U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

Incident in Sierra Chem. Co. 1998

4 fatalities and 6 injuries in booster plant explosions

INVESTIGATION PROCESS

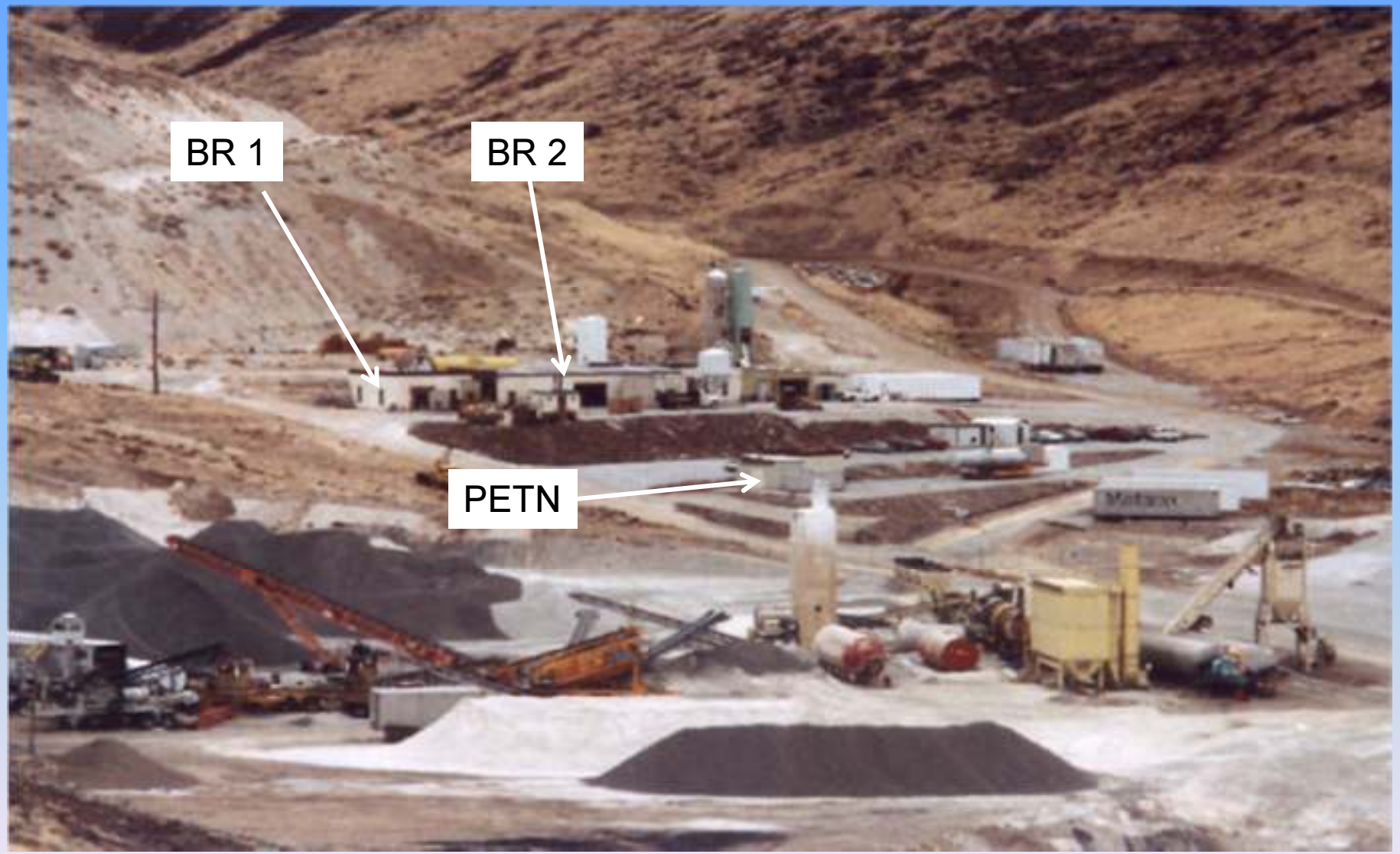
- Scope
  - examine and analyze the circumstances of the explosion,
  - to learn what happened
  - to attempt to determine the cause of the explosion.

- Evaluate the process design and safety management systems to determine their adequacy in controlling the cause of this explosion.

- To develop recommendations to help prevent similar incidents.

Facilities and Process

- Comp B, TNT, PETN(supplied wet) plus other Demil explosives
- PETN dried and stored in separate building
- Steam heated pots
- Electrically powered stirrers
- Bottom discharge
- 2 pouring rooms


BR 1
BR 2
PETN

BR 2

Explosions

- 6 am - plant start up in room 1
- 8am - 4 personnel in or near room 2 for start-up
- First explosion
- Seconds later explosion in PETN building
- 5 personnel trapped in room 1 but survived
- Crater 40x60x6ft where PETN building had been

Figure 8. Booster Room 2 After Explosion

Figure 7. Booster Room 1 After Explosion

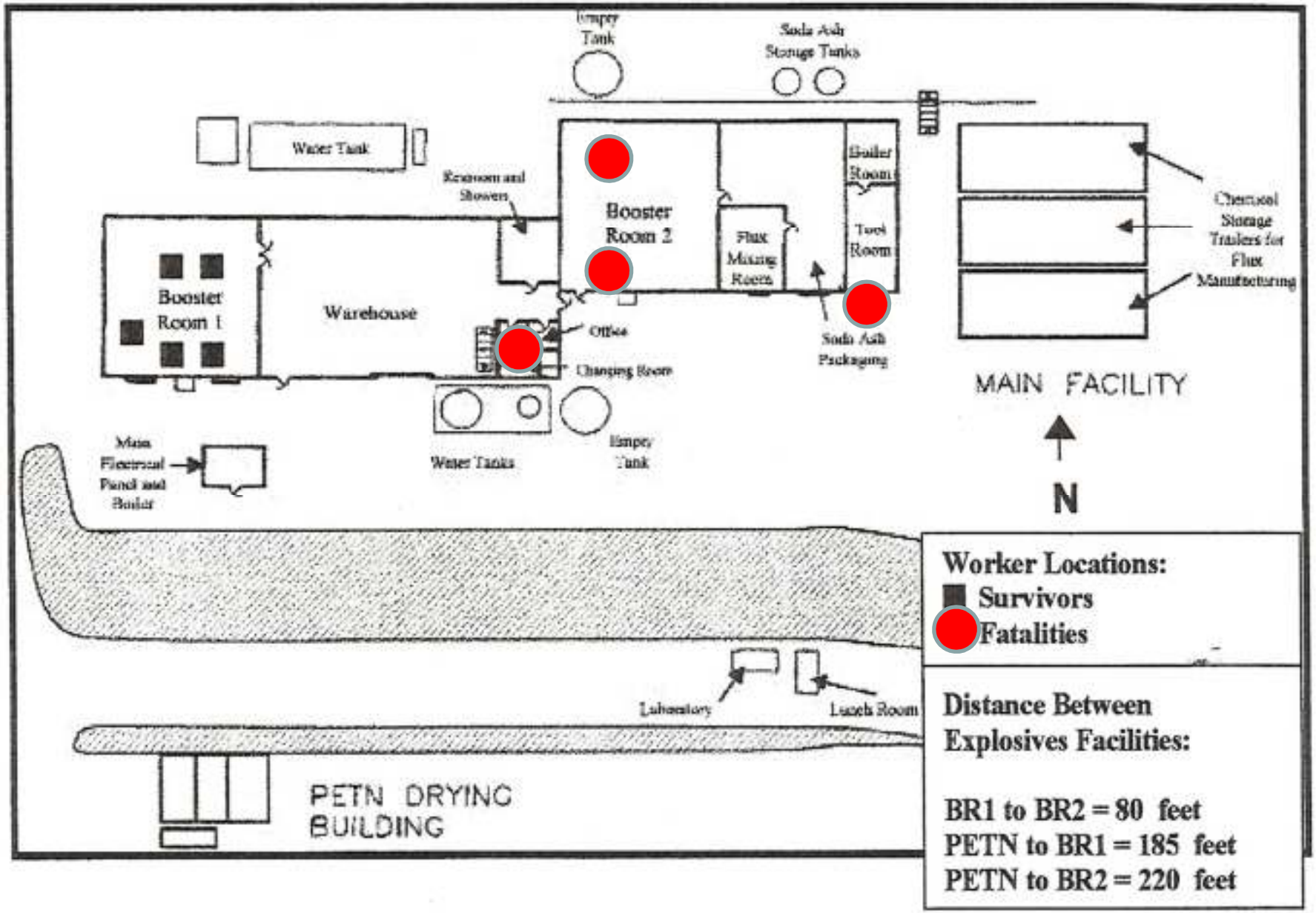


Figure 3. Layout of Production Facilities (not to scale)

Methodology

- Collect the facts by
  - examining evidence at the incident site, conducting interviews, and reviewing documentation
- Establish the sequence of events chronologically and show the related conditions.
- Hypothetical event sequences developed to test the feasibility of specific initiating events.

Methodology - continued

- Analysis of initiating events used to evaluate their likelihood.
- Change analysis used to identify changes in operations on the day of the incident
- Barrier analysis used to identify those missing physical, administrative, and management controls that contributed to the explosion.

Collect the facts

- History of the facility and equipment
- Materials used quality. Quantities etc
- Building construction
- Personnel profiles and roles
- Sequence of events up to time of explosion
- Weather conditions
- Post explosion observations

Sequence of explosions

- Seismological records from 4 stations
- Statements from witnesses
- Debris field
- Equipment and building damage analysis
- First explosion in BR 2, second in PETN building

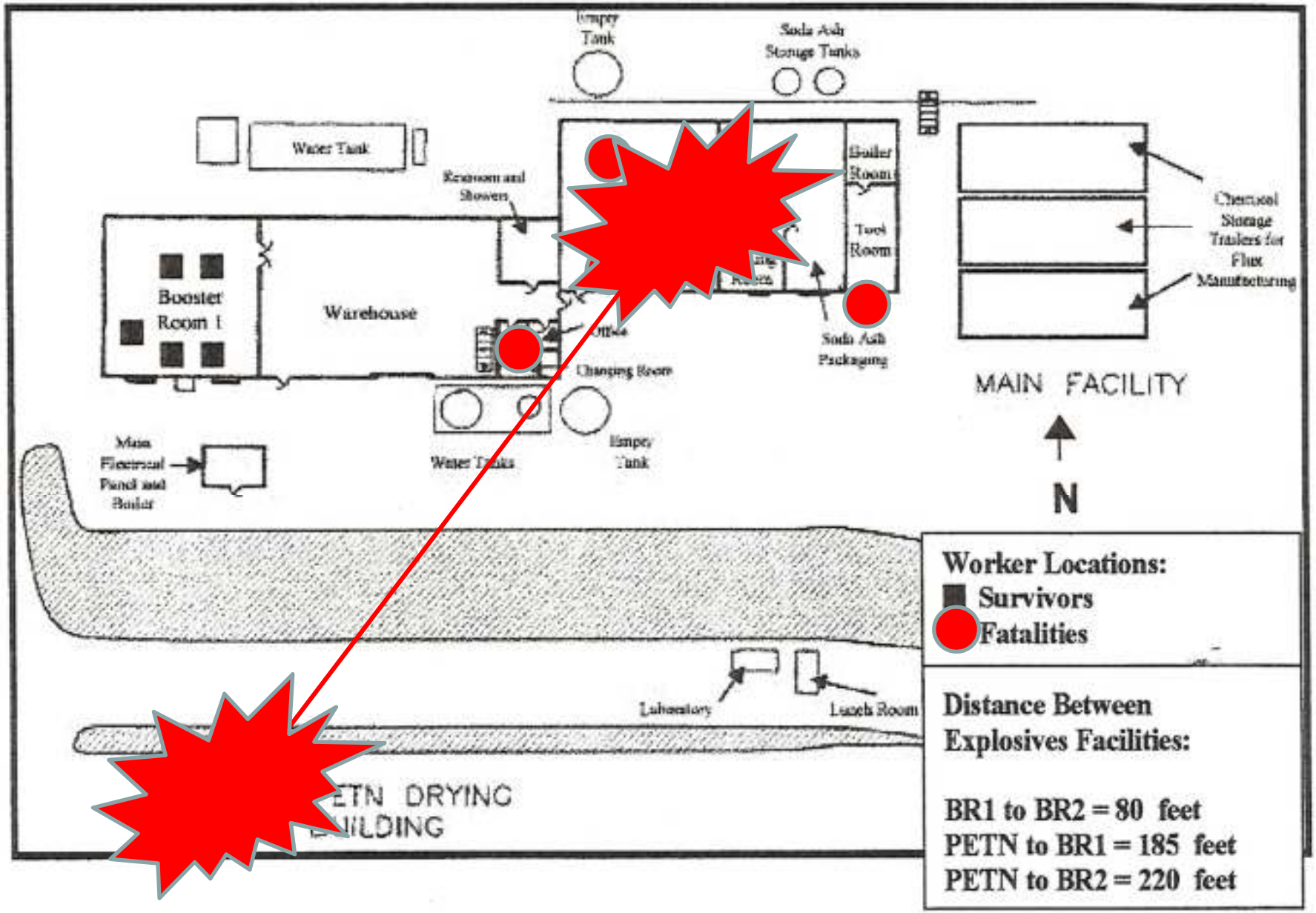


Figure 3. Layout of Production Facilities (not to scale)

Analysis of facts for probable scenario

- Pot was left overnight with 50-100lbs of mix
- Solidified overnight
- Next day operator started stirrer without checking pot.
- Bottom of stirrer initiated the mix by friction, impact or shearing.
- PETN building hit by debris causing second explosion

Other credible scenarios

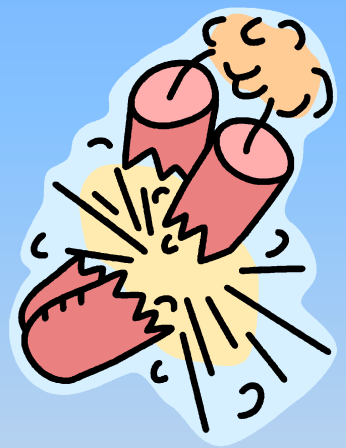
- Dry mixing of PETN
- Breaking of lumps of solid explosive by hammer
- Presence of foreign boby

Change analysis

- 13 changes identified
- Each considered for relevance in the credible scenarios
- Used to support the probable scenario

Barrier analysis

Hazard



Barrier

Target

<u>Administration</u>
- Process Hazard Analysis
- Procedures
- Management of change
- Training

<u>Management</u>
- Direct Supervision
- Management oversight
- Industry and Regulatory oversight

<u>Physical</u>
- Use of Q/D
- Siting requirement
- Facility design to prevent secondary explosion

Start-up procedures

Room 2

- Check pots for material
- Open steam supply
- Turn on mixer motors
- Break up chunks of Comp-B if necessary
- Normally left empty at end of shift

Room 1

- 2 shift so no need to check pots at start of second shift
- Normally left empty at end of second shift

Different procedures for similar operations

Building spacing and construction

- Buildings at Sierra were not located at safe distances from each other in order to prevent the propagation of an explosion from one building to another
- Building construction was inadequate.

Formal findings

- Root causes
  - Hazard study was inadequate
  - Training programmes inadequate
  - OI's inadequate or not available
  - Insufficient safety distances
  - No systematic auditing/inspection programme
  - Employee participation programme inadequate
- Contributing cause
  - Oversight by regulatory organisations inadequate.

Additional observations

- Process changes not systematically evaluated
- Lack of hazards knowledge by employees
- Deficiencies in line-managers knowledge of hazards
- Incident investigation programme in place but employees not aware of it.
- No planned safety audits to determine level of safety programme implementation
- Language problems

Recommendations

- Sierra
  - PHA (hazard studies)
  - Language issues
  - Training in explosives hazards
  - Control of modification
  - Pre-start reviews after changes
  - Audits and safety programmes to verify compliance
  - Employee participation programmes.
  - Employee safety programmes – BOS
  - Q/D requirements
  - Building design to reduce missile effects

- IME
  - Develop and disseminate training guidelines for personnel working with explosives
  - Develop safety guidelines on use of reclaimed explosives
- Dept of Defence
  - Guideline on use of reclaimed explosives
  - Access to incident reports
- Regulator
  - Increase frequency of inspections

Melt/pour Incidents Elsewhere

7/24/16 Clogged draw-off pipe was being cleared with brass rod, which impinged heated Amatol (60/90) against steel pipe, causing detonation.1 Fatality3 Injuries

11/04/18 Foreign material was present in the melt pot due to lack of screening of fresh TNT or reworked Amatol. Approximately 1,200 lbs. of TNT was added to the pot from boxes without screening or examination. About 200 lbs. of scrap Amatol was added directly.64 Fatalities, 100 Injuries

12/12/41 Sublimed TNT crystals in ventilator duct due to high TNT vapor (0.87 mg/m^3) caused the explosion. Sublimed TNT crystals are sensitive to friction, impact, or static spark.13 Fatalities, 53 Injuries

3/4/42 Draw-off valves slamming shut were suspected in detonation of TNT (60-40 Amatol). Also, the exhaustventilation system was clogged by sublimation. The TNT vapor level was 0.80 mg/m^3. 22 Fatalities, 84 Injuries

3/24/45 A hot-water hose with brass nozzle was being forced into a clogged draw-off pipe on a TNT melt unit. Impact or friction caused the explosion. 2 Fatalities

10/8/63 Cyclotol (70% RDX/30%TNT) detonation caused by impingement of explosives with spark-proof hammer and screwdriver while cleaning draw-off lines and Valves. 2 Fatalities

7/25/79 Decomposition of PETN during melting released oxides of nitrogen. Heat was removed but the reaction continued until detonation. Property damage

8/18/89 A clogged draw-off line had been removed from a pot. Pentolite in the line detonated when struck by a nonsparking screwdriver with a rawhide mallet. 2 Fatalities

Why is it a good investigation?

CONTENTS OF REPORT

4.0 ANALYSIS OF CREDIBLE INITIATING SCENARIOS AND PROCESS SAFETY MANAGEMENT

The full report can be downloaded from the CSB website

www.csb.gov/assets/document/Final_Sierra.pdf

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