while an undetermined number of the projectiles still contained base detonating fuzes intact. In this case, violations of Standard Operating Procedures (SOP's) for both the defuzing of projectiles and for operations in the burning area had been violated. The depot was most fortunate in this event as serious personnel casualties could well have resulted. Figure 10-2 shows a before and after view of this accident.

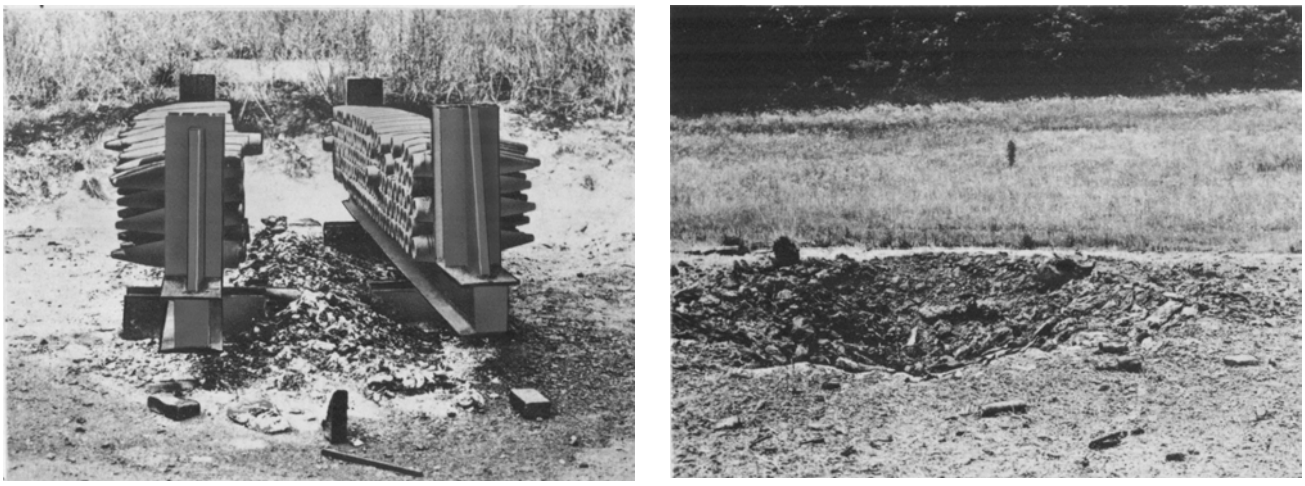

FIGURE 10-2. Before and After Views of an Ammunition Burning Accident

MISHAP 10-6: On Tuesday 27 March 2007 an unexpected event occurred at an explosives treatment plan in Indian Head, MD during explosive disposal operations. While treating CXM-3, an RDX coated with Dioctyl Maleate (DOM) a larger than expected release of energy occurred resulting in damage to the burn pan; see figure 10-3. Disposal operations are conducted remotely and no personnel injuries occurred as a result of this event.

The proper disposal of explosive waste is dependent upon the temperature, confinement, contaminants and most importantly, geometry/shape of the material. The investigation team determined that the most probable cause of this atypical burn was the 100 pounds of powdered CXM was not spread out to the required maximum depth of 2 inches. This was based upon the visual observations of another, untreated burn pan that had piles of the same explosive material between 5 to 8 inches. During disposal operations increased temperature and confinement in these larger burning piles led to a greater release of energy than expected causing the damage to the burn pan.

The following are excerpts from the investigation report on this mishap:

***Material was not spread out to its maximum depth in accordance with directions.**

***Due to the large quantity of CXM scheduled for disposal operators had been routinely burning this material for a couple of months without any problems.**

Based on this last fact, one might make the assumption that these disposal efforts had become routine to the point that personnel were just going through the motions and not thinking about the details. The very fact that the task was repeated often leads one to suspect complacency as the cause of this mishap. One learns to expect the same results until one day, the outcome changes for the worse.

Complacency is a known problem and must be clearly recognized as an underlying factor in mishaps. There is no cure for complacency, so personnel must be ever diligent in its prevention.

FIGURE 10-3. Unexpected Release of Energy Resulting in Damage to Burn Pan

10-2.2. DISASSEMBLY. In some cases, ammunition may be mechanically disassembled or partially disassembled as part of the process of disposal. Such operations require special tools, equipment, and techniques. Personnel protective measures are paramount as explosions are to be expected if such work is done in any quantity. Shielding, barricades, and remote operating equipment will usually be required. In addition, explosive limits for the operating building shall be posted and enforced. Operation buildings shall be stopped when, for any reason, the posted explosives limited is exceeded. See NAVSEA OP 5 Volume 1.

MISHAP 10-7: On May 26, 1971, at Naval Ammunition Depot Hawthorne, Nevada, 3.5-inch rockets were being renovated in the renovation facility. The renovation involved disassembly of the round, defuzing, and replacement of a fuze component, the igniter and the propellant. The explosion is reported to have occurred at the beginning of the disassembly operation and to have involved 30 to 60 pounds of explosives. Three people were killed, 10 hospitalized, and 17 others treated for minor injuries. The facility sustained major material damage to the interior and minor structural damage, resulting in hundreds of thousands of dollars damage; see figure 10-4. The cause of the incident cannot be determined but it is suspected to be as a result of dropping or of an armed rocket impacting against the wooden bottom plug of the fiber casing.

There was gross violation of the explosive limits of Building 108-20 at the time of the explosion. The violation was not only a matter of the total number of rounds in and near the building, but specifically there was an excess on the assembly line area. Rejected rockets were being reassembled in this area, contrary to provisions of the SOP. In addition, there was an excess number of rockets at the tail end of the assembly line. A safety inspector for the Armed Services Explosives Safety Board had inspected the premises 1 month earlier, and the Command had been made aware of the physical safety inadequacies of the 3.5-inch renovation layout. An oral debrief with recommendations was provided by the inspector. Consensus amongst the witnesses present during this inspection and subsequent debrief was that the inspector did not transmit to the Command any strong sense of urgency to isolate the individual operating stations on the assembly line in order to reduce what he considered to be an excessive number of personnel exposed along the line.

This accident was influential in the Navy's decision to eliminate all Composition B from its weapons.

10-3. SALE, SALVAGE, AND DISPOSITION OF INERT MATERIAL. All inert items intended for disposition, such as empty projectiles, cartridge cases, rocket warhead containers, and all inert materials shall be rigidly inspected for the presence of any explosive material prior to salvage, offer for sale, or delivery as a result of sale. The commanding officer shall take all necessary precautions to assure that the items are inert. The local activity must certify items safe prior to release. Refer to NAVSEA OP 5 Volume 1 for more information. The following accident involves Army materiel, but illustrates the need for stringent inspections where the resale of Material Potentially Presenting an Explosive Hazard (MPPEH) is concerned.

FIGURE 10-4. A 3.5-inch Rocket Exploded in this Area

MISHAP 10-8: In November 1997, a safety officer for an Army contractor was charged with second-degree murder for allegedly allowing a live military shell to be taken from Ft. Irwin to a Fontana scrap yard where it exploded and killed a worker as he attempted to dismantle it with a torch. Two other employees were injured. The 105mm shell was contained in several tons of scrap metal purchased by the scrap yard, which had been assured that the load contained no explosives. Investigators found 54 more pieces of live shells and other ammunition at the wrecking yard, and uncovered at least three instances in which live ordnance was found stockpiled at the company's yard at Ft. Irwin awaiting sale. Numerous witnesses stated that there were many occasions in which the safety officer signed off loads leaving the site that were not inspected.

Demilitarized scrap intended for resale must be inspected and certified that it no longer contains explosive material. See NAVSEA OP 5 Volume 1 for the requirements for managing, processing, and certifying MPPEH.

MISHAP 10-9: On October 18, 1990, a 120mm target practice round was discovered by a city of Kernville, California, resident in an ammunition wooden shipping container purchased at a weapons center Defense Reutilization Marketing Office (DRMO). The container had not been labeled empty and ammunition nomenclature stenciled on the box was intact and had not been obliterated.

Stringent inspections must be performed prior to disposal to ensure the removal of any explosive material or ammunition.

CHAPTER 11

ORIGIN OF ORDNANCE SAFETY TESTS

11-1. INTRODUCTION. This chapter discusses the origin of ordnance safety tests and the reasons for the test parameters. Research involved consultation with persons knowledgeable in ordnance safety and testing, access to the Safety of Ordnance Databank (SAFEORD), and review of current and historical ordnance-related instructions and reports. These sources are referenced in appendices B and C. In MIL-STD-2105 (series), hazard assessment tests have evolved, following a consistent and logical pattern that takes into account knowledge gained over many years. MIL-STD-2105 (series) replaces rote testing with an analytical process of accessing the threat to an ordnance item throughout its life cycle. WR-50, "Warhead Safety Tests, Minimum for Air, Surface and Underwater Launched Weapons" (canceled), a document issued in 1964 specifically covering high explosive warheads, was the first document to establish this logical process. It has been modified over the years. The current standard, MIL-STD-2105C includes rocket motors and pyrotechnics as well as warheads. Even though it was a warhead test requirement, WR-50 was applied to rocket motors as early as the mid-1970s because people recognized its value.

11-1.1. Prior to the publication of WR-50, warheads and projectiles were subjected to similar types of safety tests, although quantities tested were generally larger. The concept of sequential testing was not usually used. Review of late 1950 TERRIER, TARTAR, and TALOS warhead developments shows safety tests similar to modern tests. Larger numbers of test units were used and the tests were not done in a sequential manner. The same can be said for the Mk 19 and Mk 40 Warheads developed for the BULLPUP Missile. The tests were comprehensive in nature and included the tests called for in WR-50 and MIL-STD-2105 (series). However, one significant difference was that most Fast Cookoff tests of that era were conducted using oil-soaked wood bonfires rather than pans of JP-5 fuel oil.

11-1.2. In that era, rocket motor safety testing was somewhat different than warhead testing. As early as 1960, MIL-R-22713, "Rocket Motors, 40 Foot Drop Test" (canceled), gave parameters for a 40-foot drop test for rocket motors. Other safety or hazard tests for rocket motors centered around hazard classification requirements. Bureau of Weapons (BuWeps) Instruction 8020.3, "Explosive Hazard Classification Procedures" (superseded by NAVSEAINST 8020.8), issued in 1962, is the earliest reference found, although it is believed there was a prior Bureau of Ordnance (BuOrd) directive on hazard classification; see paragraph 11-2.1. Test reports based on these documents report a 40-foot drop, 20mm projectile impact, fast cookoff (bonfire), and detonation tests. The detonation tests consisted of detonating a small charge of Pentolite or Tetryl either internal to or external to a rocket motor. This test would determine the type of reaction experienced by the motor and whether or not it propagated to adjacent rounds. Prior to 1970, rocket motor safety programs did not include the environmental tests that are part of MIL-STD-2105 (series), nor did they include the slow cookoff test. The environmental tests were not neglected, but were performed as part of the rocket motor preflight rating tests as part of the rocket motor qualification process. MIL-R-23139, "Rocket Motors, Surface-Launched Development and

Qualification Requirements for" (inactive) was the specification covering this aspect of development requirements.

11-2. ORDNANCE TESTS. Each of the several tests reviewed will be discussed individually in the next few paragraphs.

11-2.1. 40-FOOT DROP TEST. Reference to 40-foot drop testing of ordnance items dates back to the early 1950s. The earliest document formally describing this test is MIL-STD-302, "40-Foot Drop Test for Use in Development of Fuzes" (canceled). In the middle to late 1950s, test reports of ordnance items larger than fuzes, such as projectiles, warheads, and rocket motors, show the 40-foot drop test being conducted on a regular basis during development. For in-service items and rocket motors, this was associated with the hazard classification process. This is the reason one can presume existence of a BuOrd Hazard Classification Directive preceding BuWeps Instruction 8020.3. A drop test of ten feet onto a studded plate was an alternative to the 40-foot drop of high explosive items in the late 1950s and early 1960s. MIL-S-23069 (WEP) of 31 October 1961, "Safety Requirements, Minimum, for Air Launched Guided Missiles" (canceled), allowed warheads to be subjected to a 10-foot drop onto a studded plate in lieu of a 40-foot drop onto a smooth plate. MIL-R-22713, "Rocket Motors, Forty Foot Drop Test" (canceled) published in November 1960, called for three motors to be dropped 40 feet, each in a different orientation. In this specification, it was noted that the test was intended to establish that rocket motors are capable of withstanding abnormal impact conditions that might occur during handling and transportation in the logistic train. It was not intended to be a direct simulation of field or fleet conditions, but to confirm safety of a missile dropped during transfer-at-sea or during other parts of the logistic cycle. Such acts might include:

a. Dropped ordnance through a hatch or an elevator to the hangar deck from the flight deck of an aircraft carrier;

b. Dropping ordnance from a crane to the bottom of a submarine; or

c. Dropping ordnance from a crane while hoisting from a pier onto a combatant or cargo ship.

11-2.1.1. There are examples of accidents involving dropped ordnance throughout this manual. Mishap 4-7 relates the loss of a C2 cargo ship used to store ammunition, while loading 500-pound bombs and aerial depth charges from LCMs alongside. The weather was rough; an explosion occurred. The entire vessel and its crew were lost. Over 50 personnel from ships in the vicinity were also killed. The Board of Investigation deduced "the most likely force to have caused the explosion was a load of ammunition set off by dropping into, or striking the hatch of No. 3 or No. 4 hold."

11-2.1.2. Naval Weapons Laboratory Letter WX:RCW:ssc 8800/S of 17 July 1963, however, belies these thoughts on the origin of the test. The paragraphs below are extracted directly from that letter, the subject of which reads, "Proposed Instruction Providing Information and Policy on the Forty-Foot Drop Test Requirement; forwarding of". They show that the test represents a severe impact greater than one might expect in normal or rough handling of ordnance.

11-2.1.3. The drop height of 40 feet is not directly related to any specific condition to be expected during handling of the ordnance item tested. Rather, it is simply a convenient method of simulating an

impact greater than is expected to be encountered during normal or rough handling of ordnance, or even during the great majority of accident situations. This results in an "overtest" condition. The overtest condition helps to compensate for the fact that the number of test items dropped in any given attitude is quite small, usually only one. In most cases, it is not economically feasible to test sufficient samples to permit precise statistical assessment of the threshold height at which the item becomes hazardous.

11-2.1.4. It should be noted that a free fall from a height of 40 feet will result in an impact velocity of 50 ft/second (34 MPH). Such an impact velocity if obtained through other means than a drop from a specific height, should in fact be considered acceptable in lieu of the drop test.

11-2.1.5. The 40-foot drop test is conducted not only to determine whether the particular sample dropped meets prescribed criteria, but perhaps more importantly, to yield information on the nature and severity of any reaction that occurs, from which handling and damage control procedures may be formulated. It is therefore neither necessary nor desirable to regard a failure of an item to meet "passing" criteria as grounds for automatic rejection of the item for service use. Criteria for passing should, therefore, be "single ended", i.e., they should be so formulated that an item which meets the criteria can be judged acceptable at once, but an item which fails to meet any such criterion will be rejected only if a technical evaluation of the test results establishes this as the appropriate course of action. In addition to criteria for passing, it may occasionally be appropriate also to specify criteria for rejection. Such criteria, if used should also be single-ended, i.e., they should be so formulated that an item which fails to meet any one rejection criterion can be judged acceptable only after technical evaluation of the results. It is important that each criterion adopted be clearly identified as to whether it is a passing criterion or a rejection criterion.

11-2.2. FAST COOKOFF TEST. There is documented evidence of fast cookoff tests being conducted in the 1950s. These tests appear to have originated as part of the hazard classification process. Most frequently, the ordnance items were laid on or suspended over oil soaked lumber. However, some fast cookoff tests of the late 1950 – early 1960 era were conducted using surplus World War II flame throwers. The ordnance was placed a short distance from the flame thrower which was then ignited. Flames impinged on the ordnance item until a reaction occurred. After the USS ENTERPRISE and USS FORRESTAL accidents; see Mishaps 2-11 and 2-13, a more standardized fast cookoff test evolved. It was originally documented as MIL-STD-1648, "Criteria and Test Procedure for Ordnance Exposed to an Aircraft Fuel Fire" (canceled), and remained in effect until the early 1990s, when the process was included in MIL-STD-2105 (series). The current test offers standardization in that a fuel, JP-4 or JP-5, with known thermal characteristics is used. The ordnance is suspended three feet above the fuel surface with an average required flame temperature of 1600 degrees Fahrenheit (F). The test is not conducted under windy conditions and the fuel pan must be large enough that the ordnance item is completely engulfed in the fire.

11-2.3. SLOW COOKOFF TEST. Reports have been found dating back to the late 1950s in which slow cookoff tests were conducted, although there have been reports of such tests being performed in the late 1940s and early 1950s. The test then was conducted essentially the same as it is now; place the ordnance in an oven or similar insulated chamber and raise the temperature at a constant rate of 6 degrees F per hour until a reaction occurs. An initial soak at some elevated temperature 100 degrees F to 150 degrees F below the expected reaction temperature was (and still is) allowed. The early documented requirement for this test that was found is WR-50, published in February 1964, although the test was performed up to 15 years prior to WR-50. The test simulates: (1) heat rise in a magazine from a steam

leak from a pipe passing through a magazine, or (2) heat from a fire in an adjacent compartment. Steam pressure in lines passing through magazines must be maintained within specific limits, which belies the first suggestion. The second suggestion is a viable reason. The 6 degree F per hour rate of temperature increase is an estimate of heat rise from a fire in an adjacent compartment. Given field instrumentation capabilities in the late 1940s and early 1950s, it was the lowest rate at which temperature controllers could maintain a steady rise with consistence. That rate of heat rise provides a close approximation to isothermal conditions through the ordnance from skin to center. It is also a worst case compatibility test. The munition can not dissipate energy as fast as it is absorbed from conduction and heat builds up. Eventually exothermic conditions cause a reaction.

11-2.4. BULLET IMPACT/MULTIPLE BULLET IMPACT TESTS. As with the other destructive tests, the bullet impact test has been performed since the mid-1950s and probably was used earlier than that. The origin most likely stemmed from the World War II threats of deck mounted ordnance on Destroyers and Destroyer Escorts being strafed by enemy forces. Frequently, that was with 20mm ammunition although some attacking aircraft had smaller caliber weapons. There was also the threat that munitions being transported across country in railroad boxcars and in semitrailers would be targeted. These are regarded as vandalizing attacks, but should not be ignored.

11-2.4.1. In old test records, 20mm AP projectiles without incendiary mix was the munition of choice. Fifty caliber and 30 caliber projectiles were used on occasion. There are test reports showing all three being used on different samples of a munition. With the tri-service adoption of MIL-STD-2105 (series), a series of three 50 caliber projectiles at extremely short time intervals was substituted for the 20mm projectiles. The Army perceived this as a more severe threat and was acceded to on this point. If one calculates the amount of kinetic energy impacting the target munition, the cumulative kinetic energy from a series of three 50 caliber rounds is slightly larger than that from one 20mm projectile. However, one can speculate that the concentrated energy in the single 20mm round might do more damage.

11-2.4.2. The earliest known safety specification, MIL-S-23069 (WEP) contained a requirement stating that a missile warhead should not detonate when penetrated by a 20mm projectile at service velocity.

11-2.5. MULTIPLE FRAGMENT IMPACT. This test does not have a long history. It was first imposed in 1991 as a mandatory requirement with the publication of Revision A to MIL-STD-2105. It does represent the type of threat that might occur with large air-to-surface missiles.

11-2.6. TEMPERATURE AND HUMIDITY CYCLING. Temperature and Humidity Cycling have been used for many years in the development, qualification, and safety testing of ordnance items. Old requirements were cycling between +160 degrees F (95% relative humidity) and -65 degrees F. MIL-STD-210, “Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment” (canceled) is the basis for determining limits of thermal cycling. It is supplemented, in the case of aircraft carried munitions, with data gathered at the Naval Weapons Center (NWC) China Lake, in the form of reports concerning depot storage, open dump storage, temperature in boxcars and semitrailers, and thermal changes during both high altitude and low altitude flights. A partial listing of the reports on these topics includes NWC TP 4917, NWC TP 5039, and NWC TP 5365. The data substantiated the extreme limits used for air-launched weapons and aided in the establishment of lesser temperature extremes for surface launched weapons. Most of the data gathered is equally applicable to surface-launched ordnance. NAVSEA-06 Note 8810 of 19 October 1978 provided guidance for thermal

cycling of surface-launched missiles. It was based on the MIL-STD-210 studies of worldwide climatic conditions as well as some of the data gathered by NWC China Lake.

11-2.6.1. For safety purposes, the test has been established as 28 days of alternating storage between high temperature, high humidity and low temperature. In addition, certain types of damage are accelerated by the presence of moisture. There were MIL-STDs in the 300 series that called for these conditions in the fuze development process in the 1950s. Test reports show that the test was conducted on projectiles and warheads in the late 1950 – early 1960 years. The test was first documented for warheads in WR-50, which also required a 4-day temperature and humidity cycle following vibration test. This is done on the premise that the mechanical stresses of vibration might create a weakness that would show up under subsequent thermal stress.

11-2.6.2. Qualification efforts also include temperature cycle. These cycles are generally drawn from MIL-STD-810 (series) and are not deemed by the safety community to be as rigorous as the 28-day cycle imposed by MIL-STD-2105 (series).

11-2.7. VIBRATION. Records of vibration tests conducted on naval ordnance exist back to the early 1950s. Tests were probably done prior to that time. The low 300 series of MIL-STDs, later superseded by MIL-STD-331 (series), included vibration tests of fuze and fuze components. MIL-STD-167 (series) has been used for items intended for shipboard storage and use. MIL-STD-810 (series) contains a variety of test procedures covering land, air, and sea transportation. It also includes vibration test procedures for weapons in a tactical environment such as external aircraft stores and armored vehicle munitions. There are over 50 references to vibration in MIL-STD-810 (series), dating back to 1958. Many of these references show the origin of the currently used vibration levels. They show surveys of vibration levels and frequencies in different transportation modes from which curves of frequency and intensity spectra have been developed. The very early vibration work was conducted in a sinusoidal manner, either step frequency or swept frequency, over the prescribed band. A review of late 1950s test reports shows this type of vibration being conducted on ordnance items.

11-2.7.1. As time progressed and test methods became more sophisticated, random vibration spectra were used in lieu of sinusoidal. However, for shipboard vibration sinusoidal remains in use because the principle component of that environment is attributed to the rhythmic motion associated with shaft rotation and the number of propeller blades on a given ship or ship class. If a given munition is going to see service only on certain classes of ships, the shipboard frequency band is tailored to provide exposure to that frequency band.

11-2.8. SYMPATHETIC DETONATION. Sympathetic detonation or sympathetic reaction has its origins in the hazard classification process. The test has been conducted as part of the hazard classification process prior to the middle 1950s. There are innumerable test reports on file in the Naval Surface Warfare Center Dahlgren Division (NSWCDD) technical library relating to hazard classification tests. Many of them include a sympathetic detonation test. Current hazard classification does much with laboratory samples of energetic material, but still has a requirement for the sympathetic detonation test with either one or a stack of munitions. If one of a stack or pallet of munitions reacts, the test provides information on whether the other items in the same stack or pallet will also react or merely be dispersed.

11-3. WHY WE TEST. One needs only to read through this manual to appreciate the need for these tests. This publication contains many examples of ordnance accidents and incidents leading to death and major damage. Many of these accidents can be attributed to personnel errors, both of commission and of omission. Others can be attributed to design flaws.

11-3.1. PURPOSE OF ORDNANCE TESTING. Testing uncovers design flaws in time to correct the flaw before a hazard exists in the fleet. An example is the temperature cycling and vibration tests conducted within the safety program for the Mk 104 Dual Thrust Rocket Motor. Under the prescribed regime of thermal cycling, minute cracks developed at the ends of stress relief boots in the motor's sustainer grain. Such cracks would allow larger burning surfaces to develop, leading to pressure ruptures. If this were to occur prior to exiting a Vertical Launching System (VLS) module, catastrophic damage could result. Finding these cracks during the safety test portion of the program allowed redesign to eliminate the stress risers causing the cracks.

11-3.1.1. Another example occurred during the low level all-up round vibration tests on two different Blocks of STANDARD Missile. It was discovered that sectional joint screws loosened, thereby weakening the missile structure. A change in screws and in tightening procedures eliminated the problem.

11-3.2. THE NEED FOR DESTRUCTIVE TESTING. Destructive tests provide information on the degree of explosive/propellant reaction. In cookoff tests, one can obtain an estimate of time before a reaction occurs, thereby obtaining an estimate of the time during which damage control personnel may safely operate in the vicinity following an accident.

11-3.2.1. Computer simulation of such work in order to eliminate testing does not show the dangers that can occur with energetic materials. The world in which we live is non-linear and analog. Destructive safety testing of ordnance items is not the exact science that simulation analysts try to make it. With the limited quantities of ordnance available for these tests, there is no assurance that a mild reaction will be replicated in future events. The destructive tests form a boundary. A bullet impact test provides data from a low end amount of kinetic energy delivered to an ordnance item. A multiple fragment impact test, on the other hand, delivers an order of magnitude higher kinetic energy. Similarly, in the cookoff tests, fast cookoff creates a rapidly changing thermal stress through the ordnance item while a slow cookoff provides nearer to an isothermal condition. The stress occurs over a longer period of time and in a different way. Non-destructive tests are overstresses that provide a safe boundary above the expected stresses of routing environments.

11-4. HAZARD CLASSIFICATION AND INSENSITIVE MUNITIONS. Some safety testing originated in the hazard classification process. Over the past decade, the insensitive munitions program has added to the testing program, not so much in additional testing, but in applying more stringent pass-fail criteria to the results of an ordnance test.

11-4.1. APPLICATIONS IN TEST PROGRAM DESIGN. Test procedures between insensitive munitions and hazard classification have been harmonized to allow programs to conduct one set of tests to satisfy both requirements. This harmonization has resulted in a standardized, single set of tests required or insensitive munitions compliance according to Joint Requirements Oversight Council Manual (JROCM) 235-06. With appropriate planning in the early stages of development, a program

could reduce verall testing by judicious design of a test program that would encompass system safety requirements, insensitive munition requirements, and hazard classification requirements. Such planning is recommended in the Foreword of MIL-STD-2105 (series) and NAVSEAINST 8020.8 (series).

11-5. CONCLUSIONS. Safety tests have their origin in trying to judge ordnance response to a threat. The term "Threat Hazard Assessment" was not in use when most of these tests originated. It is in use today; see NAVSEA SW020-AH-SAF-010, section III, chapter 18. MIL-STD-2105 (series) also requires performance of a life cycle environmental profile. By doing these two things early in a development program, an effective safety/insensitive munitions/hazard classification program can be established using a minimum quantity of costly hardware. For a 40-foot drop, one might be able to reduce the number of drop tests by demonstrating that all attitudes (nose down, aft end down, and horizontal) are unlikely and eliminate dropping in unlikely attitudes. However, if a threat is identified in the Threat Hazard Assessment that is not adequately addressed through the harmonized set of tests, then additional testing would be required.

11-6. RECOMMENDATIONS. Based on this study, it is recommended that safety testing not be reduced, but that the prescribed environmental profiles and threat hazard assessment be done during the earliest phases of a program. Then build the Hazard Assessment Program around the environmental profile and threat hazard assessment, keeping in mind that the quantities of ordnance involved only allow a judgment of risk, and are not an absolute predictor of the severity of an event.

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APPENDIX A

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Failure to Report Malfunctioning Tool	2-22	Mk 31 Tool set malfunctioned (1992)	

Safety Issue Resulting in Corrective Action	Mishap	Short Description	Figure #
Insufficient Training to Perform Task	2-4	Sentry discharged weapon through holster (January 1993)	
	2-5	U.S.S. *Oriskany*: dropped Mk 24 flares ignited, sympathetically detonating other ordnance (October 1966)	2-3
	2-6	Rammer rail fatally struck seaman in chest during ASROC rigging	
	2-7	Flare tripped and burned a Chief Gunners Mate (March 1994)	
	4-16	Forklift loaded with MK 65 Mine slid off loading dock (March 2002)	4-8
	8-4	New 5"/38 caliber gun misfired (June 1943)	8-1
	9-1	Inexperienced torpedo man killed during torpedo overhaul	
	10-3	Photoflash powder deflagrated during intentional destruction of unused ground burst projectile simulators (June 1991)	
Failure to Wear PPE	2-8	Fuel spills aboard ship (1990-1996)	
Failure to Maintain Emergency Withdrawal Distances/Personnel Exposure Limits to Hazardous Material	2-9	Truck fire (1971)	
	10-7	A live military shell, taken by a contractor from Ft. Irwin to a scrap yard, exploded (November 1997)	
Smoking in Undesignated Areas	2-10	Cigarette disposed on deck caused fire onboard (1994)	
Aircraft Munitions Cook-off	2-11	U.S.S. *Enterprise*: explosion and fire onboard	2-4
	2-13	U.S.S. *Forrestal*: explosion and fire onboard	2-6
Ammunition Exposed To Hazardous Weather Conditions	2-23	Container slid off forktruck and landed top down on flight deck (October 1995)	
	2-24	CNU-491/E Containers slid during VERTREP (November 1993)	

Safety Issue Resulting in Corrective Action	Mishap	Short Description	Figure #
Improper Ammunition Accounting and Control	2-26	Hand grenade found in weeds exploded in civilian's hand (April 1966)	
	2-27	Practice grenade placed in a bag of tools believed to be a dummy (February 1994)	
Use of Live Ammunition for Training Purposes	2-28	Shotgun discharged into victim during terrorist training (August 1993)	
Mis-identification of Ammunition	3-1	Mis-marked CIWS fired during ammunition onload (August 1994)	
	3-2	Live boosters found in boxes marked "Certified Empty" (July 1991)	
	3-3	WALLEYE weapon found in a container marked "empty" (July 1991)	
Failure to Handle Unidentified Ammunition as MPPEH	3-4	Unidentified 2.75-inch rocket found on display in museum (January 2008)	3-1
	10-8	20mm target practice round found in a wooden container at DRMO (October 1990)	

Safety Issue Resulting in Corrective Action	Mishap	Short Description	Figure #
Dropping or Roughly Handling Ammunition	2-5	U.S.S. *Oriskany*: Mk 24 Mod 3 flare dropped (October 1966)	2-3
	4-1	Ordnance dropped during routine handling operations	4-1
	4-2	Port Chicago, California: dropped Torpex-loaded weapon exploded (July 1944)	4-2
	4-3	Damaged fuze ignited (January 1994)	
	4-4	NAD Hastings, Nevada: dropped depth bomb caused violent blast (September 1944)	4-3
	4-5	Carelessly tossed bombs exploded (1945)	
	4-6	U.S.S. *Solar*: NAD Earle, NJ: hedgehog charge detonated (April 1946)	4-4
	4-7	U.S.S. *Mt. Hood*: 500-lb and aerial and depth bombs exploded (November 1944)	4-5, 4-6
	10-7	Live military shell, taken by a contractor from Ft. Irwin to scrap yard, exploded (November 1997)	
Failure to Use Spotter When Handling Ammunition	4-8	Cluster bombs toppled (November 1944)	
	4-9	Improperly assigned spotter hit on hard hat (January 1996)	
Tampering with Ammunition	4-10	Unidentified fuze exploded in enlisted man's hand (September 1960)	

Safety Issue Resulting in Corrective Action	Mishap	Short Description	Figure #
Improper Use of OHE/ MHE/WHE	4-11	HARPOON Missile fell 4 feet (1992)	
	4-12	Fire bomb punctured by fork stops	4-7
	4-13	Containerized HARM missiles dropped during forklift handling (November 1944)	
	4-14	HARPOON Missiles damaged during forklift handling (July 1996)	
	4-15	Three torpedo containers fell (1992)	
	4-16	Forklift loaded with Mk 65 Mine slid off loading dock (March 2002)	4-8
	4-17	Twenty-foot container fell 15 feet, hitting guard rail and landing upside down	
	4-18	Crane tipped over into water (November 1993)	
	4-19	Crane overloaded (1997)	
	4-20	Mobile crane tipped and damaged (1996)	
	4-21	Crossdecking between barge and VLS combatant, wire rope pendant sling parted (September 2000)	
Improper Use of Freight/Weapons Elevators and Ammunition Hoists	4-22	Weapons elevator used incorrectly	
	4-23	Sailor killed while riding a weapons elevator not designated for passenger use	
	4-24	Cargo not placed within safety margin of weapons elevator (March 1996)	
Incompatible Storage/ Stowage	2-5	U.S.S. *Oriskany*: Mk 24 Mod 3 flare dropped (October 1966)	2-3
	5-1	Incompatible items stored in magazine detonated	
	5-2	NSWC Indian Head Building 518 destroyed by chemical reaction (August 1994)	5-1
	5-3	Texas City, TX Port Disaster (April 1947)	5-2

Safety Issue Resulting in Corrective Action	Mishap	Short Description	Figure #
Deteriorated Explosives	5-4	Lone Star Army Ammunition Plant: deteriorated ordnance in magazine exploded	
	5-5	Lake City Army Ammunition Plant: deteriorated propellant auto-ignited	
	5-6	Sierra Army Depot: deteriorated BLU-82/U Bombs detonated	
Mishandling of Unstable Developmental Materials	5-7	NSWC White Oak: unstable materials in a magazine exploded (June 1992)	5-3
	5-8	Hivelite 498 chemical incompatibility	
Failure to Observe Precautions for Ammunition in Open Storage	5-9	NAS Philippines: ejector racks with photoflash cartridges exploded	5-4
	5-10	ASP grass fire (April 1969)	
Improper Loading, Blocking, Bracing of Ammunition	6-1	Lexington-Bluegrass Army Depot: fatal accident caused by pneumatic nailer use (September 1992)	
	6-2	Retrograde ammunition fell off back of flatbed truck (June 1991)	
	6-4	During UNREP unrestricted containers fell	
	6-5	S.S. *Badger State*: unrestrained 2,000 lb. bombs exploded (December 1969)	
	6-11	Semi-trailer truck loaded with explosives overturned (October 1971)	6-5
Failure to Inspect Load of Ammunition Prior to Shipment and Upon Receipt	6-3	Receipt inspection revealed incorrectly marked explosive dynamite leaked (November 1995)	
Failure to Inspect Rail Equipment/Transport Vehicle	6-9	Tobar, NV: train explosion (June 1919)	
	6-10	Roseville, CA: stationary explosions at Antelope Railyard (April 1973)	6-3, 6-4
	6-13	Tractor trailer transporting TALOS Missile caught fire and exploded (April 1983)	

Safety Issue Resulting in Corrective Action	Mishap	Short Description	Figure #
Failure to Chock Railcar Wheels	6-8	Railcar loaded with 8-inch projectiles derailed (August 1970)	6-2
Hazardous Driving of a Motor Vehicle Loaded with Ammunition	6-11	Semi-trailer truck loaded with explosives overturned (August 1971)	6-5
	6-12	NAVMAG Philippines: tractor trailer carrying flares ignited and burned (July 1971)	6-6
Failure to Observe Aircraft Preparation/ Downloading Procedures	6-14	Thermal battery initiated during weapon downloading (April 1994)	
	6-15	SIDEWINDER Missile accidentally jettisoned (May 1964)	
Disregard of Hazards Introduced by Ordnance System Test	7-1	TARTAR Missile accidentally fired (June 1968)	
	7-2	20mm gun fired during armament system check aboard aircraft carrier (June 1965)	
	7-3	Missile head lost overboard during missile launcher exercise (August 1964)	
	7-4	Gunners Mate fatally injured while testing primers in a 3-inch auto gun mount (August 1950)	
Failure to Properly Check Navy Gun Systems Prior to and Following Use	8-1	U.S.S. *Princeton*: PEACEMAKER exploded (February 1844)	
	8-2	U.S.S. *Massachusetts*: charge ignited (January 1903)	
	8-3	U.S.S. *Missouri*: smokeless powder ignited (April 1904)	
	8-4	New 5/38 Caliber gun misfired (June 1943)	8-1
	8-6	In-bore detonations: U.S.S. *Brooklyn* (August 1987) H.M.A.S. *Brisbane* U.S.S. *Henry B. Wilson* (January 1973) U.S.S. *Hoel* (November 1969)	
	8-8	Armed white star parachute flare placed inside a canvas bag fired (August 1994)	
	9-2	Depth charge projector fired aboard a destroyer during K-Gun repair (1944)	

Safety Issue Resulting in Corrective Action	Mishap	Short Description	Figure #
Malfunctioning, Misfired Damaged Ordnance	8-5	Round exploded in breech of 20mm gun	
	8-9	Aboard an LST, a round of ammunition exploded while being unloaded from a hot gun (1945)	
Disregard of Proper Disposal/ Demilitarization Procedures	10-1	Wind caused accidental initiation of a propellant train during burning operations (May 1994)	
	10-2	Black powder ignited during disposal operations (July 1988)	
	10-3	Photoflash powder deflagrated during intentional destruction of unused ground burst projectile simulators (July 1991)	
	10-4	NAD McAlester: Obsolete 20mm projectiles detonated during preparation for demilitarization (January 1971)	10-1
	10-5	NAD Crane: 75mm HE-loaded projectiles detonated during burn-out operations (June 1964)	10-2
	10-9	20mm target practice round found in a wooden container at DRMO (October 1990)	
Violation of Personnel Exposure Limits to Hazardous Material	10-7	NAD Hawthorne: 3.5-inch rockets exploded (May 1971)	10-4

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APPENDIX B

REFERENCE DOCUMENTS

B-1. GENERAL. This appendix contains all the publications referenced in this manual.

B-2. MILITARY STANDARDS

B-2.1. DOD MILITARY STANDARDS.

129M - Marking for Shipment and Storage

709C - Ammunition Color Coding

882C - Systems Safety Program Requirements

B-2.2. NAVY MILITARY STANDARDS.

1322A - Unit Loads of Ammunition and Explosives for Domestic and Overseas Shipments

1323 - Unit Loads of Ammunition and Explosives for Underway Replenishment

1324 - Palletizing Amphibious Loads

B-3. NAVAL SEA SYSTEMS COMMAND (NAVSEASYSCOM)

B-3.1. NAVSEA INSTRUCTIONS.

8020.8B - Department of Defense Explosives Hazard Classification Procedures

8024.2 - Magazine Stowage Layout Standards

B-3.2. NAVSEA ORDNANCE DOCUMENTS (OD'S).

44942 - Weapon System Safety Guidelines Handbook (4 parts)

B-3.3. NAVSEA ORDNANCE PAMPHLETS (OP'S).

4 - Ammunition Afloat

5 - Ammunition and Explosives Ashore, Safety Regulations for Handling, Storing, Production, Renovation and Shipping

1014 - Ordnance Safety Precautions, Their Origin and Necessity

2173 - Approved Handling Equipment for Weapons and Explosives (2 volumes)

2239 - Motor Vehicle Driver's Handbook, Ammunition, Explosives, and Related Hazardous Materials

3206 - Handling and Stowage of Naval Ordnance Aboard Ammunition Ships

3347 - United States Navy Ordnance Safety Instructions

3565/NAVAIR 16-1-529/NAVELEX 0967-LP-624-6010 - Electromagnetic Radiation Hazards (U) (2 volumes)

3681 - Motor Vehicle and Railcar Shipping Inspector's Manual for Ammunition, Explosives, and Related Hazardous Materials

B-3.4. NAVSEA TECHNICAL MANUALS

S9086-XG-STM-000, NSTM 700 - Ship Ammunition Handling and Stowage

SW010-AF-ORD-010 - Identification of Ammunition

SW020-AC-SAF-010/020/030 - Transportation and Storage Data for Ammunition, Explosives, and Related Hazardous Materials (formerly NAVSEA OP 5 Volume 2 and NAVSEA OP 2165 Volume 2)

SW020-AG-SAF-010 - Navy Transportation Safety Handbook for Ammunition, Explosives and Related Hazardous Materials

SW023-AG-WHM-010 (formerly OP 4461) - On-Station Movement of Ammunition and Explosives by Truck and Railcar

SW023-AH-WHM-010 (formerly OP 4098) - Handling Ammunition, Explosives and Hazardous Materials with Industrial Material Handling Equipment (MHE)

SW300-BC-SAF-010 - Safety Manual for Cleaning of Live Ammunition from Guns

B-4. NAVAL SUPPLY SYSTEMS COMMAND (NAVSUPSYSCOM).

B-4.1. NAVSUP PUBLICATIONS.

P-801 - Ammunition Unserviceable, Suspended and Limited Use

P-805 - Receipt, Segregation, Storage and Issue Sentencing

P-807 - Fleet Sentencing

B-5. MARINE CORPS (MC). Requests for Marine Corps publications should be directed to CMC (HQSP-2), Washington, DC 20380, and should be submitted in accordance with the current edition of MCO P5600.31.

B-5.1. MC ORDERS (MCO'S).

5102 - Marine Corps Ground Mishap Reporting

B-6. OFFICE OF THE CHIEF OF NAVAL OPERATIONS

B-6.1. OPNAV INSTRUCTIONS.

3770.2H - Airspace Procedures Manual

5102.1 - Mishap Investigation and Reporting

5530.13B - Department of the Navy Physical Security Instruction for Sensitive Conventional Arms, Ammunition and Explosives (AA&E)

8020.14 - Department of the Navy Explosives Safety Policy

8023.24 - Navy Personnel Ammunition and Explosives Handling Qualification and Certification Program

11320.23F - Shore Activities Fire Protection and Emergency Services Program

B-7. NAVAL MEDICAL COMMAND

B-7.1. NAVMED PUBLICATIONS.

P-5055 - Radiation Health Protection Manual

B-8. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

B-8.1. NFPA PAMPHLETS.

70 - National Electrical Code

B-9. NAVAL FACILITIES ENGINEERING COMMAND (NAVFACENGCOM)

B-9.1. NAVFAC PUBLICATIONS.

P-300 - Transportation Equipment, Management of

B-10. SUPERINTENDENT OF DOCUMENTS. The following publications are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402; Telephone (202) 783-3238.

B-10.1. CODE OF FEDERAL REGULATIONS.

Title 14, Part 77 - Aeronautics and Space

Title 49, Part 171 - General Information, Regulations and Definitions

Title 49, Part 172 - Hazardous Materials Tables and Hazardous Materials Communications Regulations

Title 49, Part 173 - Shippers - General Requirements for Shipments and Packagings

Title 49, Part 174 - Carriage by Rail

Title 49, Part 175 - Carriage by Aircraft

Title 49, Part 176 - Carriage by Vessel

Title 49, Part 177 - Carriage by Public Highway

Title 49, Part 178 - Shipping Container Specifications

Title 49, Part 179 - Specifications for Tank Cars

B-11. MILITARY SPECIFICATIONS

MIL-C-21215 - Ammunition Pallet Crate

B-12. BUREAU OF EXPLOSIVES (BOE). The following publication is published by the Bureau of Explosives, 50 F Street, NW, Washington, DC 20001 (American Association of Railroads).

B-12.1. BOE TARIFF.

BOE-6000 - Hazardous Materials Regulations of the Department of Transportation

B-13. NAVAL WARFARE PUBLICATIONS

NWP-3.04.lM - Shipboard Helicopter Procedures for Air-Capable Ships

B-14. NAVAL ORDNANCE SAFETY AND SECURITY ACTIVITY (NOSSA)

B-14.1. NOSSA INSTRUCTIONS

8023.11A - Standard Operating Procedures Development, Implementation and Maintenance for Ammunition and Explosives

B-15. ORDNANCE SAFETY TESTING BIBLIOGRAPHY. The following publications were used as source documents in the development of Chapter 11, "Origin of Ordnance Safety Tests".

Active (A) or Historical (H)	Title
A	MIL-STD-2105, Hazard Assesment Tests for Non-nuclear Munitions
H	WR-50, Warhead Safety Tests, Minimum for Air, Surface, and Underwater Launched Weapons
H	MIL-R-22713, Rocket Motors, 40-Foot Drop Test (Superseded by MIL-STD-331, Fuze and Fuze Components, Environmental and Performance Tests for)
H	BuWepsInst 8020.3, Explosive Hazard Classification Procedures (Superseded by NAVSEAINST 8020.8, Ammunition and Explosives Hazard Classification Procedures)
H	MIL-STD-302, 40-Foot Drop Test for Use in Development of Fuzes (Superseded by MIL-STD-331, Fuze and Fuze Components, Environmental and Performace Tests for)
H	MIL-R-23139, Rocket Motors, Surface Launched, Development and Qualification Requirements for
H	MIL-S-23069, Safety Requirements, Minimum, for Air-Launched Guided Missiles
H	MIL-STD-1648, Criteria and Test Procedure for Ordnance Exposed to an Aircraft Fuel Fire
H	MIL-STD-210, Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment (Superseded by MIL-HDBK-310, Global Climatic Data for Developing Military Products)

A	MIL-STD-810, Environmental Engineering Considerations and Laboratory Tests
A	MIL-STD-167, Mechanical Vibrations of Shipboard Equipment
A	NAVSEAINST 8020.8, Ammunition and Explosives Hazard Classification Procedures
A	MIL-STD-331, Fuze and Fuze Components, Environmental and Performance Tests for
H	Naval Weapons Center China Lake Technical Reports
	NWC TP 5039, Measured Temperatures of Solid Rocket Motors Dump Stored in the Tropics and Desert
	NWC TP 5365, Measurement of Missile Thermal Response During Captive Flight at High Altitudes
H	NAVSEA-06 Note 8810 of 19 October 1978, Thermal Limits for Surface Launched Missiles
A	JROCM 235-06, Insensitive Munitions Standards and Passing Criteria

APPENDIX C

ORDNANCE SAFETY AND TESTING EXPERTISE

C-1. GENERAL. Chapter 11, "Origin of Ordnance Safety Testing" was developed wholly based on a 1997 paper prepared by D. J. Ammerman, EG&G Technical Services, Incorporated for the Systems Safety Engineering Branch, Combat System Safety and Engineering Division, Naval Surface Warfare Center Dahlgren Division. The persons listed below, with their position titles at the time of the document's composition, contributed to its content.

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