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United States Environmental Protection Agency

United States Occupational Safety and Health Administration

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EPA
CEPP
OSHA

EPA/OSHA JOINT CHEMICAL ACCIDENT INVESTIGATION REPORT

BPS, Inc.
West Helena, Arkansas

REPORT

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The EPA/OSHA Joint Accident Investigation Program

EPA and OSHA work together under conditions detailed in a Memorandum of Understanding (MOU) to investigate certain chemical accidents. The fundamental objective of the Joint EPA/OSHA chemical accident investigation program is to determine and report to the public the facts, conditions, circumstances, and causes or likely causes of any chemical accident that results in a fatality, serious injury, substantial property damage, or serious off-site impact, including a large scale evacuation of the general public. The ultimate goal of the accident investigation is to determine the root causes in order to reduce the likelihood of recurrence, minimize the consequences associated with accidental releases, and to make chemical production, processing, handling, and storage safer. This report is a result of a Joint EPA/OSHA investigation to describe the accident, determine root causes and contributing factors, and identify findings and recommendations.

Under section 112(r)(1) of the Clean Air Act Amendments of 1990 (CAA) and under the OSH Act of 1970, industry has a general duty to design and maintain a safe facility taking such steps as are necessary to prevent releases, and to minimize the consequences of accidental releases which do occur, and to provide a safe and healthy workplace for workers. In addition, OSHA has promulgated the Process Safety Management Standard at 29 CFR 1910.119 for the prevention of chemical accidents that impact workers. EPA, under section 112(r)(7) of the CAA, has promulgated regulations for the preparation of risk management programs and plans for the prevention of accidental chemical releases that harm the public and the environment. However, compliance and enforcement with these provisions are not the focus of this report but will be addressed by EPA, OSHA or both as necessary in separate reports or actions.

Prior to releasing an accident investigation report, OSHA and EPA must ensure that the report contains no confidential business information. The Freedom of Information Act (FOIA), the Trade Secrets Act, and Executive Order 12600 require federal agencies to protect confidential business information from public disclosure. To meet these provisions, OSHA and EPA have established a clearance process for accident investigation reports in which the companies who have submitted potentially confidential information used in the report are provided a portion of the draft report. This portion contains only the factual details related to the investigation (not the findings, the conclusions nor the recommendations). Companies are asked to review this factual portion to confirm that the draft report contains no confidential business information. As part of this clearance process, companies often will provide to OSHA and EPA additional factual information. In preparing the final report, OSHA and EPA consider and evaluate any such additional factual information for possible inclusion in the final report.

Chemical accidents investigated by EPA Headquarters are conducted by the Chemical Accident Investigation Team (CAIT) located in the Chemical Emergency Preparedness and Prevention Office (CEPPO) at 401 M Street SW, Washington, DC 20460, 202-260-8600. More information about CEPPO and the CAIT may be found at the CEPPO Homepage on the Internet at http://www.epa.gov/ceppo. Copies of this report can be obtained from the CEPPO Homepage

or by calling the National Service Center for Environmental Publications (NSCEP) at 800-490-9198. OSHA Headquarters are located in the US Department of Labor - OSHA, 200 Constitution Ave NW, Washington, DC, 20210, 202-219-8118. More information about OSHA may be found at the OSHA Homepage on the Internet at http://www.osha.gov.

Chemical Safety and Hazard Investigation Board (CSB)

In the 1990 Clean Air Act Amendments, Congress created the Chemical Safety and Hazard Investigation Board (CSB). Modeled after the National Transportation Safety Board (NTSB), the CSB was directed by Congress to conduct investigations and report to the public the findings regarding the causes of chemical accidents. Congress authorized funding in November 1997 and the CSB began operations in January 1998. Several investigations by the CSB are underway. More information about CSB may be found at their Homepage on the Internet at http://www.chemsafety.gov or http://www.csb.gov.

EPA and OSHA plan to complete their work and issue public reports on investigations initiated prior to funding of the CSB. Under their existing authorities, both EPA and OSHA will continue to have roles and responsibilities in responding to, and investigating, chemical accidents. The CSB, EPA, and OSHA (as well as other agencies) will be coordinating their efforts to determine the causes of accidents and to apply lessons learned to prevent future events.

Executive Summary

On May 8, 1997, at approximately 1:15 p.m., Central Daylight Time , a massive explosion and fire occurred at Unit Two of the Bartlo Packaging Incorporated (BPS) facility located in West Helena, Arkansas. As a result of the explosion and fire, three West Helena firefighters were killed. Seventeen firefighters required medical attention due to heat exhaustion and injuries during the response. The Unit Two structure was completely destroyed. Hundreds of residents and patients at a local hospital were either evacuated or sheltered-in-place. The Mississippi river traffic and major roads were closed for approximately twelve hours due to the release of toxic materials from the facility.

Prior to the explosion, BPS employees observed smoke in the Unit Two warehouse. Following established procedures, all employees evacuated the building. The company placed an emergency call to local emergency response groups. Members of the West Helena Fire Department (WHFD) responded to the scene within minutes. A reconnaissance team composed of four firefighters was outside of the Unit Two warehouse when an explosion occurred inside the building. Three firefighters were fatally injured when they were struck by materials blown out of a falling cinder block wall. The fourth firefighter was seriously injured.

EPA and the OSHA conducted a joint investigation of the incident. The Joint Chemical Accident Investigation Team (JCAIT) determined that the incident was most likely caused by the decomposition of a bulk sack containing the pesticide Azinphos methyl (AZM) 50W which had been placed against or close to a hot compressor discharge pipe. Under this scenario, the heat from the discharge pipe would have caused the pesticide material to decompose and give off flammable vapors which resulted in the fatal explosion.

The investigation team could not eliminate the possibility that the AZM 50W arriving at BPS the day of the accident was already decomposing. This alternate scenario could either be an initiating event by itself or a factor influencing the preferred scenario. In other words, a decomposing bag of AZM 50W could have been placed closed to the compressor discharge pipe.

The JCAIT identified the following root causes and contributing factors of the event:

- MicroFlow Company (MFC) and BPS did not have a full understanding of the hazards associated with AZM.
- BPS did not assess the potential hazards of a hot pipe in an area where hazardous chemicals were to be stored when the new warehouse addition was constructed.
- BPS did not have standard operating procedures for material storage and handling.
- On-site information provided to the WHFD was conflicting and incomplete.

The following recommendations were developed by the JCAIT to address the root causes and contributing factors and to prevent recurrence of similar incidents at other facilities:

- Manufacturers should be proactive in testing potentially hazardous materials. Testing for actual conditions and elevated temperatures during storage should be conducted to determine safe storage conditions. Screening tests, such as Differential Scanning Calorimetry (DSC), can be helpful in determining the need for additional testing. However, thermally unstable materials which are intended to be packed and shipped in large volume containers should be tested beyond screening levels.

- Facilities which store, use, handle, manufacture or move hazardous materials should develop and implement a system to review potential hazards of modifications to facilities, equipment, chemicals, technology, or procedures. The system should analyze potential impacts to safety, health, and the environment and take appropriate actions before the modifications are implemented. OSHA's Process Safety Management (PSM), EPA's Risk Management Program (RMP), and the Center for Chemical Process Safety (CCPS) guidelines can help facilities develop such system.

- Facilities that store hazardous chemicals should develop standard operating procedures for material storage and handling that address storage restrictions. Such facilities should adhere to applicable practices outlined by CCPS and the National Fire Protection Association (NFPA). Pesticide facilities are encouraged to also follow NFPA 43D (Code for the Storage of Pesticides), specifically the non-mandatory Appendix B.

- Facilities storing hazardous chemicals should develop an inventory management system with information regarding composition, compatibility, storage, location, and quantity of incoming products. This management system can help the facility comply with storage restrictions and provide emergency responders useful information during a response action.

- EPA and OSHA, in conjunction with interested parties, should facilitate a workshop to make recommendations on how to improve the quality of hazardous materials information available during response actions. The workshop should review appropriate uses of Material Safety Data Sheets by local emergency response groups and how to provide these groups information describing the behavior of hazardous materials when they begin to react or decompose and what responders should look for during a chemical emergency.

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1.0 Background

1.1 Introduction

On May 8, 1997, an explosion and fire occurred at the Bartlo Packaging Incorporated (BPS) facility located in West Helena, Arkansas. As a result of the explosion and fire three firefighters died and seventeen other firefighters required medical attention due to heat exhaustion and minor injuries. Hundreds of residents, including local hospital patients, were evacuated or sheltered in place due to the threat of exposure to toxic chemicals released in the blast. Major roads were closed and the Mississippi river traffic halted. Several emergency response groups participated in the response action. It took approximately two weeks to extinguish the fire.

The Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) conducted a joint investigation of this event in accordance with a Memorandum of Understanding (MOU) signed in November 1996. The agencies established a joint chemical accident investigation team (JCAIT) made up of personnel from the EPA and OSHA National Offices, OSHA's Health Response Team, and Regional and contractor personnel from both agencies. This report contains a description of the incident and the results of the joint investigation.

1.2 Facility Description

BPS is a corporation with facilities in Helena and West Helena, Arkansas. The West Helena facility is located in an industrial park three miles from the central business district of West Helena, Arkansas. The facility is located in a flat area used primarily for agricultural purposes. The nearest residential area is located less than one mile northeast, and the Mississippi river is located approximately three miles east.

BPS is an agricultural chemical packaging facility. No chemical manufacturing occurs at the facility. BPS receives bulk shipments of agricultural chemicals (pesticides, insecticides, etc.) and repackages them in smaller, water soluble, containers. The operation is conducted for chemical manufacturers using tolling contracts. Under a tolling arrangement a company contracts with another company to perform a specific operation. In this case, chemical manufacturers deliver agricultural chemicals in bulk containers, which BPS repackages according to the manufacturers' specifications. BPS then ships the product back to the specified location.

The West Helena facility employs approximately 130 workers. At the time of the incident 65 employees were on duty. The facility consists of two production buildings (referred as units One and Two), two satellite buildings, and a "gel" building. The production buildings are constructed of corrugated metal with steel reinforcement. The Unit Two building (Figure 1),

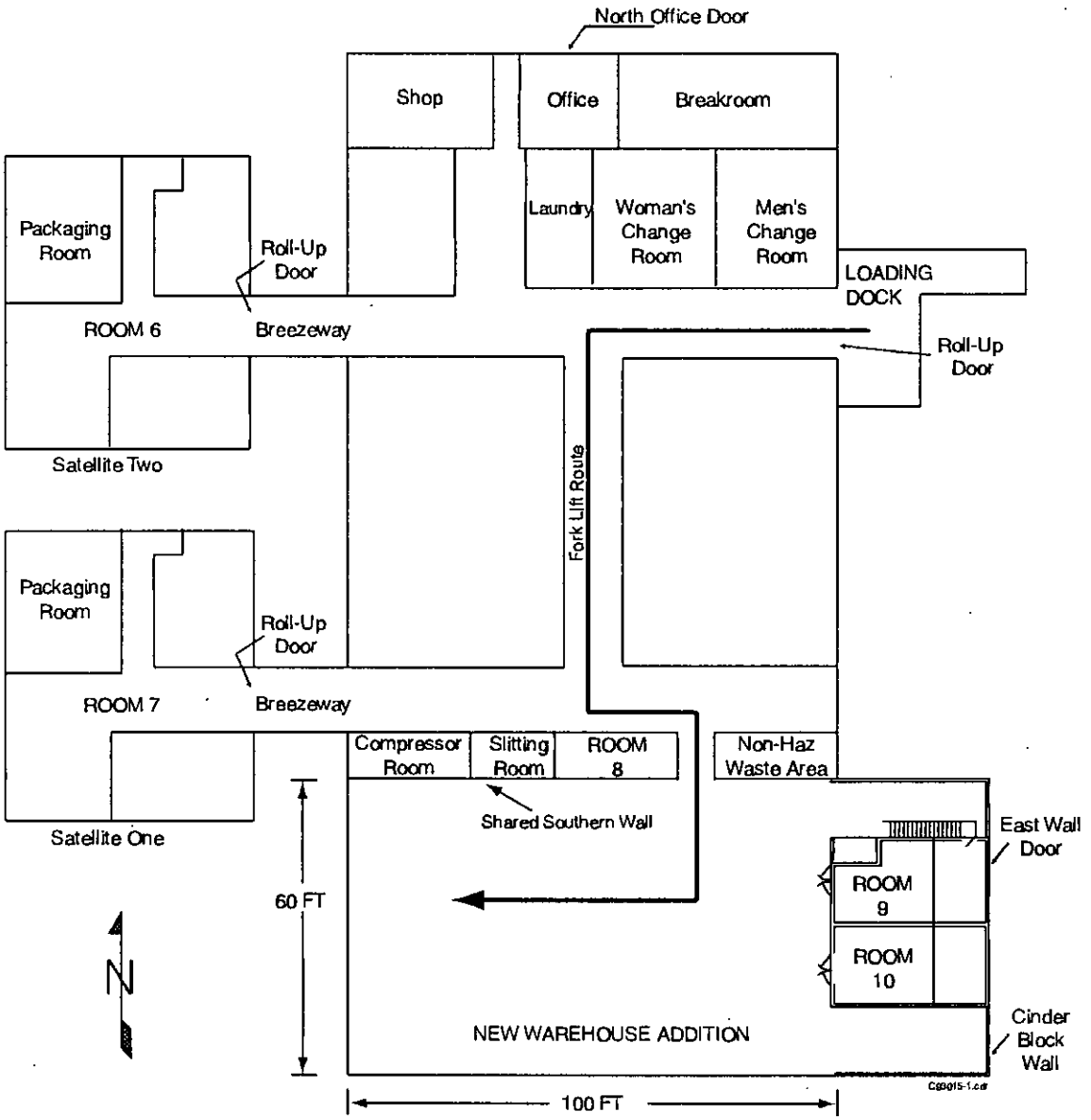

FIGURE 1: FLOOR PLAN - BPS, INC. UNIT #2

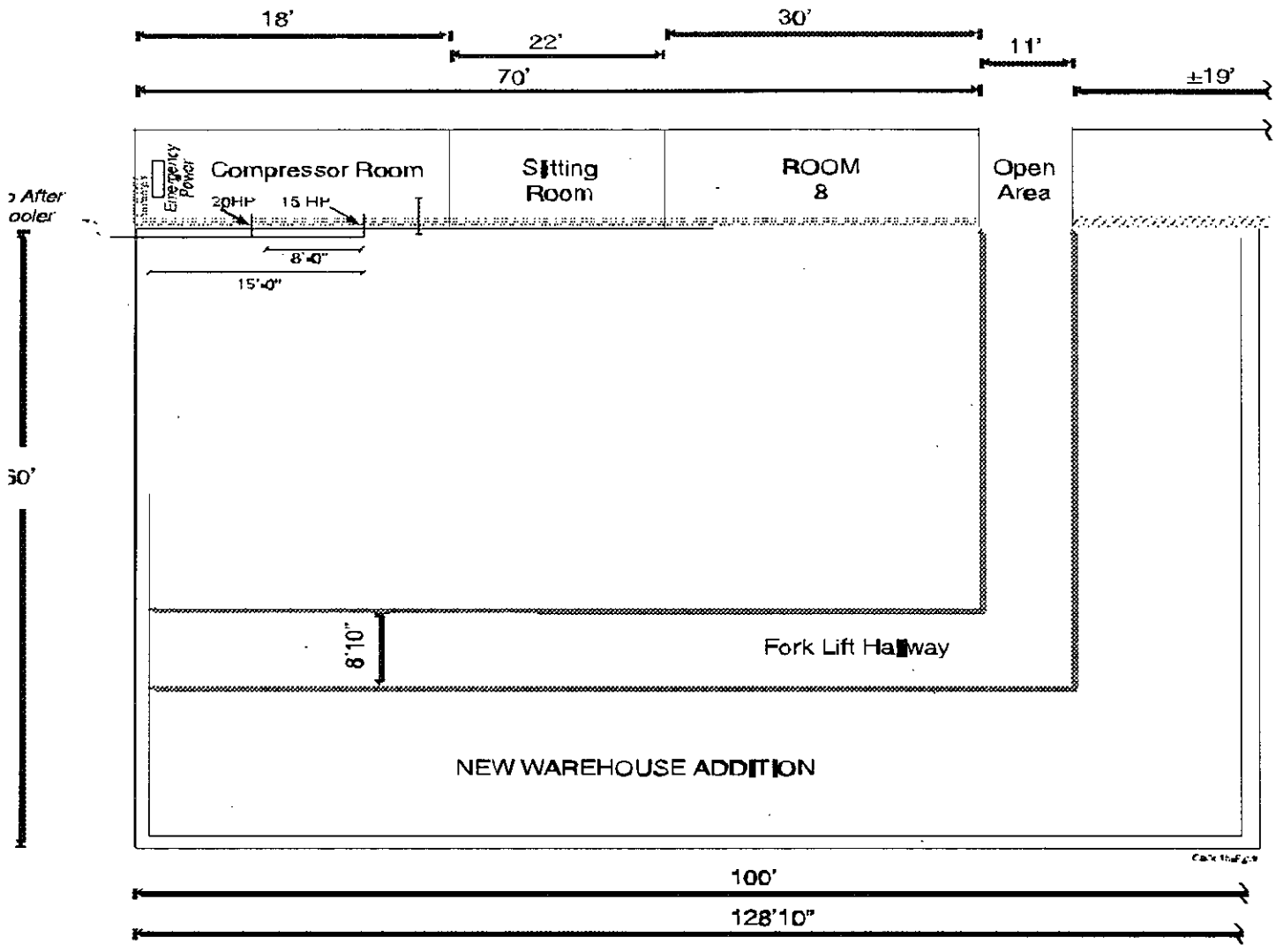

FIGURE 2: NEW WAREHOUSE ADDITION COMPRESSOR SYSTEM

NOT TO SCALE

in which the incident occurred, had a 100' x 150' main area, a 16' x 34' loading dock, and two 50' x 60' satellite buildings connected to the main area by breezeways. In October 1995, a warehouse addition was added to the Unit Two building. It shared the southern wall of the original building (referred to as the new warehouse addition north wall). The addition was approximately 7800 square feet. It was also constructed of corrugated metal with the exception of the outside eastern wall. This particular area had two stories with an exterior (eastern) wall constructed of cinder blocks.

Repackaging operations in the Unit Two building required the use of two reciprocating air compressors. The compressors were located in the southern portion of the original building. The compressors' discharge pipes went through the new warehouse addition's north wall into a common header pipe (Figure 2). This header pipe was fifteen feet long and 5'11" from the concrete pad floor. It ran parallel to the north wall to meet an after-cooler outside the new addition's west wall. The output from the after-cooler was piped back along the same wall 3'7" from the concrete floor carrying the cooled air back to the accumulator tanks under each compressor (Figures 3 and 4).

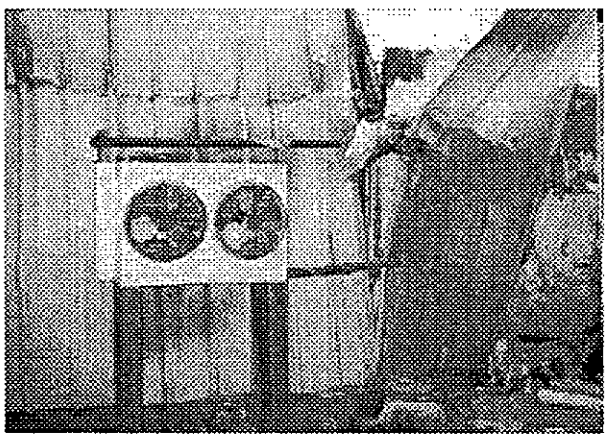

Figure 3. After-cooler

Figure 4. Compressor Discharge Pipe After the Incident

1.3 Chemicals in the New Warehouse Addition

The inventory information used by emergency responders during the response action was based mostly on BPS' management recollection. The Agency of Toxic Substances and Disease Registry (ATSDR) developed a table during the response action based on employee interviews (After Action Report, BPS Pesticide Fire, ERSAB, ATSDR, August 4, 1997). Several weeks after the incident, BPS provided to JCAIT information regarding the type and quantities of the chemicals stored in the Unit Two building the day of the incident. Based on the BPS inventory

information and witness statements, the JCAIT determined that the following chemicals were present in the Unit Two new warehouse addition at the time of the incident: Maneb 75DF, Azinphos methyl (AZM) 50W, Alliette Signature WDG, Topsin WSB, Sevin 80 WSP, and Penncozeb 75DF. Material Safety Data Sheets (MSDSs) for Maneb 75DF, Azinphos methyl (AZM) 50W, and Alliette Signature WDG are included in Appendix A.

2.0 Description of the Incident

2.1 Sequence of Events

December 1995- May 7, 1997

In December 1995, BPS provided MicroFlow Company (MFC) a quotation to repackage bulk AZM 50W into 1 lb. water soluble bags. BPS was to provide warehousing for a two-week supply of materials being repackaged and two weeks prior to and following repackaging. As part of the contract arrangement, BPS requested MFC to do a presentation to BPS workers and managers on safety and health issues related to worker exposure and handling of the AZM 50W. The request was based on AZM's toxicity. The presentation was to be delivered prior to the repackaging operation.

On January 29, 1996, BPS sent a letter to MFC expressing concern about the reactivity/flammability of AZM 50W. Their concern originated through a conversation with a representative of Bayer Agricultural Division. Bayer noted that it had experienced a number of incidents involving thermal decomposition and/or fires involving Guthion (Bayer's AZM formulation). The letter stated that many of Bayer's fires were initiated in ribbon blenders and transfer screws similar to those used at BPS. BPS noted in its letter that the Material Safety Data Sheet (MSDS) provided by MFC did not have information to support a similar situation. BPS questioned why the MSDS provided by MFC did not contain information similar to Bayer's MSDS on Guthion for flammability and reactivity. MFC's MSDS (of January1995) had a Hazardous Materials Incident System (HMIS) flammability and reactivity rating of 0 compared to Bayer's National Fire Protection Association (NFPA) rating of 2. BPS requested MFC's advice since they "have little experience dealing with reactive materials and depend on our customers to inform us of any problems inherent in their materials" (letter from BPS to MFC January 29, 1996).

MFC and BPS personnel met on February 8, 1996, to discuss the suitability of the BPS packaging equipment and the apparent inconsistency on the AZM 50W fire and reactivity hazards. As a result, BPS proposed to construct a water deluge system to accommodate a potential smoldering of the product. The parties agreed on a system that would run water lines to the repackaging hopper, with valves located by the packaging room's door. In case of a "bad odor" while running the equipment, the operator was supposed to flood the hopper with water.

At BPS's request, MFC made a safety presentation on February 12, 1996 to BPS workers

and managers. The presentation included product background, toxicity, safe work practices, and fire/reactivity issues.

On February 13, 1996, MFC sent a follow-up memo by telefax to BPS. It states that "...AZM 50W will begin to smolder and smoke at approximately 170 degrees Fahrenheit. This temperature is consistent with the 167 degrees listed on our MSDS." In the same memo, MFC stated that they were in the process of locating a sample of Guthion 50W to test and that they would update BPS with any new findings. At the time of the incident MFC had not given any additional information to BPS.

The MSDS for AZM 50W provided by MFC to BPS did not reference any 167^0 F (75^0 C) temperature. MFC used a 90% pure AZM technical grade as the AZM 50W active ingredient. The technical grade supplier has a 158^0 F (70^0 C) temperature in their MSDS "conditions to avoid" section.

May 7, 1997: Tifton, Georgia, MicroFlow Warehouse

MFC had made arrangements to ship two truckloads of AZM 50W to BPS from Tifton, Georgia on May 7, 1997 via Milan Express. Each truckload contained 26 bulk bags (supersacks) with approximately1600 pounds of AZM each. These supersacks are constructed of woven polypropylene coated fabric and have a 45 cubic foot capacity. The supersacks on both trucks had AZM 50W from batches produced from 10/96 to 4/97.

Prior to his arrival to Tifton, the first truck driver picked up the truck in South Bend, Indiana. Then, he picked up plastic lawn mower parts in Elgin, Illinois and delivered them to Macon, Georgia. At 2:45 p.m., MFC personnel started loading AZM 50W onto the first truck. Upon completing the loading, truck driver one left the Tifton warehouse at 3:45 p.m.

At 5:00 p.m. MFC personnel started loading the second AZM 50W truck. Truck driver two had not hauled pesticides before. At 6:30 p.m., the second truck loaded with AZM 50W left Tifton, Georgia bound for BPS.

May 7 - 8, 1997: Road

Truck driver one pulled over and rested for two hours at Wyona, Missouri. He stated that the AZM 50W odor was making him feel sick. He transported AZM 50W a year earlier from the MFC plant located in Macon, Georgia. He stated that the AZM 50W smell was similar to the previous truck load. The smell had made him feel sick both times, but this particular time it "really got him."

Truck driver two stopped for an eight-hour rest in route to BPS. He stated that he could smell the cargo from outside the truck. The AZM 50W smelled bad to him but did not make him feel sick.

May 8, 1997 : BPS, West Helena, Arkansas

Before the 10:00 a.m. work break

Truck driver one arrived at BPS, Unit One at 7:20 a.m. He was received by a BPS employee who directed him to Unit Two. Once in Unit Two, truck driver one broke the truck seal at 8:00 a.m. The truck was not unloaded immediately because the fork lift operators were unloading Procure empty drums. The Procure truck was unloaded by 9:55 a.m.

From 10:00 a.m. break to lunch break (11:55 a.m.)

BPS fork lift drivers began unloading the first truck after the 10:00 a.m. break. They had to move other material in the new warehouse addition (empty cardboard and drums) to make space for the incoming AZM. According to BPS forklift drivers the cargo was located along the new warehouse's north wall on a two row/double stack arrangement. They also stated that AZM pallets were spotted approximately six inches from the north wall.

While unloading, fork lift drivers and nearby employees noticed and made comments about the strong odor. They reported that the AZM in the first truck smelled worse than the AZM in the second truck and the AZM repackaged at BPS one year earlier.

A fork lift driver reported a spill in the new warehouse addition right after the 10:00 a.m. break. Twenty to thirty pounds of Alliette Signature had leaked from the top pallet of a previously patched supersack which had reopened. The spill reportedly occurred next to the new warehouse addition north wall, near some empty drums on the west side. The BPS waste monitor began to clean the spill up around 11:30 a.m. He used a forklift to move the top pallet of Alliette and took it to the stretch wrap area. He then took the waste to room seven for disposal.

The second AZM truck arrived at 11:30 a.m., when the first truck had only two pallets left to unload. BPS employees finished unloading the first truck close to lunch time. The first truck pulled away from the loading dock. Another truck, reportedly carrying cardboard, pulled in and stayed at the loading dock for approximately ten minutes. In the meantime, forklift drivers started stacking two rows of "other" product to the north wall of the new warehouse addition. After the cardboard truck pulled out, the second truck pulled into the loading dock. Truck driver two broke the truck seal but one of the fork lift operators told him that the unloading would begin after the lunch break.

Lunch break (11:55 a.m.-12:25 p.m.)

All work activities, with the exception of the spill cleanup, stopped during the lunch break. The BPS waste monitor completed the Alliette Signature spill clean-up around 12:20 p.m. He called the shift supervisor to check on the spill clean-up.

Truck driver one was dispatched to Grenada, Missouri and left the site before the explosion.

After lunch break (12:45 p.m.)

The forklift supervisor returned from lunch, then went back to the slitting room to wrap a pallet. He was the first person to see the smoke. He described it as "a yellow powder puffing through the hole" around the compressor header pipes. He reported that the smoke (or powder) was coming from the new warehouse addition through the hole and forming in the air, not dropping to the floor. He also stated that the powder had the same smell as the AZM that had been unloaded earlier. He did not see fire but called "fire" on the radio at what he thought was approximately 12:50p.m. He grabbed a fire extinguisher and went to rooms eight, nine, and ten to get people out. He then looked back to the compressor area and saw a large cloud of what appeared to be powder. He tried to go into the warehouse area but the powder was too dense. Another employee was in the warehouse with an extinguisher. Neither employee used his fire extinguisher; they left the unused fire extinguishers in the warehouse and evacuated. In the meantime, the shift foreman called "Code Red" and the evacuation process continued. Most employees reported seeing yellowish smoke. Others reported the smoke color to be lime green. All the employees reported seeing the smoke coming from the new warehouse addition area where the AZM had just been placed or through the wall holes around the compressor pipes into the slitting room. Employees also reported a rotten egg/skunk odor.

The production manager called 911. The West Helena Fire Department (WHFD) received first notification at 1:02 p.m. According to the 911 call transcription, BPS reported a small smoldering fire with no flames. The production manager stated: "is where some product was set next to a hot line off an air compressor. It's starting a little bit of a smother, but no fire. But it's a lot of smoke." The caller also referred to a 1,500 pound supersack. A second notification, to the Helena Fire Department, was received at 1:09 p.m.

Three maintenance employees went to Unit Two after the radio fire call. All of them reported seeing smoke coming through the holes around the compressor header pipes. They described it as light yellow close to the roof and thick grey/tan near the floor. One of the employees turned the exhaust fans on. Reportedly, this employee thought that "one of the supersacks of MicroFlow's was leaning against the pipes." The other employee went to the electrical panels (the electrical panel was adjacent to the compressors room on the way to the breeze way leading to satellite one) and turned the compressors off.

During the evacuation of Unit Two, truck driver two observed yellow "stuff" coming out of the back of the building. One of the fork lift operators told him that there was fire close to some pipes. Without having unloaded any product, he closed the doors to the truck and pulled his rig away from the loading dock, taking it across the street.

The shift foreman took a roll call and one employee was missing. A fire truck arrived at

1:15 p.m., just after the first roll call. The firefighters stated they thought yellow product was coming from the building. The WH Fire Chief arrived shortly after the fire truck. One of the firefighters received an MSDS from a BPS employee. He checked the Department of Transportation (DOT) Hazardous Materials Booklet and noted that one of the products on site was water-reactive. The production manager discussed the products' reactivity with the WH Fire Chief. He gave the Fire Chief a binder with the MSDS and a floor plan. The WHFD department called volunteers, other emergency services, and the Helena Fire Department for backup. After consulting with the WH Fire Chief, the maintenance manager closed the three roll-up doors to the loading dock and satellites one and two.

Several BPS employees went to satellite one to locate the missing employee. He was located upstairs in the reclaim area and escorted out. A second roll call took place and all employees were accounted for.

The WH Fire Chief and the maintenance supervisor discussed the smoke location. The Fire Chief observed that the "smoke" looked more like powder or product and that it was seeping instead of puffing. The maintenance supervisor unlocked and opened a side door on the east side of the new warehouse addition for a firefighter, but the yellow smoke was too thick for the firefighter to enter.

The firefighter reported back to the WH Fire Chief. The WH Fire Chief asked the production manager to show him the building layout to check the location of the smoldering supersack. The WH Fire Chief then asked about the danger of an explosion and the BPS President said there was none.

The four firefighters walked back toward Unit One to get a lifeline. They returned to the Unit Two building close to the room 9 exterior wall (east wall). A bell started to ring inside the building, and the maintenance supervisor explained to the firefighters that the sprinkler system alarm had just gone off. The maintenance supervisor then observed water coming from the sprinkler alarm on the east exterior wall indicating that the sprinkler system had in fact been activated. At 1:34 p.m. the alarm company received a fire notification. (The on-site activation of the sprinkler system sends an electronic notification simultaneously to the alarm company.) The maintenance supervisor asked the firefighters to wait for him to turn the power off before entering the building because the equipment was still energized.

The maintenance supervisor went to the exterior office door by the north side of Unit One to attempt to disconnect the power to the building. The disconnect power box was located in an interior hallway between the office and the maintenance shop. He entered the office and proceeded to the door leading to the hallway. Suspecting fire, he felt the door and found it hot to the touch. He cracked the door and observed that the shop area was full of smoke. He determined that he could not reach the disconnect box safely and retreated. He notified the WH Fire Chief that he was unsuccessful in disconnecting the power to the building.

An electrical company's service man had an appointment with a nearby facility. He saw the police and firemen and went directly to BPS. He tried to get in the building by the office door, but felt heat on the walls and decided to turn the power off from the main power cutouts outside near the transformer. He observed yellowish dust or smoke coming out of the vents. The main power cut consisted of three individual legs. The service man pulled the first leg. As he was getting ready to pull the second leg, an explosion occurred. A firefighter reported seeing a mushroom cloud at the east side of the building. Another firefighter reported hearing a wuff sound "like throwing gasoline on a fire," at the same time he saw a massive fireball coming from the building. The explosion caused the cinder block wall to collapse. The four firefighters standing east of room 9 were struck by the collapsing wall. Three of them were killed and the remaining one was seriously injured.

At the time of the explosion, the WHFD received a call from the New Jersey Bartlo Packaging chemist. The fireman reported that the chemist asked whether the sprinkler system had activated and explained to the firefighter that two different types of chemicals were present at the site. According to the firefighter, the chemist said the chemicals would explode if water was put on them.

At 1:39 p.m. the alarm company was notified of the explosion.

2.2 Emergency Response Actions

BPS Emergency Preplanning

BPS was an active member of the Local Emergency Planning Committee (LEPC). BPS had a written "Emergency Response and Contingency Plan" dated September 1995. They had made arrangements with the WHFD for emergency support and had provided copies of their written plan and MSDSs. BPS had also invited the fire department to tour their facility and to participate in their emergency drills. A West Helena firefighter stated that fire department personnel had toured the facility approximately one month before the incident.

According to BPS employees, the facility had several fire extinguishers but they were to be used only on non-chemical fires. Employees were instructed not to fight chemical fires but to immediately evacuate the building. The Unit Two building reportedly had a fire alarm system which was backed up with radios and intercom. Safety meetings covered evacuation routes. A floor plan showing the evacuation routes was posted on the wall.

Initial Response

Upon being called to the site, the West Helena Fire Chief called in all volunteers and off duty personnel. He also called the Helena Fire Department, the emergency medical services, the State Police, and the Phillips County Office of Emergency Services. This office notified the State Office of Emergency Services, schools and radio stations in accordance with the County and

LEPC Plan.

At the time of the explosion, the Helena Fire department had just arrived. The priority immediately after the explosion was to rescue the injured firefighters and control the fire. Both fire departments retreated from the fire after rescuing the only survivor from the reconnaissance team. Police and emergency medical services also arrived on scene. Several firefighters were treated on-site because of minor injuries and heat exhaustion. The fire chiefs issued an initial evacuation order downwind of the smoke plume, including the Helena Medical Center, and called the West Memphis HazMat team.

At 3:00 p.m. the West Memphis HazMat team arrived at the site to support fire fighting efforts. They provided the first air monitoring equipment. Due to the extreme toxicity of the chemicals involved and changing wind conditions, the evacuation was extended to a three-mile radius area. Most of the Helena Medical Center patients were taken to a community college and others to a hospital in Clarksdale Mississippi. Residents of West Helena and nearby Helena were sheltered in place. A twenty-mile section of the Mississippi river was closed to river traffic due to the prevailing winds at the time of the incident,.

Response Actions Under the Incident Command System

At 2:06 p.m. the National Response Center notified EPA Region 6 of the fire and explosion at BPS Inc. The initial notification had no information regarding fatalities, injuries or evacuations. At 5:00 p.m., EPA received a second notification indicating that the incident was out of control and requesting federal assistance. EPA Region 6 dispatched two On-Scene Coordinators (OSC) and activated the Regional Response Team (RRT). Other federal groups joined EPA in the response action. DOD's Pine Bluff Arsenal provided atropine and real time air sampling equipment. The atropine was intended to be used as an antidote for AZM exposure of responders and community members.

The RRT contacted several chemical companies for scientific and technical support. Among other companies, Mobay Chemical, DuPont, Bayer, Rhone Poulenc, and Elf Atochem sent representatives to the site to voluntarily assist in the response action. DuPont also deployed its HazMat team to provide emergency response support.

Response organizations continued air monitoring to determine if the plume contained dangerous levels of toxins. Based on wind conditions and monitoring results the evacuation was downgraded to stand-by status. Local authorities allowed evacuees in the two-mile radius return to their homes.

On May 9, 1997, the Incident Command System (ICS) was officially implemented. Numerous Federal, State, and Local agencies and organizations provided support within the ICS, including US EPA, US ARMY, Arkansas State Police, Office of Emergency Services, West

Helena/Helena/ West Memphis Fire Departments, OSHA, US Alcohol, Tobacco, and Fire Arms (ATF), Center for Disease Control, ATSDR, NFPA, DuPont, BPS, and others.

The EPA On-Scene Coordinator directed the response through the ICS operations. As more information regarding the quantity and nature of the chemicals involved in the fire became available, the fire was allowed to burn with minimal active fire fighting efforts. This decision was made based on the potential water reactivity of the burning chemicals and the concern that incomplete combustion products could be more harmful than those generated by complete combustion.

By May 14, 1997, Maneb was the primary chemical still burning at the facility. Maneb is air reactive and water reactive. After several unsuccessful efforts to extinguish the fire, emergency responders decided to spread the Maneb into thin layers and then to fog it with water. This strategy was chosen based on information provided by Rhone Poulenc on a similar incident in Brazil. All fire zones were extinguished and the site was downgraded from emergency response. After inspection on May 15, 1997, the Arkansas State Police released the site from crime scene status.

The EPA OSC opened the site for the JCAIT to take samples and document the scene before the clean up activities could begin. The JCAIT coordinated site documentation, sample planning, and sample collection with all the on-scene investigative parties. Once the JCAIT completed sample collection, the EPA OSC released the site for cleanup. The BPS contractor began cleanup operations under EPA's oversight on May 22, 1997.

2.3 Public Health and Environmental Issues

Several response organizations, including EPA, Arkansas Department of Health, Mississippi Department of Environmental Quality, and the BPS contractor performed air monitoring. This information was used to determine whether the plume could present a threat to public health or the environment. Chemical companies provided technical assistance on decomposition products and monitoring devices.

The Arkansas Department of Health requested on-site assistance from ATSDR to address the following public health issues: 1) acceptable exposure levels, 2) hospital reoccupation, 3) decontamination of business and residences, and 4) consumption of exposed food products.

On-site use of atropine was limited to one firefighter who exhibited exposure symptoms. Reportedly, this firefighter was not wearing respiratory protection. Approximately 400 people reported symptoms consistent with short term exposure to pesticides. Thirteen of those cases were referred for blood tests. These blood tests were reported as normal.

The Arkansas Department of Pollution Control and Ecology collected point of entry water

samples from the community water system wells. The impact was found to be minimal because runoff from fire fighting efforts was contained on-site and no drinking water wells were in the vicinity of the facility.

ATSDR's after action report concluded that no long-term public health effects were expected from the fire and explosion at BPS. This conclusion was based on the toxicology of the chemicals involved and the maximum contaminant levels detected in and around the businesses and residences.

3.0 Investigation and Analysis

3.1 Investigation

Members of the JCAIT interviewed BPS personnel and other individuals potentially having knowledge about the incident. The JCAIT also requested documents from the facility, documented the scene, and collected samples. Once the initial field activities were completed, the JCAIT identified two distinct problem areas: the existence of a combustible atmosphere in the new warehouse addition and the resulting three firefighter fatalities.

The primary focus of the JCAIT investigation is on the events leading to the creation of the combustible atmosphere. Therefore, most of the initial investigation activities were conducted to support the root cause analysis of this particular problem. The JCAIT acknowledged that other investigation groups, such as the NFPA and the U.S. Fire Administration (USFA), were addressing the three fatalities. It is not the intention of this report to duplicate the work performed by these groups. Instead, this report looks at general areas in the emergency response system that could have contributed to the firefighters' fatalities.

The JCAIT did not attempt to analyze the explosion dynamics. Given the presence of a combustible atmosphere, any source of ignition had the potential to initiate the explosion. However, the most likely source of ignition was the arc(s) created in the facility equipment when the electrical company service man began disconnecting the power to the facility. The JCAIT did attempt to identify the explosion origination point and the source of the combustible material in the air as relevant to the immediate cause. The investigation team used witness statements, photo-documentation of the area, and laboratory analysis in this process. The process required several iterations of analytical work. Some of the laboratory results are not discussed directly in this report because they were either inconclusive (did not confirm or disprove a conjecture) or did not include any detectable contaminants levels. Summary reports on laboratory analyses are included in Appendix B.

3.2 Analysis

3. 2. A Overview of Explosion Scenarios

BPS did not have standard operating procedures (SOPs) for material storage and handling. The general practice at the facility was to store materials in the warehouse as space was made available. There were no established methods to ensure segregation of incompatible materials or protection of stored materials from factors that could cause accidental releases, ignition or reaction of ignitible or reactive materials. According to the BPS Unit Two forklift supervisor, he was not instructed to tell forklift operators where to spot materials in the warehouse. The fork lift operators were supposed to find an "empty spot" to locate incoming materials. There was no attempt to determine the material's hazard classification and/or incompatibilities.

BPS conducted a hazard review before agreeing to repackage any product. The written procedure required going through a check list before beginning a repackaging operation. The hazard review did not address chemical handling and storage. There was no systematic review of factors that could potentially affect warehousing of hazardous chemicals. For example, in October 1995, BPS added the warehouse area to the Unit Two building. The compressors' discharge pipe was modified to pass through the new warehouse addition's north wall and take a 90-degree elbow turn to meet the outside after-cooler. This modification resulted in a fifteen foot long discharge header pipe running at a height of 6 feet inside the pesticide storage area. No assessment of the potential risks associated with this change was performed.

The incident occurred in early May, which is a peak production month for BPS as the agricultural industry begins to prepare and place orders for various products for their growing season. The morning of the event, forklift operators had to move materials around in the new warehouse to make room for off-loading Procure and AZM. During the investigation, through interviews of forklift operators and supervisors, investigators attempted to identify where materials were spotted in the warehouse. The different accounts regarding what was located in the storage area and where it was located indicated that there was no system in place to manage the storage of the various materials at the facility. This lack of an inventory management system, storage SOPs, and a system to review potential hazards of changes in the facility could have led to a number of warehouse incidents.

All witnesses agree that the smoke originated near the warehouse addition's north wall, close to the compressor header pipe. Witnesses, including the fire fighters, also reported the presence of "product" or "powder" in addition to smoke in this area. This suggest the presence of a hybrid dust/vapor mixture. The JCAIT found no visible crater for the explosion, which is consistent with a dust/vapor explosion. The explosion of an airborne flammable vapor or dust could occur at any location where a flammable concentration has accumulated. This could be at some distance from the source of the dust/vapor mixture. Presumably, the fan located on the southwest side of the building could have drawn the hybrid mixture in that direction, affecting also the direction of the blast. In any case, the explosion origination point is not necessarily the

location of the flammable material source. The source of the flammable material will be discussed in the scenario analysis.

Based on an event and causal factor diagram, analytical results, and professional judgment, the JCAIT identified the following scenarios in the development of the combustible atmosphere that led to the explosion:

- Chemical inside supersack decomposes when placed close to the compressor header pipe
- Decomposition of AZM 50W begins before arriving at BPS
- Incompatible chemicals react
- Malfunctioning compressor overheats a supersack

The JCAIT concluded that a supersack placed close or against the compressor header pipe was the most likely scenario. Several of the chemicals stored in the new warehouse addition at the time of the incident can decompose thermally while in contact with a surface within the temperature range of the compressor header. However, the JCAIT concluded that AZM 50W had a greater probability to initiate the event. It should be noted that most incidents are the result of multiple factors rather than a single cause. The JCAIT did not rule out the possibility that the AZM 50W placed close to the compressor pipe was already decomposing before arriving at the facility. Following an initial decomposition of the AZM 50W, the Maneb adjacent to it could have also been involved in the subsequent explosion. The explosion cause scenarios are discussed below.

Scenario 1: Chemical in Supersack Decomposes when Placed Close to the Compressor Header Pipe

Critical to the development of this scenario was the need to determine if a supersack was actually placed against the pipe, which chemicals were most likely to have been placed in such proximity, and whether the compressor pipe could reach temperatures high enough to cause the chemical to decompose.

Compressor Discharge Temperature

At the time of the incident, BPS personnel stated that the surface temperature in the pipe was approximately 145^0 F (63^0 C). In order to confirm this statement and determine the potential involvement of the compressor in the incident, the JCAIT conducted a series of activities. First, the team inspected and documented the compressor system conditions after the event. Observations from this inspection were supplemented with interviews with BPS employees and management and the compressor manufacturer.

Second, the JCAIT conducted a forensic analysis of the compressors and estimated the anticipated temperatures in the discharge pipe's system. The analysis is presented in a report dated August 20, 1997 and referenced as DNV Project No. 232-8384, *Insecticide Warehouse*

Explosion Investigation. The summary report is included in Appendix B.

Finally, the JCAIT participated in a simulation conducted by MFC at Tifton Industrial Controls in Tifton, Georgia on May 15, 1998. The simulation intended to measure a range of temperatures in a compressor system re-constructed to simulate BPS operations at the time of the event.

Of particular interest was the surface temperature of the common header pipe at the approximate point were the supersacks could have been spotted. MFC, with the concurrence of OSHA and EPA, developed a testing protocol to provide and connect two compressors to simulate the BPS conditions. The compressors were connected under EPA and OSHA oversight. The JCAIT measured the piping surface temperature at several locations and under different conditions (insulated vs non-insulated).

A summary of the findings is presented below:

- The piping configuration between the compressors and the after-cooler included approximately twenty feet of discharge piping and two short radius turns.

- Discussions held with the manufacturer of the two compressors used at BPS indicated that there are a number of factors which can affect the compressor discharge temperature such as ambient temperature and discharge pressure. However, under normal operating conditions the maximum discharge air temperature of the compressors at the cylinder head would be expected to be in the range of 300^0 to 350^0 F (149^0 - 177^0 C).

- JCAIT estimated that the discharge temperature on a compressor system like the one used at BPS would be approximately 350^0 F (177^0 C). The associated external pipe temperature would be 280^0 F (138^0 C). If the pipe is engulfed by an insulating type material, such as a supersack, the pipe would be expected to attain the same temperature as the discharge air. See DNV Project No. 232-8384 in Appendix B.

- During the MFC's Tifton simulation, the team measured the non-insulated pipe temperature at the distance where the supersack could have been in contact with the header pipe. Once equilibrium was reached, the surface temperature at that point was approximately 255^0 F (124^0 C). The group then wrapped a two foot section of the pipe with a fibrous glass insulation to roughly simulate the effect of a supersack against the pipe. The temperature increased from 255^0 to 301^0 F (124^0 to 149^0 C) in less than 30 minutes. The maximum insulated header temperature in the simulation was 336^0 F (169^0 C).

The JCAIT also reviewed technical literature, including the compressor operator's manual, to determine how the BPS compressor system compares with industry practices:

- The *Operator's Manual* for the Model 460 Compressor, Overheating Section, states that the piping to the after-cooler location should be as short as possible, preferably no more than three feet. For runs over three feet, the pipe size should be increased by one pipe size for each eight foot run.

- The *Compressed Air and Gas Handbook*, published by the Compressed Air and Gas Institute, states that the discharge piping, i.e., the piping between the compressor and the after-cooler, the after-cooler separator, and the air receiver, should be as short and direct as possible and should use "long-radius" elbows where bends are necessary.

- The American Society of Mechanical Engineers (ASME B19.1 - 1995) *Safety Standards for Air Compressor Systems*, Section 2.1.8. High Temperature states, "External surfaces subject to temperatures in excess of 175^0 F (80^0 C) which personnel may have contact, shall be guarded or insulated."

The JCAIT concluded that the common header pipe connected to the two-compressor discharges was in fact substantially higher than the 145^0 F (63^0 C) estimated by BPS employees and management. From the above results, the JCAIT estimates that the discharge header in the warehouse could have been in excess of 300^0 F (149^0 C).

Chemical Location

Shortly after the incident, BPS employees and management identified the decomposing material as an AZM supersack placed against or close to the hot compressor discharge pipe. The JCAIT confirmed that supersacks of materials were being spotted in close proximity or against walls at BPS. After the incident, JCAIT observed supersacks spotted along the wall in the Unit One warehouse. In this case, the supersacks were stacked two-high. The edge of the bottom supersack was within inches of the wall. The top supersack was listing so that it was in contact with the wall (Figure 5).

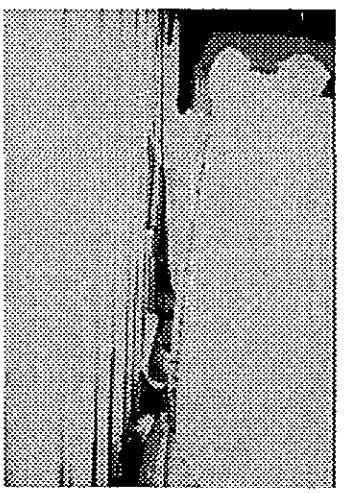

Figure 5. Supersack set-up at BPS Unit One

Several of the chemicals stored in the new warehouse addition at the time of the incident had the potential to decompose thermally while in contact with the hot compressor pipe. The JCAIT collected bulk samples of the combusted residue where the explosion occurred, attempting to determine the exact location of each chemical pallet. The analysis of these samples was of limited use due to the total destruction of the area and combustion of the sampled material (Figure 6). The collection and analysis of samples was supplemented with the analysis of other physical evidence and witnesses' statements.

Figure 6. Aerial Photo BPS Unit Two

Based on witness interviews, the JCAIT identified the approximate location of the chemicals in the warehouse area (Figure 7). Even though witness accounts are somewhat conflicting regarding the quantity and approximate location of the stored chemicals, most statements agree that AZM supersacks had just been placed next to the compressor piping. Witnesses also agree that the yellow smoke or powder was coming from this location. Forklift operators recollect placing Maneb pallets by the compressor pipe in an attempt to make room for the incoming AZM. In addition to the witness statements the JCAIT:

- Screened the bulk residue samples for various pesticides including AZM, Maneb, Topsin, and Sevin. Only semi-quantitative values of AZM and Maneb were reported.

- Secured and analyzed the remains of the new warehouse addition ventilation fans which had visible yellow residue (Figure 8). AZM and its major decomposition products were confirmed.

The JCAIT concluded that it was highly probable that pallets of both AZM and Maneb were placed along the compressor pipe the day of the event.

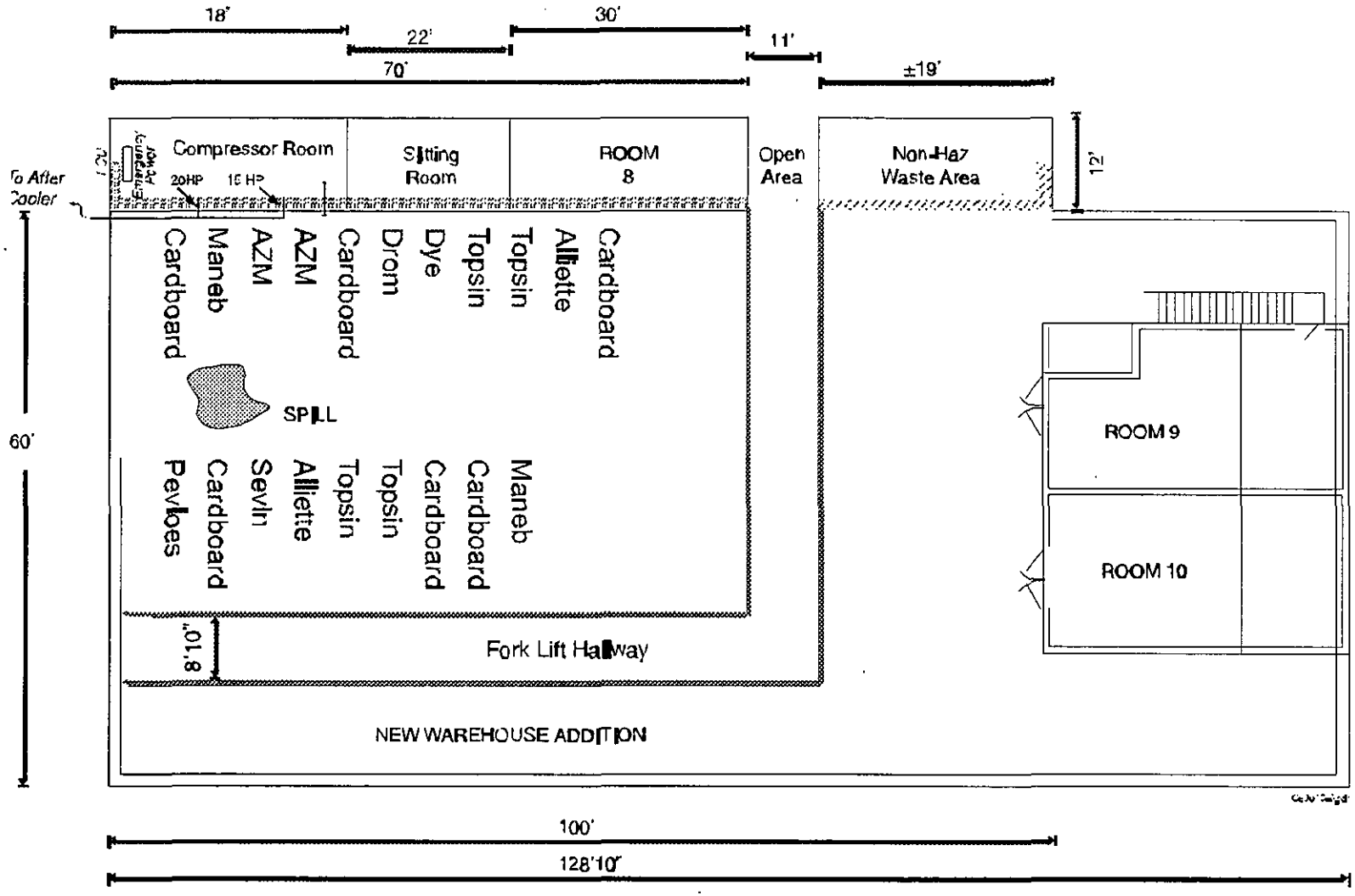

FIGURE 7: APPROXIMATE LOCATION OF CHEMICALS IN THE NEW WAREHOUSE ADDITION.

NOT TO SCALE

Figure 8. Ventilation Fan with Yellow Residue

AZM and Maneb Thermal Decomposition

Both AZM and Maneb can decompose thermally if they are exposed to elevated temperatures during a period of time.

Maneb is classified by the Department of Transportation (DOT) for transportation purposes as an "Spontaneously Combustible Material" unless it is stabilized. If it is stabilized, Maneb is classified as a "Dangerous When Wet Material." This classification includes materials that evolve flammable gas when in contact with water. Maneb presumably falls in this category because of formation of carbon disulfide. According to the MSDS, the Maneb at BPS was stabilized.

Data related to AZM decomposition temperature is rather conflicting. MSDS do not identify AZM as flammable and most literature provides a decomposition temperature of 320^0 F (160^0 C).

The JCAIT requested representative samples from the manufacturers of AZM 50W and Maneb 75DF to conduct several thermal stability tests including decomposition temperature and color changes associated with temperature. The JCAIT also conducted Differential Scanning Calorimetry (DSC) tests on other AZM formulations, including the 90% pure technical formulation used as the active ingredient in AZM 50W. A summary of the tests findings and literature search are presented below:

AZM 50W

- AZM 50W showed visible color change to dark tan at 217^0 F (103^0 C). The sample showed visible smoke at 340^0 F (171^0 C).

- The DSC analysis showed the 90% AZM technical formulation decomposing exothermally (1100 J/g) at approximately 320^0 F (160^0 C). Other formulations, including AZM 50W, decomposed exothermically (600 J/g) at approximately 338^0 F (170^0 C). The smaller amount of heat released by the 50% formulations compared to the 90% pure technical grade is consistent with the addition of inert ingredients.

- A basket test to determine safe storage temperatures for bulk AZM 50W showed decomposition of the sample beginning between 158^0-176^0 F (70^0-80^0 C). The decomposition temperature corresponds to an estimated safe storage temperature of 79^0 F (26^0 C), using a 10% safety factor, based on volume and surface area specifications for supersacks provided by MFC. It should be noted that the test does not predict a safe time interval corresponding to this temperature.

- MFC conducted a twelve month storage stability study in support of registration of its product. The procedure included the use of two 2.5 pound samples. For this test the product was stored at 68^0 F ± 36^0 F (20^0 C ± 2^0 C) for twelve months.

- The *EPA Office of Pesticides' Product Properties Test Guidelines* (OPPTS 830.6317) for pesticide registration requires storage stability tests to be conducted under either of the following conditions: A) At 68 ^{0} or 77^0 F(20^0 C or 25^0 C); B) Under warehouse conditions which reflect the expected storage conditions of the commercial product; C) The test parameters may be expanded to include accelerated conditions, such as elevated temperatures (104^0-129^0 F) (or 40^0-54^0 C) or cold temperature (-20^0-0^0 C).

- In a test to determine whether it would melt, decompose, or the vapor given off would ignite, the AZM sample turned yellowish brown, then black, gave off yellow smoke, and the vapors ignited. A second test confirmed these results.

A study conducted by G. Bertoni and Co-workers; *Lazioni Commerciali in Ambienti Refrigerata,*, Annali di Chimica, 1985, states that "accidental overheating of an AZM mixture may occur during the mixing process and since the active principle melts at low temperatures (m.p.162^0 -165^0 F) (m.p. 72^0-74^0 C) and decomposition begins at a temperature of about 212^0 F (100^0 C), gases and vapors are set free." The study concluded that:

- The product begins decomposition around 100^0 C. As temperature increases an intense exothermic reaction occurs between 338^0 and 356^0 F (170^0 and 180^0 C) with a loss of volatile products of about 40% of the initial weight.

- AZM is a thermally unstable material; a slow process of degradation of the compound occurs below 122^0 F (50^0 C).

- The spontaneous degradation of AZM is noticeably accelerated by any increase of temperature so that attention has to be paid to storage of this product and its commercial forms.

- It is recommended to keep AZM away from any heating. If the temperature rises above 100^0 C decomposition is very fast and at 170^0-180^0 C the product decomposes almost instantaneously.

MANEB 75DF

- The sample of Maneb 75DF showed a black spot beginning at 320^0 F. Visible smoke was observed at 340^0 F (171^0 C).

- Under nitrogen atmosphere, Maneb 75DF did not release a significant amount of energy when heated during the DSC. In the temperature range of 338^0-410^0 F (170^0-210^0 C) the samples heated in nitrogen showed an exothermic reaction followed by an endothermic reaction. The net result under these conditions was a slight absorption of heat with decomposition occurring at approximately 338^0 F (170^0 C).

- Zi-Ru Liu, et al. published a study in *Thermochimica Acta* 220 (1003) 229-235 entitled *Heat Changes Associated with the Thermal Decomposition of Maneb and Zineb.* This study focuses on the heat changes on thermal decomposition of Maneb and Zineb using DSC. It acknowledges that both endothermic and exothermic processes are present in their initial decomposition. The study concludes that the initial decomposition temperature in air is greatly decreased compared with that in nitrogen. The study indicates that the thermal decomposition of Maneb is accelerated and is an exothermic process accelerated in air or oxygen gas.

- The basket test results for Maneb 75DF showed an onset temperature between 221^0-239^0 F (105^0-115^0 C). Using similar procedures as described for AZM, an estimated maximum safe storage temperature of 181^0 F (83^0 C) was calculated for a supersack of Maneb. The test does not predict a safe time interval corresponding to this temperature.

- When tested for melting, decomposition, and evolution of ignitible vapor, Maneb 75DF decomposed into a black material, white vapors evolved from the decomposing sample, the vapors ignited into a yellow/orange flame, and the vapor flame self-sustained several seconds after the removal of the ignition source. In a second test Maneb produced vapors that ignited as a yellow flame; at full decomposition the sample produced white smoke.

As mentioned before, both AZM 50W and Maneb 75DF could have been placed close or

against the compressor header pipe. The test on both substances indicate that decomposition could have occurred at the temperature likely reached by the compressor exhaust pipe, but AZM begins to decompose at a lower temperature than Maneb. Statements provided by most witnesses of the incident describe a yellow smoke or gas which is consistent with what was observed during experimental tests.

The JCAIT concluded that AZM 50W was the material responsible for the initial evolution of the combustible atmosphere. If a supersack of AZM 50W was placed in contact with or in close proximity to the hot compressor pipe, the heat could have initiated its thermal decomposition. The decomposing material would propagate away from the pipe in the direction of the center of the supersack. The contact of the decomposing material with the pipe in this instance would not necessarily be prolonged. The decomposition would be accompanied by the evolution of gas and smoke (the products of decomposition).

AZM's volatile decomposition products, as all organic compounds, evolve flammable constituents upon decomposition. In particular, a literature reference (*Combustion Products from Pesticides and Other Chemical Substances Determine by Use of DIN 53 436*, L. Smith-Hansen and K. Haahr-Jorgensen, *Fire Safety Journal* 23(1994), 51-66), lists six organic combustion products from the decomposition of AZM. The article further states that generally, large numbers of different organic species are formed during decomposition due to incomplete decomposition and partial oxidation. As mentioned before, the flammable gases from decomposition would not have been confined to the immediate area above the supersacks and could have ignited/exploded at some distance from the origination point.

Scenario 2. AZM decomposition begins before arriving to BPS:

The JCAIT postulated as a possible scenario that a thermal decomposition was occurring inside a supersack of AZM 50W before it arrived at BPS. This decomposition could have generated the airborne flammable substances that exploded in the warehouse. The scenario is supported mostly by witness statements concerning the smell of the supersacks that were unloaded the morning of the event. The truck driver reported that the AZM 50W smell had made him feel sick and that he had to stop and rest for that reason. On separate interviews, BPS employees stated that he had made the same remarks to them the morning of the incident. Other BPS employees reported the unusual smell as well.

Chemical powders can undergo smoldering combustion. Hot temperature spots can become entrapped in bulk containers (e.g. a supersack). Smoldering can also occur as a result of self heating when the temperature of a bulk material is raised to a level at which the rate of heat production exceeds the rate of heat loss. In either case, the container and contents can thermally insulate, allowing exothermic reactions to continue at a very slow rate. When the container is disturbed, the reaction can spread and the reaction rate can increase until the self heating reaction reaches the surface. The hot material or its decomposition products may reach temperatures sufficient to burst into flames, especially when disturbed.

Less' *Loss Prevention in the Process Industry*, volume 2; 17.5 explains as follows: "A dust deposit can undergo smoldering for a long period. It is not unknown for large piles to smoulder for a matter of years. Both air access and heat loss are restricted so that combustion is very slow, but is sustained. Such smouldering may give no readily detectable effects. In particular, there may be no smoke or smell from the burning. This delay between ignition and outbreak of flaming can create hazards. Fire may break out unexpectedly in a factory shut down overnight or at a weekend, or the cargo of a ship may be discovered to be on fire when it is unloaded. Hazards of dust fires include those of a dust explosion resulting from the formation and ignition of a dust suspension, of the ignition of other flammable materials and of the evolution of toxic combustion products."

The AZM unloaded at BPS the day of the incident was contained in supersacks approximately1600 pounds of material each. The product had been stored in Tifton, Georgia. NOAA reported a daily average temperature of 76^0 F (24^0 C) for Tifton, GA during the month of April. The maximum temperature reported by NOAA for Helena, Arkansas on May 8, 1997 was 82^0 F (28^0 C).

MFC files show eight minor incidents from 1987-1996. These incidents were associated with AZM 50W smoldering as a result of the material coming in contact with hot surfaces (mostly hot bearings) during production. In those instances, MFC flooded the smoldering product with water. A manufacturer of another AZM formulation reported twelve incidents in the 1960's, five in the 1970's, and seven in the 1980's. All of them involved excessive heating during processing or storage. As stated in previous sections, MFC had discussed with BPS the product's potential for smoldering while in contact with hot bearings. Reportedly, MFC advised BPS to flood production hoppers in the presence of a bad odor during the repackaging operation.

In theory, one of the AZM 50W supersacks could have had a smoldering hot spot as a result of the mixing operations. A smoldering spot in a bulk container could have been in storage without being detected. Sensors normally used in automatic fire protection systems cannot usually detect this kind of condition. This hot spot could have initiated a self heating reaction which accelerated during the unloading at BPS. The smoke or powder was discovered right after the lunch break. There is an approximate 15 minute time span from the time the waste monitor left the new warehouse addition, and the smoke was discovered. After the discovery, the reaction seemed to have continued at an increasingly accelerated rate. An accelerated reaction rate after being disturbed is consistent with industry's experience of smoldering spots insulated by the bulk container.

The scenario, however, is based solely on witness statements. These statements are not consistent. Thermally stable AZM has a very strong and persistent odor. The truck driver and BPS employees were not familiar with AZM. Their statements concerning whether or not this load had a different odor from a previous one are at times contradictory.

The JCAIT inspected the truck several days after the incident looking for evidence of AZM 50W decomposition. Prior to the incident, the truck had transported plastic lawn mower parts. Therefore, there was no potential for the AZM 50W to react with a compound previously transported in the truck. Wipe samples conducted in the truck confirmed only the presence of AZM. Early AZM decomposition products would be in the form of volatile gases and vapors. Since several days had passed since the incident, it was not reasonable to expect positive sampling of volatile compounds.

The JCAIT requested MFC split control samples from the production batches offloaded at BPS. Laboratory analysis showed no signs of thermal decomposition. The fact that the control samples showed no signs of decomposition, however, does not rule out the possibility of a hot spot entrapped in a supersack. In addition, these control samples have been in a controlled environment that could be substantially different from actual storage conditions. Similarly, there is no evidence that the AZM supersacks delivered at BPS were exposed to factors that could induce its thermal decomposition.

The JCAIT concluded that this is a possible scenario but the available evidence is uncertain and cannot substantiate it. However, the team acknowledges that a self heating process could have either initiated the event or accelerated the thermal decomposition of a supersack placed close to a heat source.

Scenario 3. Incompatible Chemicals React

The following pesticides were present in the Unit Two new warehouse addition at the time of the incident: Azinphos methyl 50W, Maneb 75DF, Alliette Signature WDG, Topsin WSB, Sevin 80 WSP, and Penncozeb 75DF. In addition, a spill of twenty to thirty pounds of Alliette Signature was reported next to the new warehouse addition north wall shortly before the incident.

The team reviewed the chemical properties and reactivity of these pesticides to estimate potential hazardous reactions that could have initiated the explosion and subsequent fire. This review is discussed below and summarized in the table at the end of this section. The pesticides present represent the following types of chemicals:

- Carbamate - Topsin and Sevin;
- Dithiocarbamate - Maneb and Penncozeb; and
- Organophosphorus - Azinphos methyl and Alliette.

The analysis showed that none of the pesticides would be expected to be highly reactive with each other under normal conditions. Based on their chemical structures, there would be no reason to expect any of these substances to react with each other if they were accidentally mixed together. The form in which these substances were stored (i.e., solid formulations) and the presence of inert ingredients would make reactions particularly unlikely.

The carbamates and Dithiocarbamate are chemically similar; chemical reactions would not be expected to take place between such similar chemicals. Maneb and Penncozeb (Mancozeb), in particular, are compounds of the same base chemical and are very similar; Maneb is the manganese salt of dithiocarbamic acid, and Penncozeb is a compound of dithiocarbamic acid and both manganese and zinc. Topsin (Thiphanate methyl), a carbamate, is combined in formulations with both Maneb and Mancozeb (*Farm Chemicals Handbook*, 1994), indicating that o reaction takes place when these substances are mixed. There appears to be no reason to expect a reaction between the carbamates Topsin and Sevin (carbaryl), because of their chemical similarity, or between Sevin (carbaryl) and Maneb or Penncozeb, by analogy with Topsin.

Alliette (Fosetyl-aluminum) and Azinphos methyl are Organophosphorus compounds, not carbamates or Dithiocarbamate, but no reaction would be expected upon mixing with carbamates or Dithiocarbamate, based on the chemical structures of these substances. Fosetyl-aluminum is combined in formulations with Mancozeb (*Farm Chemicals Handbook*, 1994), indicating that no reaction would take place between these substances. This type of formulation also provides evidence that Fosetyl-aluminum likely would not react with Maneb, because Maneb is very similar to Mancozeb, and would be expected to react similarly.

Several of the pesticides are reported to be incompatible with strong oxidizers, and it is likely that all of them would react with strong oxidizers under some conditions. No oxidizers were reported to be present, however. Based on this analysis, the JCAIT concluded that the event was not initiated by the Alliette Signature spill or the reaction of incompatible chemicals placed in proximity.

Reactivity and Flammability of Pesticides Present in New Warehouse Addition at BPS

Name	Common Name/Chemical Name/Formula of Active Ingredient	Reactivity and Flammability Data	Potential Reactions with Other Pesticides Present
Azinphos methyl	Azinphos methyl O,O-(Dimethyl S[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)methyl] phosphorodithioate $C_{10}H_{12}N_3O_3PS_2$	Decomposes at elevated temperatures. Hydrolyzed in alkaline and acidic media. Contact with strong oxidizers may cause fires and explosions. Combustible (conflicting data).	None expected.
Topsin	Thiophanate-methyl Dimethyl[(1,2-phenylene)bis (iminocarbonothionyl)]bis(carbamate) $C_{12}H_{14}N_4O_4S_2$	Compatible with other agricultural chemicals that are neither highly alkaline nor contain copper. No data on flammability (probably combustible).	None expected. May be combined in formulations with Maneb and Mancozeb (Penncozeb), indicating no reaction.
Alliette Signature	Fosetyl-aluminum Aluminum tris(O-ethyl phosphonate) $C_6H_{18}AlO_9P_3$	Stable under storage conditions. Incompatible with strong bases, mineral acids, strong oxidizers, strong reducing agents. Non-flammable.	None expected. May be combined in formulations with Mancozeb (Penncozeb), indicating no reaction.
Sevin	Carbaryl 1-Naphthyl -methyl carbamate $C_{12}H_{11}NO_2$	Stable under storage conditions. Incompatible with alkalies and strong acids. Combustible.	None expected.
Maneb	Maneb Manganese ethylenebis(dithiocarbamate) $(C_4H_6MnN_2S_4)_x$	Decomposes on prolonged exposure to air or water. Incompatible with strong acids and strong oxidizers. Classified by DOT as spontaneously combustible or dangerous when wet.	None expected. May be combined in formulations with Thiphanate-methyl (Topsin) and Mancozeb (Penncozeb), indicating no reaction.
Penncozeb	Mancozeb Manganese ethylenebis(dithiocarbamate) complex with zinc ion $(C_4H_6MnN_2S_4)_x(Zn)_y$	Stable under storage conditions. Decomposed in acid and alkaline conditions, by heat, and when exposed to moisture and air. Incompatible with strong acids and strong oxidizers. Compatible with most common pesticides. No data on flammability - probably similar to Maneb.	May be combined in formulations with Thiphanate-methyl (Topsin) and Maneb, and with Fosetyl-aluminum (Alliette) indicating no reaction.

Sources:
Farm Chemicals Handbook '94.Hazardous Substances Databank (HSDB), National Library of Medicine, for Azinphos methyl, Fosetyl-aluminum, Maneb, Mancozeb.
MSDS for Azinphos methyl 50W, Alliette Signature, Sevin, Maneb 75DF, Penncozeb 75DF.
TOMES for carbaryl. Worthing, ed., *The Pesticides Manual* (1987).]

Scenario 4. Malfunctioning Compressor Overheats Supersacks Near the After-cooler Piping

Two multistage reciprocating air compressors were used in the Unit Two building. As stated previously, these compressors discharged into a common header pipe that was located on the warehouse side of the wall, approximately five feet above the deck. This header was 15 feet long and led to an after-cooler outside the building. The 15-hp unit suffered substantial damage during the incident. After the explosion, this unit was found lying on its side with no lubricating oil in the crankcase. The concrete foundation by the compressor had substantial heat damage and spalling in a configuration that suggested a liquid had burned on the surface. The 20-hp unit had only moderate damage, remained in its upright position after the event, and had a substantial amount of oil in the crankcase.

The JCAIT dismantled the 20-hp compressor. The 20-hp compressor did not show any observable internal damage. The JCAIT also performed a forensic analysis of the 15-hp unit to determine whether or not the unit was working properly at the time of the event (DNV Project No. 232-8384). The forensic analysis conducted on the 15-hp compressor showed that:

- The aluminum bell housing for the electric motor and the aluminum header for the first stage had melted away. The melted residue had been deposited on the engine and compressor mount platform immediately below the motor when it was still in the upright position. This indicates that the compressor was exposed to heat before falling on its side.

- The pulley side of the compressor had sustained direct flame impingement heat, but little was observed on the opposite side. The damage areas indicate that an intense fire had been burning on the deck next to the pulley side while the compressor was still upright.

- The connecting rod and journal bearings had not been scored. This indicates that the unit had sufficient lubrication when last run.

- A coke-like residue was inside the crankcase. This indicates that a lubricating oil fire had developed inside. Presumably, it was ignited by a liquid fire on the deck after the compressor fell over. It is also likely that the oil leaked out through the pulley side bearing.

Based on these findings, JCAIT concluded that the 15-hp compressor was not malfunctioning before the event. Therefore, this scenario was discarded by the investigation team.

3. 2. B Overview of Early Emergency Response

There are many factors that could be root causes or could have contributed to the three firefighter fatalities. A formal analysis requires a thorough review of operational parameters and human performance influencing factors including training, competency, pre-planning, policies and procedures, etc. A critique of these factors and the local emergency response activities is outside the scope of this investigation. However, the JCAIT evaluated some general aspects of the emergency response system (related to the BPS explosion) which can foster unsafe situations. By doing this, the JCAIT attempts to promote efforts to provide local emergency response groups with information critical to their safety when responding to chemical incidents.

BPS personnel believed and informed the WHFD that a smoldering "bag" of AZM had initiated the incident. This fact is indicated in witness accounts, the BPS 911 call transcript, and an early press release from the facility management. As a repackaging tolling operator, BPS did not have in-house expertise to test and identify the hazards associated with the chemicals they were handling. Instead, BPS was relying on the chemical manufacturer's information (in this case MFC) to address the chemical hazards. On the other hand, the WHFD relied on BPS to provide them with chemical hazard information.

On-site information

BPS management told the WH Fire Chief that AZM would not explode. Neither the facility personnel nor the documents handed to the fire department conveyed the danger of explosion. The MSDS for AZM used by the BPS personnel and firefighters was provided to BPS by MFC. The MSDS includes the following information concerning the thermal stability and reactivity and flammability hazards of AZM 50W:

- HMIS flammability rating of 0 (non-combustible).
- HMIS reactivity rating of 0.
- Stable under normal conditions.
- High temperatures may cause hazardous vapors.
- Store in cool, dry, well ventilated place. Do not place near heat or open flame.

There is no data on the AZM 50W indicating the possibility of an explosion hazard. It does not include a safe storage temperature or a decomposition temperature. It does, however, warn against placing AZM near heat. The JCAIT reviewed several other MSDS for different AZM formulations, in particular, the MSDS for Bayer's Guthion, which BPS had discussed with MFC. This MSDS includes the following information:

- NFPA flammability rating of 2. (JCAIT Note: An NFPA flammability rating of 2 applies to materials that must be moderately heated or exposed to relatively high ambient conditions before ignition can occur. These materials would not under normal conditions form hazardous atmospheres with air, but under high ambient temperatures or under moderate heating might release vapor in sufficient quantities to produce hazardous atmospheres with air.)
- NFPA reactivity rating of 2. (JCAIT Note: An NFPA reactivity rating of 2 applies to materials that are normally unstable and readily undergo violent chemical change, but are not capable of detonation. It applies to materials that can undergo chemical change with rapid release of energy at normal temperatures and pressures and materials that can undergo violent chemical changes at elevated temperatures and pressures.)
- During routine handling of this material, there should be little risk of dust explosion.

- Stable material. Unstable in sustained temperature above 100 ^{o}F (38^{0} C).

- Storage temperature: 30-day average not to exceed 100 ^{o}F.

- Store in cool, dry area away from heat source.

It should be noted that NFPA 472 *Standard on Professional Competency of Responders to Hazardous Material Incidents*, 1997 edition, Non mandatory Appendix A-21.4 explains that: "Some materials have products of combustion or decomposition that present a significant greater degree of hazard that the inherent physical and toxic properties of the original material. The degree of hazard is dependent on the conditions at the time of the incident".

In addition to the AZM 50W, the WHFD had the DOT's *Emergency Response Guidebook*. In the 1993 edition, Guide Number 55 applies to AZM. In the Fire and Explosion Section, Guide 55 indicates " Some of these materials may burn, but none of them ignites readily. Container may explode violently in heat of fire."

The WH Fire Chief reported during an interview that fire personnel received the following HazMat training; two career firemen (both killed during the event) had 80 hours of technician level training; all fire personnel had training through the awareness level; and other firemen were trained through the technical and operational level. As part of the emergency preparedness program, the WHFD received MSDSs from BPS and had been invited to tour the facility and participate in their emergency response drills. As mentioned before, the fire department had toured the facility one month before the incident.

Training and pre-planning are critical to emergency response groups. Additionally, adequate information is essential for incident-specific risk management. Chemical emergency situations are among the worst work environments for human performance. It is in emergency situations where the human information processing system is burdened with multiple and critical tasks. The information provided to local emergency responders has to be structured and prioritized for this specific use to maximize human performance.

MSDSs are developed to comply with OSHA's Hazard Communication Standard to communicate the hazards posed by chemicals to employees. Additionally, they are extensively used by emergency response groups during chemical releases. The JCAIT looked at the MSDSs present at BPS at the time of the incident from a local emergency response standpoint. The number of MSDSs at BPS do not constitute a statistical representation of the MSDSs developed by the chemical industry. Evaluating the MSDSs present at BPS, the JCAIT found the following:

- MSDSs did not have a standard format. Information relevant or critical during an emergency response operation may not be readily available or may be presented in a confusing format.

- Some MSDSs had a check-box format. In the case of the Maneb MSDS, information was incomplete or conflicting. For example, hazard information stated the chemical was "water reactive." However, the information on firefighting stated "use water." No further explanation on how the firefighting water will interact with the Maneb was provided (e.g. should the firefighters use fog vs a large stream). Similarly, no information was provided related to Maneb being stored in the presence of a water-based sprinkler system.

- Some terms were not clearly explained. In the case of the AZM 50W MSDS, information included in the section "Unusual Fire and Explosion Hazards" stated that the "vapors and fumes from fire are hazardous." The term hazardous does not convey whether the vapors and fumes are toxic, combustible or both.

The JCAIT concluded that the on-site hazard information was conflicting and incomplete. It is critical that fire departments collect as much hazard information as possible within the time, resources, and training limitations. In addition to MSDS, NFPA 472 *Standard on Professional Competency of Responders to Hazardous Material Incidents*, 1997 edition, Appendix A Explanatory Material, identifies other sources of information for hazard identification such as the *North American Emergency Response Guidebook*, hazardous material databases, technical information centers (CHEMTREC/CANUTEC/SETIQ), shipper/manufacturer contacts, and monitoring equipment.

Risk Perception/Risk Management

The WHFD was reviewing MSDSs when the explosion occurred. The firemen that died were close to the building getting ready to enter the building. From witness interviews they were trying to locate the smoldering "bag" in the warehouse.

BPS employees were not aware of any explosion hazards. The employees did not show extreme concerns to the WHFD. The facility personnel conveyed more the need of air-packs due to the toxicity of the chemicals rather than any fire and explosion hazards. The production manager had entered the building several times just before the explosion. He actually closed the building doors (with the fire chief approval) which in effect confined the combustible atmosphere.

The lack of awareness of the potential explosion hazard played an important role in the tactics used by the WHFD. With a better understanding of the potential hazards, the WHFD would presumably have been more cautious. NFPA 1561, *Standard on Fire Department Incident Command System*, Explanatory Appendix A-4-1.2, explains that the risk to fire department personnel is the most important factor to be considered by the incident commander in determining the strategy to be employed in each situation. One of the factors involved in the management of risks levels is the pessimistic evaluation of changing conditions.

NFPA 1561, 4-1.2 states that "The concept of risk management shall be utilized on the basis of the following principles: (a) Activities that represent a significant risk to the safety of personnel shall be limited to situations where there is a potential to save endangered lives; (b) Activities that are routinely employed to protect property shall be recognized as inherent risks to the safety of personnel, and actions shall be taken to avoid these risks; (c) No risk to the safety of personnel shall be acceptable where there is no possibility to save lives or property".

NFPA 1561, A-4-1.3, further explains: "The acceptable level of risk is directly related to the potential to save lives, the risk to fire department personnel must be evaluated in proportion to the ability to save lives, the risk to fire department personnel must be evaluated in proportion to the ability to save property of value. Where there is no ability to save lives or property, there is no justification to expose fire personnel to any avoidable risk, and defensive fire suppression operations are the appropriate strategy."

As stated in the previous section, the on-site information available to the WHFD was conflicting. The AZM 50W MSDS did not state the potential for an explosion hazard. In addition, BPS management may have given the WHFD a false sense of risk when asked about the danger of an explosion. However, chemical warehouses may present unique and unexpected hazards to emergency responders because of unknown combustion products and chemical interactions. In the BPS incident, the building had been evacuated and no lives were threatened. Factoring conflicting information and the unexpected hazards presented in a chemical storing area into the risk management decision process could have helped the emergency responders to develop a safer response strategy.

4.0 Root Causes and Recommendations

4.1 Root Causes and Contributing Factors

Root causes are the underlying prime reasons, such as failure of particular management systems, that allow the faulty design, inadequate training, or deficiencies in maintenance to exist. These, in turn, lead to unsafe acts or conditions which can result in an accident. Contributing factors are reasons that, by themselves, do not lead to the conditions that ultimately caused the event; however, these factors facilitate the occurrence of the event or increase its severity. Although the JCAIT cannot precisely determine the exact cause of this event, there is sufficient information to support several root and contributing causes. The root causes and contributing factors of this event have broad application to a variety of situations and should be considered lessons for industries that conduct similar operations. The JCAIT identified the following root causes and contributing factors of the event:

- **MFC and BPS did not have a full understanding of the hazards associated with AZM.**

EPA's Office of Pesticides requires manufacturers to conduct storage stability tests under one of the following conditions: A) At 20^0 C or 25^0 C; B) Under warehouse conditions which reflect the expected storage conditions of the commercial product; C) The test parameters may be expanded to include accelerated conditions , such as elevated temperatures (or 40^0 C-54^0 C) or cold temperature (-20^0 C-0^0 C). MFC conducted the study at 20^0C $\pm$ 2^0 C for twelve months and a two pound bag. In order to comply with the Office of Pesticides requirements, MFC should have tested for the actual container size (1,600 pounds) and expected storage and transportation temperatures which can be considerably higher than the 20^0C used by MFC in their test.

In addition, the Office of Pesticide Programs requires the use of DSC to test pesticides for explosiveness. DSC is a screening test. For thermally unstable materials, the DSC test does not provide specific enough information to predict safe storage temperatures of large storage or shipping containers.

MFC failed to provide BPS with adequate information on the hazards associated with the chemical. As MFC did not perform adequate testing, hazard information relative to the thermal stability and explosiveness of AZM was not included in the MSDS.

- **BPS did not assess the potential hazards of a hot pipe in an area where hazardous chemicals were to be stored when the new warehouse addition was constructed.**

In October of 1995 BPS added the warehouse area to the Unit Two building. The compressors' discharge pipe was modified to go through the area where hazardous chemicals were stored. A review of the impact of the change should have identified the risks associated with this configuration to workers and/or heat sensitive chemicals.

- **BPS did not have standard operating procedures for material storage and handling**

Standard operating procedures could have prevented BPS from placing a thermally unstable substance next to a heat source, in this case, the compressor header pipe.

- **On-site information provided to the WHFD was conflicting and incomplete.**

The AZM 50W MSDS did not specifically identify an explosion hazard. Generally, chemical hazard information on MSDS is not structured and prioritized for local emergency response use. MSDSs may not have enough information to help emergency responders conduct safe operations and should not be relied upon as the sole source of information during an emergency response. In fact, DOT's *Emergency Response Guidebook* on-site had a warning related to containers exploding violently in the heat of fire. Additional sources of information can help local responders to conduct safer operations.

4.2 Recommendations

The following recommendations were developed by the JCAIT that address the root causes and contributing factors to prevent recurrence or similar incidents at other facilities:

- Manufacturers should be proactive in testing potentially hazardous materials. Testing for actual conditions and elevated temperatures during storage should be conducted to determine safe storage conditions. Screening tests, such as DSC, can be helpful in determining the need for additional testing. However, thermally unstable materials which are intended to be packed and shipped in large volume containers should be tested beyond screening levels.

- Facilities which store, use, handle, manufacture, or move hazardous materials should develop and implement a system to review potential hazards of modifications to facilities, equipment, chemicals, technology, or procedures. The system should analyze potential impacts to safety, health, and the environment and take appropriate actions before the modifications are implemented. OSHA's Process Safety Management (PSM), EPA's Risk Management Program (RMP), and the Center for Chemical Process Safety (CCPS) guidelines can help facilities develop such system.

- Facilities that store hazardous chemicals should develop standard operating procedures for material storage and handling that address storage restrictions. Such facilities should adhere to applicable practices outlined by CCPS and NFPA. Pesticide facilities are encouraged to also follow NFPA 43D (Code for the Storage of Pesticides), specifically the non-mandatory Appendix B.

- Facilities storing hazardous chemicals should develop an inventory management system with information regarding composition, compatibility, storage, location, and quantity of incoming products. This management system can help the facility comply with storage restrictions and provide emergency responders useful information during a response action.

- EPA and OSHA, in conjunction with interested parties, should facilitate a workshop to make recommendations on how to improve the quality of hazardous materials information available during response actions. The workshop should review appropriate uses of MSDS by local emergency response groups and how to provide these groups information describing the behavior of hazardous materials when they begin to react or decompose and what responders should look for during a chemical emergency.