# A SUMMARY OF THE SIERRA CHEMICAL EXPLOSIVES MANUFACTURING INCIDENT INVESTIGATION

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The United States Chemical Safety and Hazard Investigation Board (CSB) is a congressionally mandated, independent federal agency. Its mission is to improve the safety of workers and the public by preventing or minimizing the effects of industrial chemical incidents. One of the CSB's duties is to conduct field investigations of serious incidents to identify the causes and recommend changes to prevent recurrence.

On January 7, 1998, two explosions in rapid succession destroyed the Sierra Chemical Company Kean Canyon plant near Mustang, Nevada, killing four workers and injuring six others. Because of the loss of life and extensive damage, the CSB sent a team to investigate the explosion in an attempt to understand the causes of the incident. The investigation, which was the first investigation initiated by the CSB, focused on identifying the most probable initiating event and the factors that may have contributed to the incident.

This paper examines the investigative process from a contract investigator's point of view. We present the most credible incident scenarios and a summary of key findings and recommendations. We also present lessons learned from the first of many national investigations by the U.S. CSB.

## INTRODUCTION

For years, even though it had been Congressionally mandated through the Clean Air Act Amendments of 1990, the United States Chemical Safety and Hazard Investigation Board (CSB) languished without funding. Neither the Bush nor Clinton administrations funded the agency because there was little support from the public or industry. Slowly, as regulatory authorities assumed the role of accident investigator, industry and public opinions changed and lobbying efforts resulted in CSB funding effective January 6, 1998.

We recall seeing the news story on January 7 talking about an accident at an explosives plant (Sierra Chemical Company) in Kean Canyon, Nevada. It had happened before – a Nevada explosives plant accident. With the knowledge of the CSB funding, it was therefore not an entire surprise when we received a call on January 8 asking if we could immediately respond to assist the CSB with their first investigation.

Sierra Chemical Company (Sierra) is a privately held, diversified chemical manufacturing company whose products primarily support the mining, municipal, and wastewater industries. The Kean Canyon facility manufactured explosive boosters, mixed custom flux for gold-smelting operations, and repackaged bulk soda ash for sale to the mining industry.

On January 7, 1998, at 7:54 a.m., two explosions killed four workers, injured six others, and destroyed Sierra's Kean Canyon plant, 12 miles east of Reno near Mustang, Nevada. Because of the loss of life and extensive damage, the CSB sent our team to investigate the causes of this incident.

The Kean Canyon plant manufactured explosive boosters for the mining industry. When initiated by a blasting cap or detonation cord, boosters provide the added energy necessary to detonate less sensitive blasting agents or other high explosives. The boosters manufactured at the Kean Canyon plant consisted of a base mix and a second explosive mix, called Pentolite, both of which were poured into cardboard cylinders. The primary explosives used in the base mix were TNT (2,4,6-trinitrotoluene), PETN (pentaerythritol tetranitrate), and Comp-B, a mixture of TNT and RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine). The Pentolite is a mix of TNT and PETN

**PLANT FACILITIES**

Sierra's explosives facilities were located approximately seven miles east of the company headquarters in Sparks, Nevada. The plant was located in Kean Canyon, north of Interstate 80. Sierra also leases land in Kean Canyon to the Frehner Construction Company, which operates an adjacent gravel pit south of the plant. There was one primary access road to the explosives facility, which was controlled by a locked gate. All of the magazines and buildings at the Sierra facility had either key or combination locks. These buildings typically were locked, except when workers required access during the workday.

The plant's facilities were built on a series of terraces as shown in Figure 1. The highest terrace was a storage yard for equipment and materials. The next terrace contained storage tanks for process water and soda ash. Booster production, flux mixing, and soda ash repackaging operations were located in the production building on the third terrace down, approximately ten feet below the previous terrace. A chemistry lab, an employee break room, and a parking area were located on the fourth terrace, which was 18 feet lower than the previous terrace. The PETN building and magazine were located on the fifth terrace, approximately five feet below the previous one, or about 23 feet below Booster Room 2.

The production buildings housing the booster manufacturing, flux, and soda ash operations were constructed over several years as add-ons to an expanding operation. The explosives-manufacturing buildings were constructed of fully grouted, reinforced, 8-inch concrete block. They had asphalt and tar roofs supported by wooden trusses. A pre-fabricated metal building warehoused paper products and finished flux.

Figure 2 shows the various buildings and rooms used in the melt/pour, flux, and soda ash operations. Booster Room 2 was built before 1974 and was refurbished for the melt/pour operation in 1996. For convenience, north is shown to be at the top of Figure 2, perpendicular to the back wall of the production buildings.

Booster Room 2, shown in Figure 3, was approximately 40 feet wide by 40 feet long and had been put into operation about four months prior to the explosions. A platform along the north wall of Booster Room 2 had an 8-inch, reinforced, poured-concrete floor supported by steel I-beams. Workers placed materials in the center of the platform between two independent melt/pour production lines.

Booster Room 2 contained six mixing pots on or beside the four-foot high platform along the north wall. These pots were numbered 1 to 6 from east to west. Pots 1, 2, and 3 were placed in a mirror image of pots 6, 5, and 4, respectively. Pots 1 and 6 had not yet been placed in service. Pots 2 and 5 were used to make the base mix consisting of TNT, Comp-B, and PETN. Pots 3 and 4 were smaller and were used to make Pentolite from PETN and TNT. They were mounted in an I-beam support structure located directly in front of the raised platform. All mixing pots were equipped with gauges that indicated steam jacket temperatures and explosive mixture temperatures to aid operators in controlling the process. Each pot had an exhaust line to carry any dust or vapor from the pots outside through a series of particulate filters. The mixing pots in Booster Room 2 and the location of explosives between the pots is shown in Figure 4.

Pots 1, 2, 5, and 6 were acquired as excess equipment from the Department of Defense. A two-horsepower motor, coupled through a 38:1 gear reducer, drove stainless-steel mechanical mixing blades. The blades on the large pots were attached to a central shaft and curved upward along the inside surface of the pot in an elliptical fashion. The pots were stainless steel with a carbon-steel steam jacket. Two “breaker bars” extended down into the mixing pot to help agitate and break up chunks of material that might be present. Steam provided heat to the pots through the steam jacket and the two breaker bars, and through a jacket on the explosives draw-off line on the bottom of the vessel.

Pots 3 and 4 were purchased from an industrial food-processing supplier. The pots were similar to the other four pots, except they were smaller and constructed of lighter-gauge stainless steel. Stainless-steel stirrers provided agitation. The stirrers had two mixing blades extending parallel to the pot wall from the bottom of a central shaft in the shape of an anchor. Steam heated the water jackets and draw-off lines.

Two pouring tables were used to hold the booster cylinders during the pouring and cooling process. The tables had a fresh-air-supply hood that provided initial cooling for the poured boosters. Finished boosters cooled in bins located south of the pouring tables. Workers boxed the finished boosters and placed them on pallets or finished-product shelves before moving the boxed boosters to outside storage magazines. Paper products were stored on shelves on the south wall.

Booster Rooms 1 and 2 were similar in design and size. Booster Room 1 contained three melting and four mixing pots. Three of the mixing pots were used in the melt/pour operation. Workers used the fourth pot to maintain a liquid supply of Comp-B, one of the ingredients in the melt/pour operation. The three melting pots were used to maintain a supply of liquid TNT. The room also contained a small portable magazine in the northwest corner of the room that was used for PETN storage.

PETN is shipped wet to reduce its sensitivity. The PETN building, where the water was removed from the PETN, was constructed of fully grouted, reinforced, 8-inch concrete block. The reinforced-concrete roof had a skylight over the drying room. The building consisted of three rooms (see Figure 3). One room was a weather room to permit the offloading of material during inclement weather. The second room, called the drip room, was where wet PETN was transferred to canvas bags and spun in a centrifuge to remove water. The last room, called the drying room, was where workers placed de-watered bags of PETN on racks to dry. Adjacent to the PETN building, and connected to it via heating ductwork, was the PETN magazine. The magazine was a skid-mounted steel structure also used for storing the PETN while it was drying. The PETN building and magazine were normally locked.

## INVESTIGATION PROCESS

The CSB investigation team conducted an on-site investigation from January 10, 1998, to February 6, 1998. The scope of the investigation team’s responsibility was to examine and analyze the circumstances of the explosion, to learn what happened, and to attempt to determine the cause of the explosion. The team evaluated the process design and safety management systems to determine their adequacy in controlling the cause of this explosion. The ultimate objective of this investigation was to develop recommendations to help prevent similar incidents.

The team used the following investigation methodology, adapted to address overlapping roles and responsibilities of other agencies investigating this incident. Facts were compiled by examining evidence at the incident site, conducting interviews, and reviewing documentation. To minimize duplication of effort, the team used the information collected by other agencies to the maximum extent practical.

Events and causal-factors charting were used to establish the sequence of events chronologically and show the related conditions. Because there were no survivors from Booster Room 2, the building where the four workers were killed, hypothetical event sequences were developed to test the feasibility of specific initiating events.

An analysis of initiating events was used to evaluate their likelihood. Change analysis was used to identify changes in operations on the day of the incident and differences between operations in Booster Room 1 and Booster Room 2 that could provide an explanation as to why an explosion might occur in Booster Room 2. Barrier analysis was used to identify those missing physical, administrative, and management controls that contributed to the explosion.

## FINDINGS

### EVENT DESCRIPTION

The first explosion occurred at 7:54:03 a.m., and was followed by a second, larger explosion 3.5 seconds later, as recorded by the Seismology Laboratory at the University of Nevada, Reno. The interval between the explosions was estimated by the laboratory to be accurate to ± 0.2 seconds. The CSB investigation team determined that the first explosion occurred in Booster Room 2, the second in the PETN building.

The explosions involved a number of explosive materials, including PETN, Comp-B, TNT, and other explosives purchased through the Department of Defense demilitarization program, such as A-3 and LX-14, used in place of Comp-B. Management estimates of the explosive materials present in the operating facilities at the time of the incident are presented in Figure 5. The total quantities of each explosive ingredient are based on management's estimate of inventory differences following the explosion, compared to the December 31, 1997, inventory, and reconciled to account for shipments made and received. There were 47,000 pounds of unaccounted-for explosives estimated to have been destroyed by the explosions and subsequent fire.

The quantities of explosives reported for each booster room in Figure 5 are management's estimates. Workers estimated that Booster Room 2 contained 7,000 to 8,000 pounds of explosives, rather than the 12,000 pounds estimated by management. Regardless of which estimate of explosives in Booster Room 2 is most accurate, the PETN Building by all accounts contained a greater quantity of explosives, about 15,000 pounds.

### SEQUENCE OF EVENTS

Operators were responsible for the preparation of explosive mixes, the operation of the mixing pots, and pouring mixes into booster cylinders. (See Figure 4 for layout of Booster Room 2.) At 3:00 p.m. on January 6, an operator for the west side of Booster Room 2 left work early, leaving 50 to 100 pounds of melted explosive base mix in pot 5. He mentioned this to the other operator in the room, who later checked and saw the explosives in pot 5.

Explosives manufacturing operations began the next morning, January 7, shortly after 6:00 a.m. in Booster Room 1. Both Booster Rooms 1 and 2 were scheduled to make 227-gram boosters that day. Two teams of two workers each had finished mixing operations for the first batch of the day and were beginning to pour. A fifth worker was also working in Booster Room 1, packing the finished boosters from the previous day.

The operator for the west side of Booster Room 2 arrived at work, and at about 7:30 a.m. visited Booster Room 1 to greet his fellow workers who were pouring boosters. He talked briefly with a Booster Room 1 operator about a pouring pitcher he had returned to that worker's locker in the change room, and then left at about 7:35 a.m. The supervisor arrived at approximately 7:40 to 7:45 a.m., stopped in Booster Room 1 for about 5 minutes, then rode to the nearby gravel pit in a backhoe with another worker.

Besides the operator assigned to the west side of Booster Room 2, there were three other workers in or near Booster Room 2. One of these three, an outside worker, was in the changing room waiting to clock-in at 8:00 a.m. A boxer was packing finished boosters in Booster Room 2, and the last worker was moving materials from storage trailers to the flux room. The suspected locations of the four workers are consistent with the locations of human remains found during the investigation.

When the first explosion occurred, a worker in Booster Room 1 saw a huge fireball engulf a truck, which was parked immediately outside the building. The Booster Room 1 worker was thrown against the west wall, as the ceiling and east wall of the room collapsed on top of him and four other workers. Seconds later, a second, louder explosion occurred. After the explosions, the north, west, and south walls of Booster Room 1 were still standing; however, the rest of the site, including Booster Room 2, was essentially leveled. The site of the PETN building and adjacent magazine was now a 40- by 60-foot crater, which had a depth of as much as six feet. The explosions were felt as far as 20 miles away.

A total of 11 Sierra employees were at the site at the time of the incident. Following the explosions, five workers in Booster Room 1 were trapped temporarily under the collapsed building, but were able to crawl out within a few minutes; three were seriously injured and two received minor injuries.

Concerned about possible additional explosions, the workers from Booster Room 1, after calling for other possible survivors, went to the entrance to the facility. There they met two other workers who had been in the gravel pit below the site, approximately 350 feet southwest of the PETN building. The other four workers who were believed to have been in or near Booster Room 2 had been killed by the explosions.

The blast effects of the explosions leveled the site and threw structural materials, manufacturing equipment, raw materials from the booster and flux operations, and other fragmentation up to 1,000 yards away. Figure 6 shows Booster Room 1 and Figure 7 shows Booster Room 2 following the explosions. The legs and cross bracing from an empty tank, which previously stood at the corner of the change room, were imbedded in a motor home located 900 feet from the production building. The doors of one of the large magazines and a portable magazine located west of the production facility were sprung open by the negative pressure pulse; however, large quantities of explosive materials that were stored inside did not detonate. Many undetonated boosters had been scattered throughout the site by the explosion. Other hazards at this time included fires, toxic chemicals, and potential detonation of the explosives in Booster Room 1 as the fire progressed.

## CAUSES OF THE EVENT

The investigation team determined that the first explosion occurred in the plant’s Booster Room 2 and was followed seconds later by an explosion in the PETN building. There was no physical evidence or eyewitness that could conclusively pinpoint the cause of the explosion in Booster Room 2; however, the team identified four credible scenarios. Based on seismic data, interviews of workers, and the physical evidence observed during the investigation, the team believes the following explanation to be the most probable scenario.

The day before the incident, one melt/pour operator working in Booster Room 2 needed to leave work early. When he left, there were between 50 and 100 pounds of base mix left in his large mixing pot. The mixing pot’s blade extended about two inches into the mix. The following morning, the same operator turned on the motor to the mixing pot in which the mix had stratified and solidified overnight. The bottom of the mixer blade, which was embedded in the solidified explosives in the pot, detonated the explosives by impact, shearing, or friction of the explosive material with the pot wall. Another possibility is that chunks of explosive material were pinched between the mixer blade and the pot wall, causing the detonation.

The explosive shock wave detonated several thousand pounds of explosives in the room that then destroyed the building. A heavy piece of equipment or burning debris from this first blast most likely fell through the reinforced-concrete roof or the skylight of the PETN building, initiating the second explosion 3.5 seconds later.

Root causes of the incident that were identified by the investigation team are outlined below in Table 1.

**Table 1. Causes of the Incident**

| ROOT CAUSES OF INCIDENT | KEY FINDINGS |
|---|---|
| ***Process hazard analysis*** (PHA) conducted by the facility was inadequate. | Supervisors and workers from the Kean Canyon plant were not involved in the process hazard analysis of the operation. The PHA for Booster Room 1 was conducted by company personnel from other locations and did not consider safe siting of buildings or human factors issues. These deficiencies in the PHA program allowed unsafe conditions and practices in the facility to go unrecognized and uncorrected. No PHA was conducted for Booster Room 2. |
| ***Training programs*** for facility personnel were inadequate. | Managers believed that, short of using a blasting cap, it was almost impossible to detonate the explosive materials they used or produced. Worker training was conducted primarily in an ineffective, informal manner that over-relied on use of on-the-job training. Poor management and worker training led to a lack of knowledge of the hazards involved in manufacturing explosives. |
| Written ***operating procedures*** were inadequate or not available to workers. | Personnel primarily relied on experience to perform their jobs. Procedures and other safety information were not available in the language spoken by most workers. Operators routinely made changes in the steps they took in manufacturing explosives. This resulted in the use of inconsistent and hazardous work practices. There were no written procedures for Booster Room 2. |
| There was no systematic ***safety inspection or auditing program***. | Safety walkthrough inspections were unfocused and did not examine process safety management (PSM) program effectiveness, resulting in management being generally unaware of unsafe practices and conditions. |
| The ***employee participation program*** was inadequate. | Employees had not been involved in developing or conducting process safety activities. This resulted in a lack of understanding of process hazards and controls by workers. It also resulted in management not benefiting from the experience and insights of workers. |
| The facility was built with insufficient ***separation distances*** between different operations and the design and construction of buildings was inadequate. | Because unrelated chemical operations were located in the same building as Booster Room 2, an additional fatality and extensive property damage resulted. Close proximity of structures allowed the explosion to spread to a second building. |

 

| CONTRIBUTING CAUSE OF INCIDENT | KEY FINDINGS |
|---|---|
| ***Oversight*** by regulatory organizations was inadequate. | Safety inspections were conducted infrequently and inspectors generally did not have expertise in explosives manufacturing safety. This allowed unsafe conditions at Sierra to go uncorrected. |

Analysis of seismic data recorded by the Seismological Laboratory at the University of Nevada, Reno, on January 7, pinpointed the time between the explosions and their sequence. This seismic data also unambiguously demonstrated that the northern of the two explosions occurred first. Because Booster Room 2 was located north of the PETN building, these findings confirmed the investigation team's determination that the first explosion took place in Booster Room 2.

The Kean Canyon Plant is covered under the Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM) Standard (29 CFR 1910.119). The PSM standard requires that companies using highly hazardous materials have in place an integrated safety management system. The investigation of this incident revealed that many essential elements of process safety management were missing or deficient.

The investigation also determined that reclaimed, demilitarized explosive materials purchased by Sierra from the Department of Defense (DOD) sometimes contained foreign objects. The risk of using contaminated explosive materials was not adequately examined by the company or by the DOD.

## INVESTIGATION RECOMMENDATIONS

### SIERRA CHEMICAL COMPANY AND OTHER EXPLOSIVES MANUFACTURERS

Process Safety Management (PSM) requires both careful planning and implementation. Preventing explosions, as well as preventing the propagation of explosions, requires a clear understanding of explosives safety principles and safe practices. Based on the conditions found at Sierra's Kean Canyon plant, the investigation team recommended that explosives manufacturers evaluate the effectiveness of their explosives safety programs using the following recommendations to ensure that

1. Process hazard analyses include examination of quantity-distance requirements, building design, human factors, incident reports, and lessons learned from explosives manufacturers.

2. Written operating procedures are specific to the process being controlled and address all phases of the operation.

3. Procedures, chemical hazards, and process safety information are communicated in the language(s) understood by personnel involved in manufacturing or handling of explosives.

4. Explosives training and certification programs for workers and line managers provide and require demonstration of a basic understanding of explosives safety principles and job-specific knowledge.

5. Process changes, such as the construction or modification of buildings, or changes in explosive ingredients, equipment, or procedures are analyzed and PSM elements are updated to address these changes.

6. Pre-startup safety reviews are performed to verify operational readiness when changes are made.

7. All elements of OSHA's Process Safety Management Standard are verified by performing periodic assessments and audits of safety programs.

8. The employee participation program effectively includes workers and resolves their safety issues.

9. Explosives safety programs provide an understanding of the hazards and control of detonation sources, including
   - foreign objects in raw materials
   - use of substitute raw materials
   - specific handling requirements for raw materials
   - impact by tools or equipment
   - impingement
   - friction
   - sparking
   - static discharge

10. The following issues are addressed in plant design or modification:
    - Operations in explosives manufacturing plants are separated by adequate intraplant distances to reduce the risk of propagation.
    - Unrelated chemical or industrial operations or facilities are separated from explosives facilities using quantity-distance guidelines.
    - Facilities are designed to reduce secondary fragmentation that could result in the propagation of explosions.

INSTITUTE OF MAKERS OF EXPLOSIVES (IME)

1. Develop and disseminate process and safety training guidelines for personnel involved in the manufacture of explosives that include methods for the demonstration and maintenance of proficiency.

2. Distribute the CSB report on the incident at Sierra to IME member companies.

3. Develop safety guidelines for the screening of reclaimed explosive materials.

NEVADA OCCUPATIONAL SAFETY AND HEALTH ENFORCEMENT SECTION

Increase the frequency of safety inspections of explosives manufacturing facilities due to their potential for catastrophic incidents. (Note: Nevada Governor Bob Miller signed an Executive Order on June 10, 1998, that will require inspections at least twice a year.)

DEPARTMENT OF DEFENSE

1. Develop a program to ensure that reclaimed, demilitarized explosives sold by the Department of Defense are free of foreign materials that can present hazards during subsequent manufacturing of explosives.

2. Provide access to explosives incident reports and lessons learned information to managers and workers involved in explosives manufacturing, associations such as IME, government agencies, and safety researchers.

**CSB ISSUES**

During the Sierra Chemical investigation and subsequent observations of CSB operations, we noted several opportunities for increasing the effectiveness of the Board.

PROCEDURES AND PROTOCOLS

When we arrived on-site for the Kean Canyon investigation, the CSB had few staff. In the process of conducting the investigation, we followed a general process that we had developed for use by other government agencies. During the investigation we adapted these procedures in an *ad hoc* manner to fit the circumstances. This was necessary because the CSB did not have procedures at the initiation of the first investigation. The CSB has continued to rely on the experience of the field investigators since its inception and does not have formal procedures or protocols for conducting investigations.

NEED FOR GREATER INTEGRATION OF INDUSTRIAL EXPERTISE

Most of the CSB investigators come from other government agencies or labor unions. The large investigations conducted by the CSB have been staffed from the national laboratories. The national laboratories have broad resources in management, investigation, and basic science and technology capabilities. However these resources may not have industry-specific experience. Although the CSB has drawn on industry experience, this expertise has generally not been applied in the field during the investigative process. This gap impacts the team's ability to understand industry practices and norms. It also increases the likelihood that the investigators would fail to recognize and understand actions that could have far wider implications than the incident being investigated. This problem is compounded by the lack of policies and procedures to guide development of root cause and lessons learned. An industry expert included in the field investigation team would improve the investigation process.

POLITICS

The CSB, like other investigative agencies, has had to face a serious dilemma in presenting its findings. Incident investigations that have implications on a national level, must not only be correct but must be acceptable to stakeholders in other agencies. A significant number of CSB actions are governed by such political pressures. Incidents chosen for investigation are often the result of requests by different government officials. Staff who prepare official reports are often not part of the investigation. As a result, recommendations and findings can be subject to what is politically expedient rather than what comes from careful consideration by the investigation team.

The Sierra investigation received resistance for our recommendation that the Department of Defense change their procedures to remove contaminants from explosives sold to civilian explosives manufacturers because DOD voiced opposition. It was not until DOD agreed to the recommendation that CSB allowed inclusion of the recommendation in the final report. In other investigations, CSB staff have added recommendations to those made by the investigation team even though they did not address the root causes of the incident. These recommendations were easy to implement. This appeared to be done to demonstrate CSB accomplishment, which is also a political expedient.

There always will be pressure created by the political process. To effectively manage through this pressure, the CSB needs to have clear policy guidance and procedures.

## INSTITUTIONAL BARRIERS

The CSB has a very important mandate; that is, to improve safety and to protect workers and the public. However, in conducting investigations, the CSB team is often at odds with the goals of other agencies and attorneys for the parties involved in the incident. Other agencies and plaintiff attorneys focus on finding fault. Defendant attorneys focus on protecting clients. As a result, questioning by other parties has the potential of biasing witness testimony.

The charter of the CSB was constructed with the intent of protecting the companies from the information that is gathered during a CSB investigation. However, this protection is incomplete because although information in CSB reports cannot be used in a civil law suits, the information, confirmed through other sources, can be used. In addition, there is no protection for parties from the use of CSB information in criminal actions. As a result companies interfacing with the CSB must chose a corporate strategy from somewhere between full open disclosure to full protection against potential legal consequences.

In the "full open disclosure" end of the spectrum, the CSB can readily achieve its mission; however, in the "full protection" mode, the CSB is forced to have higher costs and greater difficulty at arriving at root causes.

These realities jeopardize the quality of the investigation and the ability of the CSB to achieve its primary purpose, that is to objectively identify root causes and lessons learned to prevent recurrence. These issues need to be addressed to ensure the future success of the CSB.

## INTERAGENCY COOPERATION

One of the challenges faced by the CSB is the field involvement of a number of other agencies, each with a common need for information, but with different goals and approaches for achieving those goals. Memoranda of agreement have been established between the CSB and several other federal agencies that have helped to define roles and responsibilities between agencies; however, this process often does not cover state and local agencies. As a result there are in a number of potential jurisdictional issues, such as control of the accident scene, access to information, and public communication that must be resolved during the initial hours of an investigation.

These issues have to be resolved, typically in an *ad hoc* manner and are highly reliant on the interpersonal skills and perceived integrity of the lead investigator and his or her counterpart in the state and local agencies. The CSB has been successful because the field teams have had such leadership and have focused on the ultimate goal of the investigation rather than concerns about prestige, power, and control.

The cooperation that has been achieved during CSB investigations in spite of the need to maintain independence, has been an important factor in the success of the investigation process. Maintaining positive relationships with other organizations has reduced barriers to acceptance to CSB recommendations and as a result, government agencies and industry are willing to act positively to effect change.

 

## CONCLUSIONS

When the CSB investigation team arrived at the Sierra's Kean Canyon site, the CSB was less than one week old. The investigation operated using the general guidelines set forth in the Congressional legislation that established the CSB success. We sifted through the scattered debris and analyzed testimonies of numerous individuals, many of whom had motives far different from CSB's objective of seeking root causes of events, and arrived at what the investigators believe was the most probable sequence of events. The recommendations have spurred both government agencies and the explosives industry to action.

Since its first successful investigation, the CSB has laid the foundation for fulfilling its mandate of improving safety for workers and the public. Critical to its success have been experienced investigators who have maintained a clear focus; the dedicated and capable CSB staff; and its ongoing positive relationships with other organizations.

The CSB has been successful in identifying important issues; however, the importance of its mission demands continuous review of CSB activities and strategic directions to identify ways to improve its effectiveness. Many challenges lay ahead. To meet these challenges and mature as an agency the CSB needs to establish internal policies and procedures. By establishing the policies and protocols associated with conducting investigations and how the Board interacts with outside entities the staff and investigation teams will become more empowered to focus their expertise in conducting investigations and to recommending improvements.

The CSB is at a critical point. If the CSB can overcome the political pressures associated with being a new government agency and firmly establish a clear identity and sense of purpose, it will become a force for pushing chemical facility safety to new heights.

## REFERENCES

1. U.S. Chemical Safety and Hazard Investigation Board, Investigation Report Explosives Manufacturing Incident, Report Number 98-001-1-NV

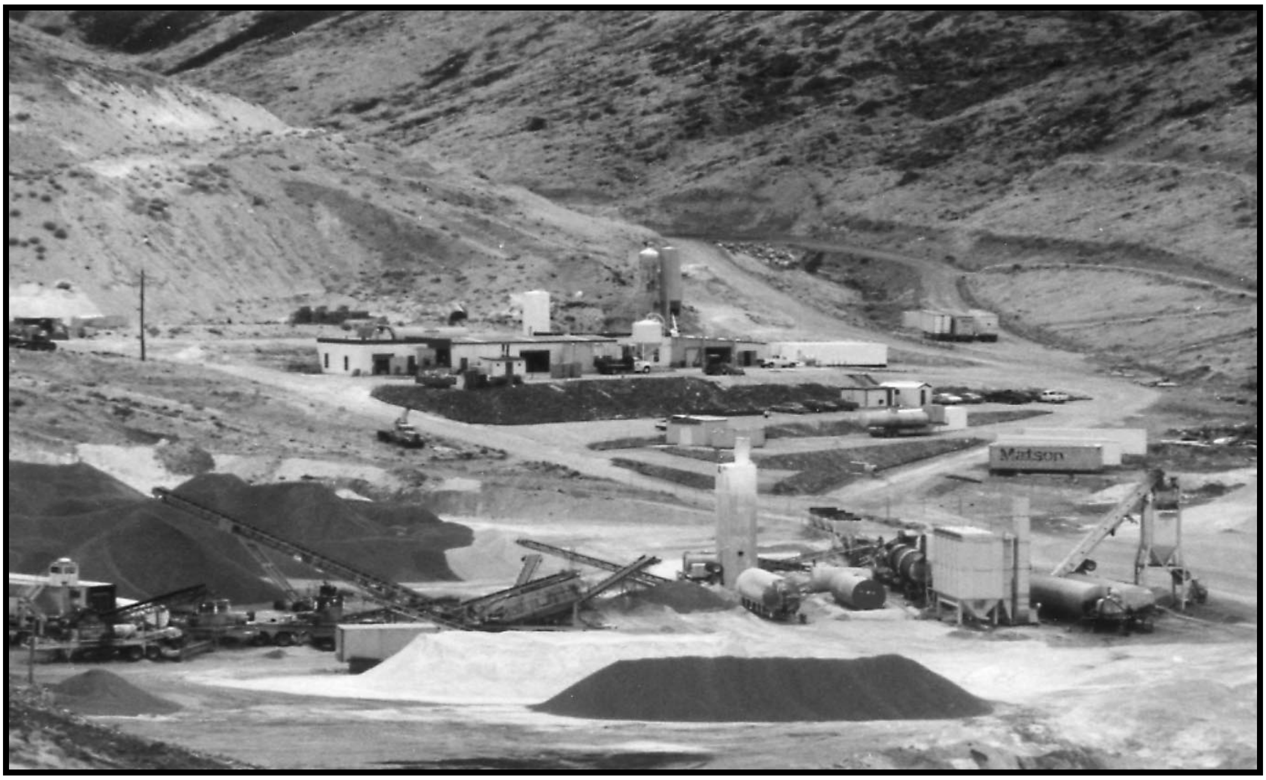

**Figure 1. Kean Canyon Facility**

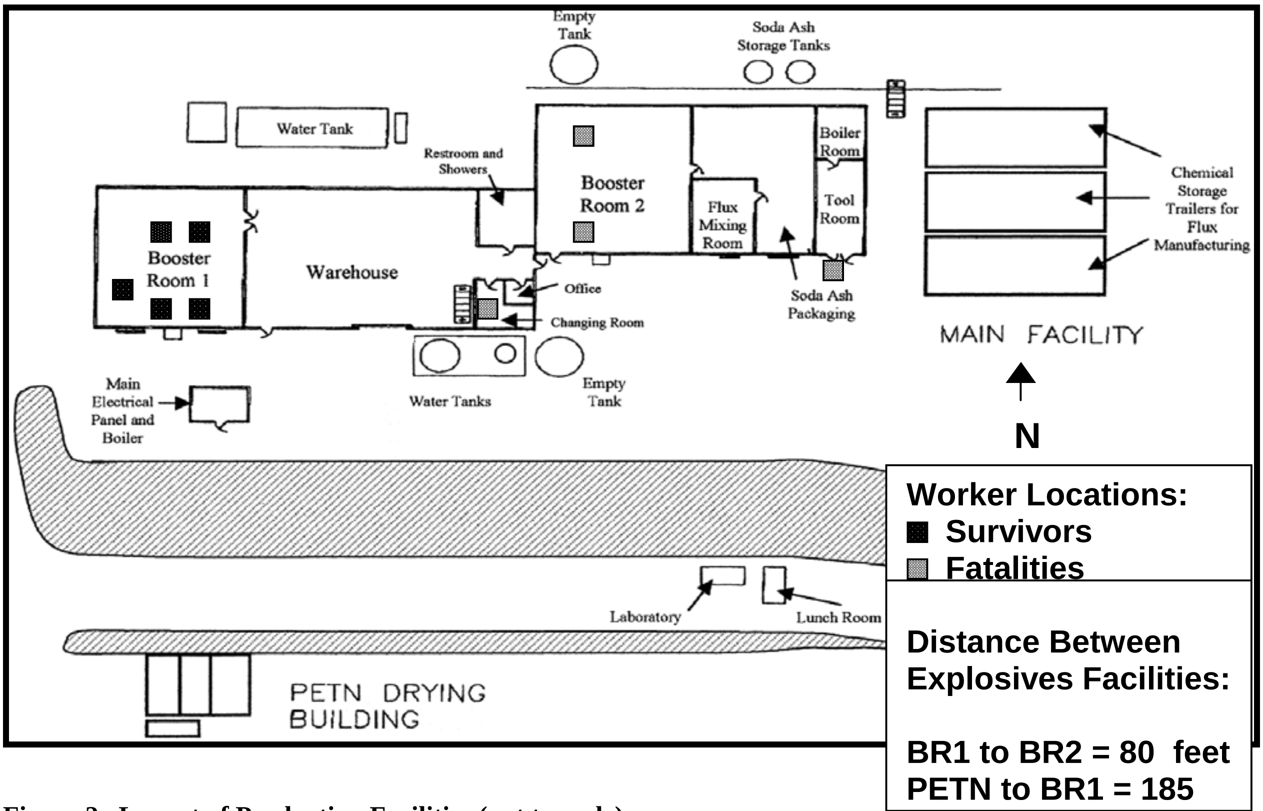


**Figure 2. Layout of Production Facilities (not to scale)**

**Figure 3. Booster Room 2**

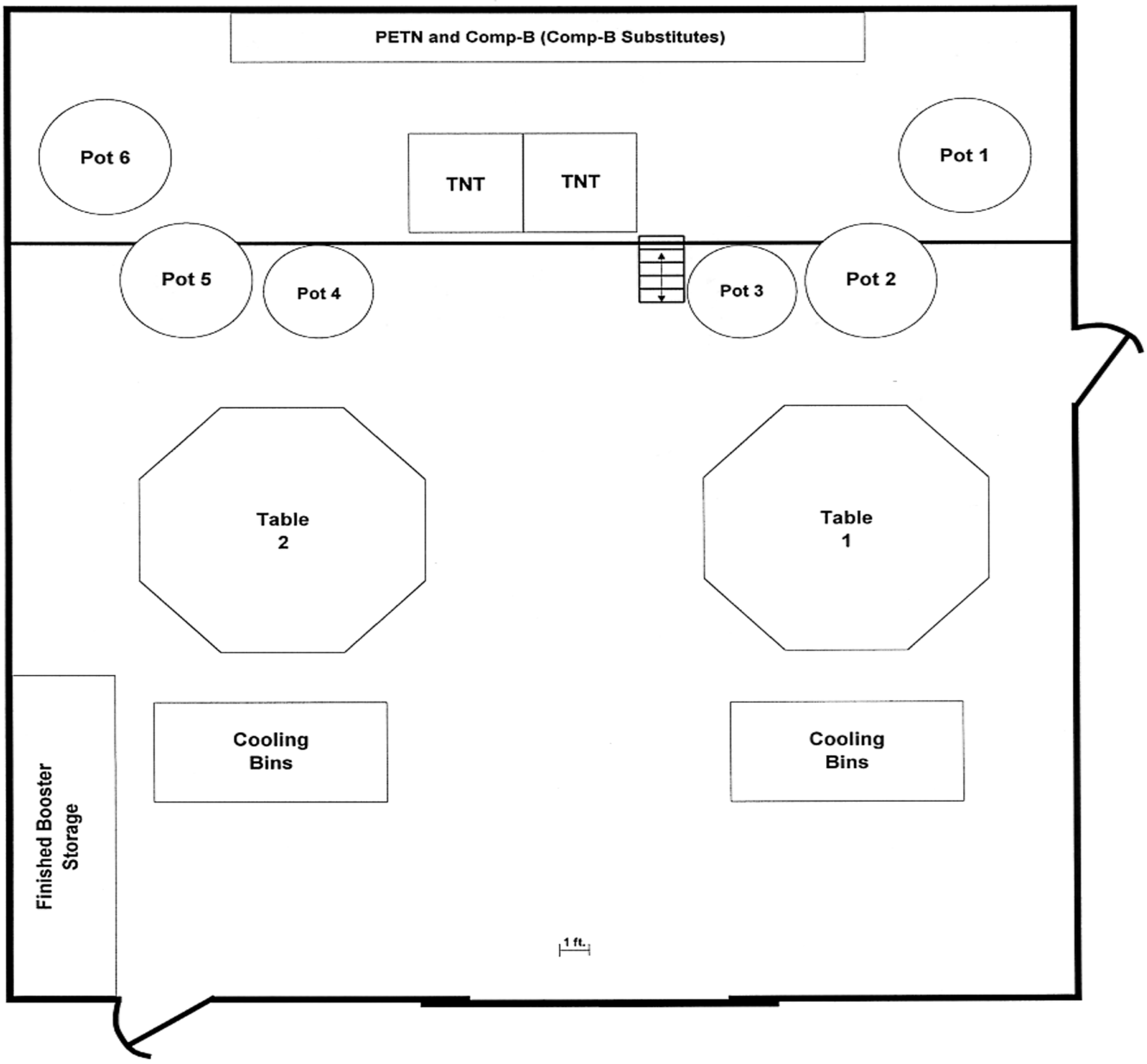


**Figure 4. Booster Room 2 Layout**

| Location | TNT (lbs.) | Comp-B (lbs.) | PETN (lbs.) | Total (lbs.)* |
|---|---|---|---|---|
| Booster Room 1** | 14,000 | 2,000 | 4,000 | 20,000 |
| Booster Room 2 | 9,000 | 2,000 | 1,000 | 12,000 |
| PETN Building and Magazine | | | 15,000 | 15,000 |

*Based on company's estimate and includes the explosive quantities in finished boosters.
**No detonation occurred in this room.

**Figure 5. Estimate of Explosive Materials in Operating Buildings at Time of Incident**

**Figure 6. Booster Room 1 After Explosion**

**Figure 7. Booster Room 2 After Explosion**