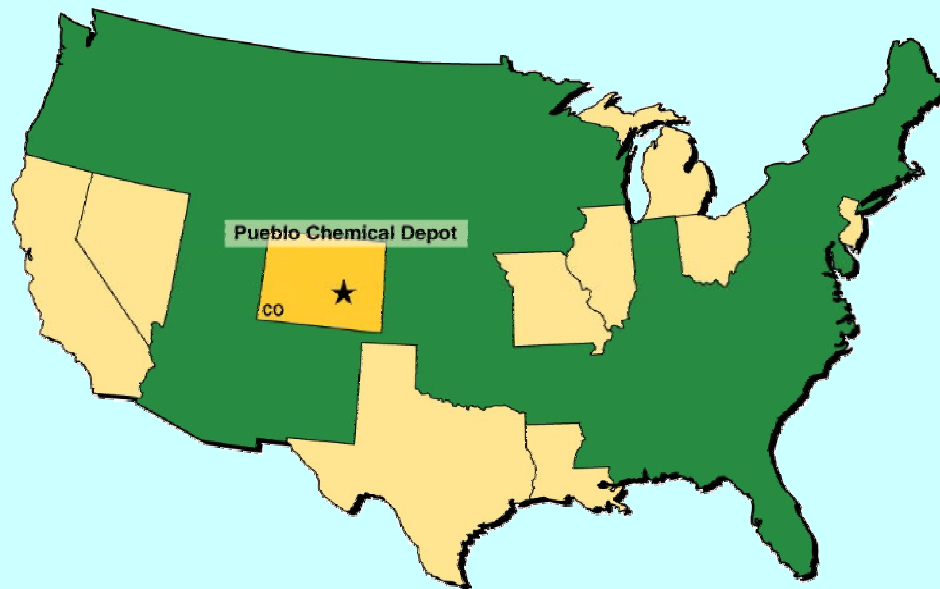


# **Transportation Risk Assessment:**

## **Options for the Off-Site Shipment and Disposal of Residual Wastes from the Destruction of Chemical Weapons at the Pueblo Chemical Depot**



Prepared for

**Program Manager,  
Assembled Chemical Weapons Assessment  
Aberdeen Proving Ground, Maryland**

Prepared by

**Argonne National Laboratory,  
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Argonne, Illinois**

April 2003

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## **Transportation Risk Assessment:**

# **Options for the Off-Site Shipment and Disposal of Nonagent Chemical Weapons from the Pueblo Chemical Depot**

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**April 2003**

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## NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this report.

### ACRONYMS, INITIALISMS, AND ABBREVIATIONS

|        |   |
|--------|---|
| AAP    | Army ammunition plant                                     |
| ABCDF  | Aberdeen Chemical Agent Disposal                          |
| ACW    | Assembled Chemical Weapons                                |
| ACWA   | Assembled Chemical Weapons Assessment                     |
| AHR    | agent hydrolysate reactor                                 |
| BRS    | brine reduction system                                    |
| CASRAM | Chemical Accident Stochastic Risk Assessment Model        |
| CFR    | Code of Federal Regulations                               |
| DAC    | Defense Ammunition Center                                 |
| DOE    | U.S. Department of Energy                                 |
| DOT    | U.S. Department of Transportation                         |
| DPE    | Demilitarization Protection Ensemble                      |
| ECR    | explosive containment room                                |
| EDP    | engineering design package                                |
| EDS    | Engineering Design Studies                                |
| ERH    | energetics rotary hydrolyzer                              |
| FRA    | Federal Rail Administration                               |
| GATS   | General Atomics Total Solution                            |
| GIS    | geographic information system                             |
| HD     | Mustard agent   |
| HDC    | heated discharge conveyor                                 |
| HR     | hazard rating   |
| HRT    | hydraulic retention time                                  |
| HW     | hazardous waste   |
| ICB    | immobilized cell bioreactor                               |
| MDB    | Munitions Demilitarization Building                       |
| MIDAS  | Munitions Items Disposition Action System                 |
| MPT    | metal parts treater                                       |
| NaOH   | sodium hydroxide  |
| NTRA   | National Transportation Risk Assessment                   |
| ORNL   | Oak Ridge National Laboratory                             |
| OSHA   | Occupational Safety and Health Administration             |
| PCAPP  | Pueblo Chemical Agent Destruction Pilot Plant             |
| PCD    | Pueblo Chemical Depot                                     |
| PMACWA | Program Manager for Assembled Chemical Weapons Assessment |
| RCRA   | Resource Conservation and Recovery Act                    |
| SBCCOM | Soldiers Biological and Chemical Command                  |
| SBR    | sequencing batch reactor                                  |
| TDG    | thiodiglycol  |

TIGER Topologically Integrated Geographic Encoding and Referencing (System)  
TNT 2,4,6-trinitrobenzene  
TSDF treatment, storage, and disposal facility  
WebTRAGIS Web-based Transportation Routing Analysis Geographic Information System  
3X U.S. Army safe to handle decontamination level designation

## UNITS OF MEASURE

|                |                          |
|----------------|--------------------------|
| ft             | foot(feet)               |
| g              | gram(s)                  |
| gal            | gallon(s)                |
| h              | hour(s)                  |
| in.            | inch(es)                 |
| kg             | kilogram(s)              |
| km             | kilometer(s)             |
| lb             | pound(s)                 |
| m              | meter(s)                 |
| m <sup>3</sup> | cubic meter(s)           |
| mg             | milligram(s)             |
| mi             | mile(s)                  |
| MJ             | megajoule(s)             |
| mm             | millimeter(s)            |
| ppb            | part(s) per billion      |
| psi            | pound(s) per square inch |
| s              | second(s)                |

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## Summary

This study evaluated the risk associated with three residual waste stream transportation options for the Assembled Chemical Weapons (ACW) stored at Pueblo Chemical Depot (PCD), Colorado. The options – designated as Options A, B, and C – differ in how various components would be treated and where they would be shipped and/or stored. (Details are provided in Section 1.) This transportation risk assessment showed that the risk associated with all options would be very small. These risks are well within the range of risks associated with national averages for the commercial shipment of “dangerous goods” over the U.S. highways and railways.

The analysis indicated that Option A would have the lowest risk, while Options B and C would have the highest. The results are governed by the characteristics of the waste streams (e.g., volume, mass, and composition) designated for off-site treatment and disposal under each option, and the associated number of shipments and transport distances involved. Each of the highest risk options (B and C) represents up to about 4 times the risk associated with Option A.

The energetics (e.g., explosives, fuzes, bursters) would be shipped only under Option C. The energetics hydrolysate<sup>1</sup> would be shipped only under Option B, along with the agent hydrolysate. Although the energetics constitutes the most risky cargo being considered for off-site shipment, the analysis shows that the injury and fatality risks under Options B and C are about the same. This result is due to the risk trade-off between shipping the energetics hydrolysate (without any energetics components) under Option B and shipping the energetics components (without decontamination-derived hydrolysate) under Option C.

The U.S. Department of Transportation (DOT) regulates the shipment of Division 1.1 explosives as hazardous cargo or “dangerous goods.” These types of shipments are more risky than the energetics hydrolysate shipments if shipped over similar distances. However, the larger agent or energetics hydrolysate shipment distances to treatment, storage, and disposal facility (TSDF) sites essentially make the risk from shipping these two cargos (energetics hydrolysate and energetics) about the same. On the basis of the composition and concentrations of the agent and energetics hydrolysates, the unit risk (injury or fatality per ton-mile shipped) from shipping this cargo is essentially identical to the risk of shipping any cargo that is not considered “dangerous goods.”

The analysis shows that the injury risk for truck shipments attributable to explosion of the energetics represents between 5% and 15% of the total injuries from these shipments, with the remaining risk being vehicle crash accident-related (e.g., driver and/or other involved vehicles). However, the fatality risk from truck accidents involving a fire and explosion contributes between 35% and 70% of the total fatalities from these energetics shipments. For rail shipments, the reverse is true; as much as 45% of the injury risk and only about 10% of the fatality risk are attributed to the explosive part of the shipment cargo. These findings are consistent with the findings for explosive and other chemical hazardous cargo shipments analyzed in the DOT’s National Transportation Risk Assessment (NTRA).

---

<sup>1</sup> The agent and energetics hydrolysate is the aqueous solution of products coming from agent treatment using neutralization. The neutralization process typically involves the reaction of the agent with a water-base (sodium hydroxide) solution in which some chemical bond is broken in the agent by insertion of a hydroxide ion (OH<sup>-</sup>) or a hydrogen ion (H<sup>+</sup>).

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**Transportation Risk Assessment:**  
**Options for the Off-Site Shipment and Disposal of Residual Wastes**  
**Generated from the Destruction of Chemical Weapons at**  
**the Pueblo Chemical Depot**

**1 Introduction**

This assessment summarizes the transportation risks for three disposal options (A, B, and C), on the basis of potential treatment, storage, and disposal facilities (TSDFs) identified by the Program Manager for Assembled Chemical Weapons Assessment (ACWA) (see Table 1). The assessment conservatively assumes that all the residual waste generated at the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) at the Pueblo Chemical Depot (PCD) in Colorado would be hazardous waste (HW) and would be shipped to an appropriately licensed HW TSDF. Some of the wastes may be “delisted,” allowing shipment to a local Pueblo disposal facility, thus decreasing the estimated transportation risks. The estimated risk accounts for the routine accident hazards associated with highway and rail travel (noncargo) and the hazard associated with shipment accidents that may also involve the cargo.

Each of the options and the basic transportation-related assumptions can be summarized as follows:

**Option A:** The uncontaminated metal parts, dunnage and ash, the bioreactor salt cake, sludge and washout solution would be shipped off-site. Any surface-contaminated dunnage or metal parts would be decontaminated to the XXX level (3X, level safe for handling) in accordance with applicable standards (U.S. Department of the Army 2001a) before shipment off-site<sup>2</sup>. A decontamination method commonly used to clean contaminated metal parts would be the application of a sodium hydroxide (NaOH) spray. Biotreatment of the agent and energetics occurs on-site.

- Dunnage (wood pallets) and metal parts would be decontaminated (3X) on-site, with 90% (by weight) shipped off-site for final disposal (to Last Chance, Colorado; HW landfill) and 10% (by weight) assumed to fail 3X and treated in the metal parts treater (MPT) on-site

---

<sup>2</sup> In accordance with Chapter 5 of the Army’s DA 361-61, “Decontamination and Disposal,” the following guideline of 3X decon applies to items or materials that have a solid physical state (e.g., metal parts). The symbol with three Xs (“XXX”) “indicates that the item has been surface decontaminated by locally approved procedures, has been bagged or contained in an agent-tight barrier (plastic bags may be used if they have been tested and found to be effective for the purpose) of sufficient volume to permit sample air to be withdrawn while minimizing dilution with incoming air, and/or appropriate tests/monitoring have verified that concentrations of 0.003 mg/ m<sup>3</sup> for H or HD do not exist. Monitoring is not required for completely decontaminated and disassembled parts that are shaped simple (no crevices, threads, or the like) and are made of essentially impervious materials (such as simple lab glassware and steel gears).

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TABLE 1 Potential Disposal Site Locations Considered in the Analysis of Transportation Risk of Nonagent Chemical Weapon Components at the Pueblo Chemical Depot<sup>a</sup>

| Waste Type/Destination City <sup>b</sup> | Destination State | Distance from PCD (km) | Shipment Mode | Off-Site Disposal Option | Waste Stream (WS)                         | Agent/Energetics Hydrolysate | Treatment Technology                        |
|--|-------------------|------------------------|---------------|--------------------------|---|------------------------------|---|
| <b>Solid Wastes/Sludges<sup>c</sup></b>  |                   |                        |               |                          |   |                              |   |
| Last Chance                              | Colorado          | 270                    | Truck only    | A, B and C               | Metal parts, dunnage/ash, salt cake, etc. | No                           | NA <sup>e</sup>                             |
| <b>Agent/Energetics Hydrolysate</b>      |                   |                        |               |                          |   |                              |   |
| Deepwater                                | New Jersey        | 3,110                  | Rail          | B and C <sup>d</sup>     | All except energetics                     | Yes                          | Hydrogen peroxide + PACT                    |
| Dayton                                   | Ohio              | 1,980                  | Rail/truck    | B and C <sup>d</sup>     | All except energetics                     | Yes                          | Solid/Wastewater Treatment                  |
| Vernon                                   | California        | 2,200/1,830            | Rail/truck    | B and C <sup>d</sup>     | Liquid only                               | Yes                          | Metal precipitation/ carbon filter          |
| Detroit                                  | Michigan          | 2,370/2,230            | Rail/truck    | B and C <sup>d</sup>     | Liquid only                               | Yes                          | Wastewater                                  |
| Deer Park                                | Texas             | 1,620/1,530            | Rail/truck    | B and C <sup>d</sup>     | Liquid only                               | Yes                          | Wastewater                                  |
| <b>Energetics</b>                        |                   |                        |               |                          |   |                              |   |
| Colfax                                   | Louisiana         | 1,580                  | Truck only    | C                        | Explosives/ components                    | No                           | Open burning                                |
| Hawthorne                                | Nevada            | 2,050/1,950            | Rail/truck    | C                        | Explosives/ components                    | No                           | Rotary furnace, w/open detonation if needed |
| Joplin                                   | Missouri          | 1,200/970              | Rail/truck    | C                        | Explosives/ components                    | No                           | NA  |
| Sauget                                   | Illinois          | 1,510/1,430            | Rail/truck    | C                        | Explosives/ components                    | No                           | NA  |

<sup>a</sup> Sources: PMACWA (2002); Starnes (2002).

<sup>b</sup> Names of commercial TSDF companies are not listed; the Army has also not formally selected or contracted with any specific TSDF.

<sup>c</sup> Metal parts, treated dunnage/ash (the ash is considered as hazardous waste; includes wood carbon, Demilitarization Protection Ensemble (DPE), DPE, and propellant), washout solution sludges, and wood pallets.

<sup>d</sup> Agent hydrolysate only.

<sup>e</sup> NA = not available.

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**Option B:** The mustard agent hydrolysate and energetics hydrolysate<sup>3</sup> would be shipped off-site for final treatment and disposal. Decontaminated metal parts, dunnage, and ash would be shipped to Last Chance as done under Option A, except for the bioreactor waste (e.g., salt cake).

- It is assumed that the agent and energetics hydrolysate would be shipped off-site by tanker truck or rail to one of five TSDF sites (see Table 1). For the rail shipment alternative, the hydrolysate would be shipped by tanker truck to a rail transfer facility approximately 20 mi from the PCAPP and from there by rail to the TSDF sites.

**Option C:** The mustard agent hydrolysate would be shipped off-site for final treatment and disposal (same as Option B). The energetics hydrolysate would not be shipped but would be treated on-site. The energetics, defined as the following components of the munitions: burster, propellant, fuze, and the explosive material (i.e., tetryl<sup>4</sup>), would be shipped to designated TSDFs. Decontaminated metal parts, dunnage, and ash would be shipped to Last Chance as done under Option A, except the bioreactor waste (e.g., sludge).

- It is assumed that the agent hydrolysate would be shipped off-site by tanker truck or rail to one of five TSDF sites (see Table 1). For the rail shipment alternative, the mustard hydrolysate would be shipped by tanker truck to a rail transfer facility approximately 20 mi from the PCAPP and from there by rail to the TSDF sites. The packaging requirements for off-site shipments of energetics would necessitate removal of the energetics components from the munitions body, decontamination (3X), and separation. The current recommendation is for separate packaging, when practical (see Appendix C), and shipment of component parts by type or Army nomenclature (e.g., M5 bursters).

Options B and C have two alternative shipment modes; one involving only truck shipments and the other using rail shipments where possible. In addition, Option B has five alternative TSDF site destinations for disposal of the agent and energetics hydrolysate, with the metal parts and dunnage (solid waste) going to Last Chance as in Option A. Option C uses the same five TSDF sites for the agent hydrolysate only, but uses four additional TSDF sites for the disposal of the energetics components and explosive material. It is identical to Option B for solid waste. Option A considers only one mode of transportation (i.e., truck transport) and only one interstate only shipment location. The rail mode for Option A is not possible since there is no rail access to the HW TSDF located at Last Chance, Colorado, which is the closest appropriate facility to the PCD. Options B and C also use the Last Chance facility for the shipment, treatment, and

---

<sup>3</sup> The agent and energetics hydrolysate is the aqueous solution of products coming from agent treatment using neutralization. The neutralization of mustard agent uses a hydrolysis process, which typically involves the reaction of the agent with a water-base solution in which the insertion of a hydroxide ion (OH-) or a hydrogen ion (H+) into the bond cleavage breaks a key chemical bond in the agent. The resulting hydrolysate is the product of hydrolysis.

<sup>4</sup> Tetryl (trinitrophenylmethylnitramine) is a crystalline solid powder explosives material (clear, yellow, or gray in color), practically insoluble in water but soluble in acetone, benzene, and other solvents. It is generally used in the form of pressed pellets and has been approved as the standard bursting charge for small caliber projectiles, since it gives much better fragmentation than TNT (2,4,6-trinitrotoluene). It also has greater shattering ability than any other military high explosive and must be properly protected from bullet fire. Its rate of detonation is 23,600 to 23,900 ft/s.

disposal of metal parts and dunnage/ash. A complete set of basic and design assumptions used in the option comparisons is included in Appendix A.

Table 2 summarizes residual waste shipments under each option by waste type (solid, liquid, and explosive) and mass fraction, and number of shipments. Although both highway and railway shipment modes were considered, only highway (i.e., via van truck) shipment frequencies are shown. These numbers and the ones for rail were derived from requirements/restrictions in packaging the waste for shipment. Some of the major packaging requirements are summarized in Appendix A for hydrolysate and Appendix B for the energetics. Although the differences in the total number of shipments between options is relatively small, especially between Options B and C, the total shipment miles also factor into the relative risk differences between options. The transportation risks are assessed for 10 possible disposal sites; the specific site locations and travel distances under each of the three disposal options are identified in Table 1. The risk assessment approach, along with the main factors contributing to the transportation risk, is discussed below.

**Table 2: Residual Waste Shipments by Disposal Option**

| Waste Type                                 | Waste Description                             | Total Generation   | Wt. Type     | Option | # of Truck Shipments |
|--|---|--------------------|--------------|--------|----------------------|
| <b>Solid Waste</b>                         |   | (lb)               | (%)          |        |                      |
| Treated Dunnage/Ash <sup>a</sup>           |   |                    |              | A/B/C  | 4                    |
|  | Wood  | 21,842             |              | A/B/C  | 1                    |
|  | Carbon  | 29,253             |              | A/B/C  | 1                    |
|  | DPE   | 23,402             |              | A/B/C  | 1                    |
|  | Propellant                                    | 1,382              |              | A/B/C  | 1                    |
|  | Subtotal                                      | 75,880             | 0.2%         |        |                      |
| Metals                                     |   |                    |              | A/B/C  | 1,281                |
|  | Munitions bodies                              | 37,519,174         |              | A/B/C  | 1,251                |
|  | Fuzes <sup>b</sup>                            | 606,403            |              | A/B/C  | 21                   |
|  | Burster casings <sup>b</sup>                  | 269,613            |              | A/B/C  | 9                    |
|  | Subtotal                                      | 38,395,189         | 94.7%        |        |                      |
| Wood Pallets                               |   | 2,071,000          | 5.1%         | A/B/C  | 70                   |
| DPE <sup>c</sup>                           |   | 0                  |              |        |                      |
|  | <b>Option A: Solid Waste Totals</b>           | 40,542,069         | <b>37.7%</b> |        |                      |
| <b>Liquid Waste</b>                        |   |                    |              |        |                      |
| Hydrolysates <sup>d</sup>                  |   |                    |              | B/C    | 865                  |
|  | Agent hydrolysate                             | 34,917,812         | 53.2%        | B/C    | 838                  |
|  | Energetics hydrolysate                        | 1,413,776          | 2.2%         | B      | 27                   |
| Spent Decon <sup>d</sup>                   |   | 4,150,015          | 6.3%         | B/C    | 91                   |
| BRS Washout Solution                       |   | 1,250,000          | 1.9%         | A      | 25                   |
| Sludges                                    |   |                    |              | A      | 799                  |
|  | <i>Biotreatment Sludge<sup>e</sup></i>        | 5,520,000          | 8.4%         | A      | 184                  |
|  | <i>BRS Salt Cake<sup>f</sup></i>              | 18,430,000         | 28.1%        | A      | 615                  |
|  | <b>Option B &amp; C: Liquid Waste Totals</b>  | 65,681,603         | <b>61.1%</b> |        |                      |
| <b>Explosive Solid Waste</b>               |   |                    |              |        |                      |
| Energetics                                 |   |                    |              | C      | 38                   |
|  | Fuzes   | 612,528            | 48.7%        | C      | 21                   |
|  | Bursters                                      | 505,713            | 40.2%        | C      | 17                   |
|  | Propellant                                    | 138,240            | 11.0%        | C      | 5                    |
|  | <b>Option C (A+: Energetics Waste Totals)</b> | 1,256,481          | <b>1.2%</b>  |        |                      |
| <b>Total Waste Shipped (lbs):</b>          |   | <b>107,480,153</b> |              |        |                      |
| <b>Total Number of Shipments: Option A</b> |   |                    |              |        | <b>2,179</b>         |
| <b>Option B</b>                            |   |                    |              |        | <b>2,311</b>         |
| <b>Option C</b>                            |   |                    |              |        | <b>2,322</b>         |

a. The ashes are assumed to be a hazardous waste.

b. The fuzes and burster casings shown here are the residuals from the Metal Parts Treater (MPT) and nonhazardous metal scrap.

c. All DPE is processed on site.

d. The transportation of the hydrolysates and spent decon is from Pueblo Chemical Agent Disposal Pilot Plant (PCAPP) to a railroad transfer station.

e. The biotreatment sludge for this study is assumed as hazardous waste, but it would likely be delisted as nonhazardous waste for its ultimate disposal.

f. The salt cake is assumed as hazardous waste, but it is likely to be classified as nonhazardous waste for final disposal.

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## **2 Routing Model**

The Transportation Routing Analysis Geographic Information System (WebTRAGIS) software package was used in determining representative waste transport routes for this analysis. WebTRAGIS was developed by Oak Ridge National Laboratory (ORNL) with the support of the U.S. Department of Energy (DOE), National Transportation Program (Johnson and Michelbaugh 2000). It replaces the older HIGHWAY (Johnson et al. 1993a) and INTERLINE (Johnson et al. 1993b) models that previously were the standard models used for routing analyses. WebTRAGIS is designed to route in the continental United States using rail, truck, and waterway transportation modes. The rail network in the model uses a modified database developed for the Federal Rail Administration (FRA) in the mid-1970s and periodically updated by ORNL. The truck database is developed from the U.S. Bureau of Census Topologically Integrated Geographic Encoding and Referencing (TIGER) system (U.S. Bureau of the Census 2002).

WebTRAGIS has nodes at or near (within several miles of) PCD and the destination facilities. The routes were selected to be reasonable and consistent with routing regulations and general practice. They are, however, considered representative, because the actual routes to be used would be chosen in the future and are often determined by the carrier. For truck shipments, such determination depends on such variables as weather conditions, road closures or maintenance, and traffic congestion. Selection of the rail routes by WebTRAGIS was based on current practices used by the rail industry and depends on the railroad company used if more than one company services the destination facilities. The truck routes were checked against designated routes for hazardous materials in each state that is traversed. In addition to providing the mileage in each state, the route-specific population density, based on 2000 census data, was provided in the WebTRAGIS output for use in the accident risk calculations.

## **3 Vehicle Risks**

Vehicle-related accident risk refers to the potential for transportation-related accidents that result in injuries and fatalities due to physical trauma that are not related to the cargo in the shipment. State average rates for transportation-related injuries and fatalities are used in the assessment (Saricks and Tompkins 1999). Vehicle-related risks are presented in terms of estimated injuries and fatalities for the truck and rail options considered. Vehicle-related accident risks were calculated by multiplying the distance traveled by the appropriate rate for transportation-related injuries or fatalities. If dedicated trucks or railcars were used for this project, the risks presented in Tables 2 and 3 would need to be doubled to account for the return-trip vehicle-related risks.

For truck transportation, the accident and casualty rates presented in Saricks and Tompkins (1999) are specifically for heavy combination trucks involved in interstate commerce. Heavy combination trucks are rigs composed of a separable tractor unit containing the engine and one to three connected freight trailers. Truck accident rates are computed for each state on the basis of statistics compiled by the U.S. Department of Transportation (DOT), Office of Motor Carriers, for 1994 to 1996. Saricks and Tompkins (1999) present accident involvement and injury and fatality counts, estimated kilometers of travel by state, and the corresponding average accident involvement and fatality rates for the three years investigated. Fatalities (including crew

members) are deaths attributable to the accident that occurred any time within 30 days of the accident.

Rail accident rates are computed and presented similarly to truck accident rates in Saricks and Tompkins (1999); however, for rail transport, the unit of haulage is the railcar. State-specific rail accident involvement and injury and fatality rates per railcar-kilometer are based on statistics compiled by the FRA for 1994 to 1996. Rail accident rates include both main-line accidents and those occurring in rail yards.

The accident rates used in this assessment were computed using all interstate shipments, regardless of the cargo. Saricks and Kvittek (1994) point out that shippers and carriers of hazardous material generally have a higher-than-average awareness of transportation risk and prepare cargoes and drivers for such shipments accordingly. This preparation should have the twofold effect of reducing component and equipment failure and mitigating the contribution of human error to accident causation. However, these effects were not considered in the accident assessment.

The vehicle-related injury and fatality risks for each of the three off-site disposal options are presented in Tables 3 and 4. These risks are the probability that an accident will result in injuries and fatalities due to physical trauma and are not related to the cargo in the shipment. On the basis of the results in Tables 3 and 4, the vehicle-related risks for Option A are the lowest, about 3 to 5 times lower than those for Options B and C. The ranges of vehicle-related risks for Options B and C are very similar, and, when the risks from transporting dunnage to the HW disposal facility at Last Chance, Colorado, are included, there is not much difference in vehicle-related risk among any of the options considered. Injury risks from rail transport are 3 to 6 times lower than the injury risks associated with truck transport; there is less difference between rail and truck transport with respect to fatality risks. All options are estimated to result (statistically) in less than one fatality and less than one injury. All risks are relatively low, which indicates that none of the options would impose an unsafe level of vehicle-related transportation risk.

**TABLE 3 Vehicle-Related (Noncargo) Injury and Fatality Transportation Risks: Options A and B for the Disposal of PCD Assembled Chemical Weapons Components**

|   | <b>Option A<sup>a</sup></b>              | <b>Option B<sup>b</sup></b>   |  |                          |                              |                      |                         |
|---|--|---|--|--------------------------|------------------------------|----------------------|-------------------------|
|   | <b>Dunnage and Metal Parts to</b>        | <b>Dunnage and Metal Parts to</b>   | <b>Agent and Energetics Hydrolysate to</b> |                          |                              |                      |                         |
| <b>Risk Factor</b>                      | <b>Last Chance, Colorado<sup>c</sup></b> | <b>Last Chance, Colorado<sup>c</sup></b>  | <b>Vernon, California</b>                  | <b>Detroit, Michigan</b> | <b>Deepwater, New Jersey</b> | <b>Dayton, Ohio</b>  | <b>Deer Park, Texas</b> |
| <b>Truck</b>                            |  |   |  |                          |                              |                      |                         |
| <i>Distance (km)</i>                    | 261                                      | 261   | 1,823                                      | 2,228                    | 2,830                        | 1,973                | 1,529                   |
| Number of shipments                     | 2,179                                    | 1,355   | 956  | 956                      | 956                          | 956                  | 956                     |
| Crash injuries per shipment             | $8.2 \times 10^{-5}$                     | $8.2 \times 10^{-5}$  | $2.5 \times 10^{-4}$                       | $4.4 \times 10^{-4}$     | $7.6 \times 10^{-4}$         | $4.9 \times 10^{-4}$ | $7.3 \times 10^{-4}$    |
| Crash fatalities per shipment           | $3.0 \times 10^{-6}$                     | $3.0 \times 10^{-6}$  | $1.8 \times 10^{-5}$                       | $2.4 \times 10^{-5}$     | $2.2 \times 10^{-5}$         | $1.6 \times 10^{-5}$ | $1.9 \times 10^{-5}$    |
| Number of crash injuries                | $1.8 \times 10^{-1}$                     | $1.1 \times 10^{-1}$  | $2.4 \times 10^{-1}$                       | $4.2 \times 10^{-1}$     | $7.3 \times 10^{-1}$         | $4.7 \times 10^{-1}$ | $7.0 \times 10^{-1}$    |
| Number of crash fatalities              | $6.5 \times 10^{-3}$                     | $4.1 \times 10^{-3}$  | $1.7 \times 10^{-2}$                       | $2.3 \times 10^{-2}$     | $2.1 \times 10^{-2}$         | $1.5 \times 10^{-2}$ | $1.8 \times 10^{-2}$    |
| <b>Option range of total injuries</b>   | 0.18                                     | <b>0.35 – 0.84</b>  |  |                          |                              |                      |                         |
| <b>Option range of total fatalities</b> | 0.0065                                   | <b>0.019 – 0.027</b>  |  |                          |                              |                      |                         |
| <b>Rail</b>                             |  |   |  |                          |                              |                      |                         |
| <i>Distance (km)</i>                    | NA <sup>d</sup>                          | 261 (truck)   | 2,198                                      | 2,368                    | 3,108                        | 2,211                | 1,620                   |
| Number of shipments                     | NA                                       | 1,355 (truck)   | 240  | 240                      | 240                          | 240                  | 240                     |
| Crash injuries per shipment             | NA                                       | $8.2 \times 10^{-5}$  | $4.5 \times 10^{-5}$                       | $1.0 \times 10^{-4}$     | $1.1 \times 10^{-4}$         | $7.6 \times 10^{-5}$ | $8.4 \times 10^{-5}$    |
| Crash fatalities per shipment           | NA                                       | $3.0 \times 10^{-6}$  | $4.2 \times 10^{-5}$                       | $4.4 \times 10^{-5}$     | $6.4 \times 10^{-5}$         | $3.5 \times 10^{-5}$ | $3.6 \times 10^{-5}$    |
| Number of crash injuries                | NA                                       | $1.1 \times 10^{-1}$  | $1.1 \times 10^{-2}$                       | $2.4 \times 10^{-2}$     | $2.6 \times 10^{-2}$         | $1.8 \times 10^{-2}$ | $2.0 \times 10^{-2}$    |
| Number of crash fatalities              | NA                                       | $4.1 \times 10^{-3}$  | $1.0 \times 10^{-2}$                       | $1.1 \times 10^{-2}$     | $1.5 \times 10^{-2}$         | $8.4 \times 10^{-3}$ | $8.6 \times 10^{-3}$    |
| <b>Option range of total injuries</b>   | 0.18                                     | <b>0.12–0.14</b><br><b>(Rail for agent/energetics hydrolysate; truck for dunnage and metal parts)</b>     |  |                          |                              |                      |                         |
| <b>Option range of total fatalities</b> | 0.0065                                   | <b>0.013 – 0.019</b><br><b>(Rail for agent/energetics hydrolysate; truck for dunnage and metal parts)</b> |  |                          |                              |                      |                         |

<sup>a</sup> Option A is complete treatment at PCD, transportation of dunnage by truck to Last Chance, Colorado.

<sup>b</sup> Option B is neutralization at PCD, transportation of agent and energetics hydrolysate to chosen TSDF by truck or rail; dunnage to Last Chance by truck.

<sup>c</sup> Last Chance shipments are truck only, since there is no rail spur available at the Last Chance TSDF.

<sup>d</sup> NA = not applicable.

**TABLE 4 Vehicle-Related (Noncargo) Injury and Fatality Transportation Risks: Option C<sup>a</sup> for the Disposal of PCD Assembled Chemical Weapons Components**

| Risk Factor                             | Dunnage and Metal Parts to  | Agent Hydrolysate to            |                      |                       |                      |                      | Energetics to        |                                |                      |                      |
|---|---|---------------------------------|----------------------|-----------------------|----------------------|----------------------|----------------------|--------------------------------|----------------------|----------------------|
|   | Last Chance, Colorado <sup>b</sup>  | Vernon, California <sup>a</sup> | Detroit, Michigan    | Deepwater, New Jersey | Dayton, Ohio         | Deer Park, Texas     | Sauget, Illinois     | Colfax, Louisiana <sup>b</sup> | Joplin, Missouri     | Hawthorne, Nevada    |
| <b>Truck</b>                            |   |                                 |                      |                       |                      |                      |                      |                                |                      |                      |
| <i>Distance (km)</i>                    | 261   | 1,823                           | 2,228                | 2,830                 | 1,973                | 1,529                | 1,423                | 1,576                          | 969                  | 1,948                |
| Number of shipments                     | 1,355   | 929                             | 929                  | 929                   | 929                  | 929                  | 38                   | 38                             | 38                   | 38                   |
| Crash injuries (per shipment)           | $8.2 \times 10^{-5}$  | $2.5 \times 10^{-4}$            | $4.4 \times 10^{-4}$ | $7.6 \times 10^{-4}$  | $4.9 \times 10^{-4}$ | $7.3 \times 10^{-4}$ | $4.1 \times 10^{-4}$ | $6.84 \times 10^{-4}$          | $2.6 \times 10^{-4}$ | $4.8 \times 10^{-4}$ |
| Crash fatalities (per shipment)         | $3.0 \times 10^{-6}$  | $1.8 \times 10^{-5}$            | $2.4 \times 10^{-5}$ | $2.2 \times 10^{-5}$  | $1.6 \times 10^{-5}$ | $1.9 \times 10^{-5}$ | $1.2 \times 10^{-5}$ | $1.93 \times 10^{-5}$          | $6.5 \times 10^{-6}$ | $1.9 \times 10^{-5}$ |
| Number of crash injuries                | $1.1 \times 10^{-1}$  | $2.3 \times 10^{-1}$            | $4.1 \times 10^{-1}$ | $7.1 \times 10^{-1}$  | $4.6 \times 10^{-1}$ | $6.8 \times 10^{-1}$ | $1.5 \times 10^{-2}$ | $2.6 \times 10^{-2}$           | $9.9 \times 10^{-3}$ | $1.8 \times 10^{-2}$ |
| Number of crash fatalities              | $4.1 \times 10^{-3}$  | $1.7 \times 10^{-2}$            | $2.2 \times 10^{-2}$ | $2.0 \times 10^{-2}$  | $1.5 \times 10^{-2}$ | $1.8 \times 10^{-2}$ | $4.7 \times 10^{-4}$ | $7.3 \times 10^{-4}$           | $2.5 \times 10^{-4}$ | $7.1 \times 10^{-4}$ |
| <b>Option range of total injuries</b>   | <b>0.34 – 0.82</b>  |                                 |                      |                       |                      |                      |                      |                                |                      |                      |
| <b>Option range of total fatalities</b> | <b>0.0044 – 0.026</b>   |                                 |                      |                       |                      |                      |                      |                                |                      |                      |
| <b>Rail</b>                             |   |                                 |                      |                       |                      |                      |                      |                                |                      |                      |
| <i>Distance (km)</i>                    | 261 (truck)   | 2,198                           | 2,368                | 3,108                 | 2,211                | 1,620                | 1,506                | NA <sup>c</sup>                | 1,197                | 2,049                |
| Number of shipments                     | 1,355 (truck)   | 233                             | 233                  | 233                   | 233                  | 233                  | 15                   | NA                             | 15                   | 15                   |
| Crash injuries per shipment             | $8.2 \times 10^{-5}$  | $4.5 \times 10^{-5}$            | $1.0 \times 10^{-4}$ | $1.1 \times 10^{-4}$  | $7.6 \times 10^{-5}$ | $8.4 \times 10^{-5}$ | $3.1 \times 10^{-5}$ | NA                             | $2.5 \times 10^{-5}$ | $2.8 \times 10^{-5}$ |
| Crash fatalities per shipment           | $3.0 \times 10^{-6}$  | $4.2 \times 10^{-5}$            | $4.4 \times 10^{-5}$ | $6.4 \times 10^{-5}$  | $3.5 \times 10^{-5}$ | $3.6 \times 10^{-5}$ | $1.6 \times 10^{-5}$ | NA                             | $1.2 \times 10^{-5}$ | $2.4 \times 10^{-5}$ |
| Number of crash injuries                | $1.1 \times 10^{-1}$  | $1.0 \times 10^{-2}$            | $2.3 \times 10^{-2}$ | $2.6 \times 10^{-2}$  | $1.8 \times 10^{-2}$ | $2.0 \times 10^{-2}$ | $4.7 \times 10^{-4}$ | NA                             | $3.7 \times 10^{-4}$ | $4.2 \times 10^{-4}$ |
| Number of crash fatalities              | $4.1 \times 10^{-3}$  | $9.8 \times 10^{-3}$            | $1.0 \times 10^{-2}$ | $1.5 \times 10^{-2}$  | $8.2 \times 10^{-3}$ | $8.4 \times 10^{-3}$ | $2.4 \times 10^{-4}$ | NA                             | $1.8 \times 10^{-4}$ | $3.6 \times 10^{-4}$ |
| <b>Option range of total injuries</b>   | <b>0.12–0.14</b><br><b>(Rail shipment of agent hydrolysate, energetics, and truck shipment of dunnage and metal parts)</b>  |                                 |                      |                       |                      |                      |                      |                                |                      |                      |
| <b>Option range of total fatalities</b> | <b>0.012–0.02</b><br><b>(Rail shipment of agent hydrolysate, energetics, and truck shipment of dunnage and metal parts)</b> |                                 |                      |                       |                      |                      |                      |                                |                      |                      |

<sup>a</sup> Option C is agent neutralization at PCD, transportation of agent hydrolysate and intact energetics to chosen TSDFs by truck or rail; dunnage to Last Chance, Colorado, by truck.

<sup>b</sup> Last Chance, Colorado, and Colfax, Louisiana, shipments are truck only, since there are no rail spurs available at the Last Chance or Colfax TSDF.

<sup>c</sup> NA = not applicable.

## 4 Cargo Risks (Energetics and Other Cargo)

Cargo-related risks are those risks of injury and fatality associated with the release of explosive energy from the detonation and explosion of cargo energetics shipment in a highway or a railway accident. For the solid waste and sludges (e.g., cleaned metal casings, treated dunnage, and ash) and agent and energetics hydrolysates that would be shipped under the various options, the cargo-related risks would be negligible. Because these substances are nonreactive and have low volatilities, risk from potential exposure of members of the general public to accidentally released materials would be very small by comparison with the vehicle transportation risk (much less than 1% of the total shipment risk). More detailed information describing the low toxicity of mustard agent hydrolysate and energetics hydrolysate is given in Appendix B. However, the transport of the Division 1.1 explosives<sup>5</sup> portion of the energetics components parts (which would occur only under Option C) presents a cargo-related risk from possible explosions during transport. If this Option were selected, U.S. Department of Defense (DoD) and DOT packaging and shipping regulations for transport of energetics would be followed, thus minimizing the risk of explosion hazards.

### 4.1 Characteristics, Packaging, and Shipment of the Energetics (Explosives and Other Material)

Energetics shipments under Option C would be made by van-trucks or railcars from PCD to one of four sites, as designated by the ACWA Program Manager. Each of the energetics components would be disassembled subsequent to removal of agent and cleaning/decontamination of metal casings and energetics components. The removal of agent and cleaning/decontamination would be performed in the munitions demilitarization building (MDB).

The decontamination would follow 3X procedures and most likely involve a sodium hydroxide (NaOH) spray similar to that used prior to the shipment of dunnage. The specific major components to be shipped would include the bursters, fuzes, propellants, ignition cartridges, and the explosives. Most of the explosive (85 to 100%) is contained in the burster. The explosive component of the energetics in the chemical weapon stockpile at PCD is a crystalline solid powder material. Explosives are a mixture or chemical compound; when subjected to sufficient heat, shock, or friction, they undergo a sudden chemical change with the liberation of energy and the development of high gas pressure. The tetryl and tetrytol (70–80% tetryl + 20–30% TNT) explosive materials used in the bursters are classified as Division 1.1 high explosives, a classification that depends on the rate at which this reaction takes place. Tetryl has a high detonation rate or velocity, in excess of that exhibited when TNT (2,4,6-trinitrotoluene) detonates ( $\approx 21,000$  ft/s). TNT is one of the principal “high explosive” constituents of many explosives. High-explosives are those that change almost instantaneously from a solid to a gaseous state. When the explosive is set off, the detonating heat-generated shock wave runs through the whole mass of explosive. When pure, it resembles light brown sugar and has a crystalline appearance with a very pale straw color. Ammunition loaded with TNT can be

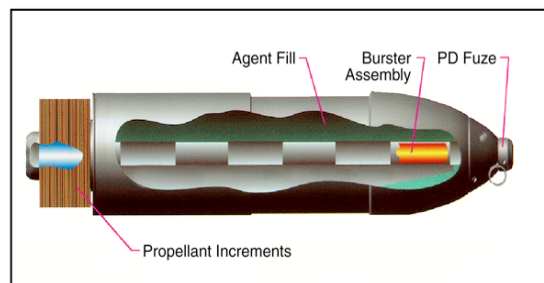
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<sup>5</sup> Explosives classified as Division 1.1 explosives under the Department of Transportation’s highway or railway shipment regulations (DOT 49 CFR 173.50, *Code of Federal Regulations*) are a class of explosives that exhibit a mass explosion hazard, or an explosion that affects almost the entire load instantaneously. These explosives are sometimes referred to as Class 1 or “high explosives.”

stored, handled, and shipped with comparative safety. It is used for bursting, demolition, blasting, and general detonation. Its velocity of detonation is 21,000 ft/s.

The M2/M2A1 mortars contain M8 propellant with an M6 propelling charge. When taken off the mortar and put in a box or drum or stored or shipped in “bulk,” the downloaded bulked propellant poses an explosive hazard. As required by DOT regulations it would need to be identified with hazard class of 1.1C (mass detonating hazard). The M8 propellant is a double base (nitrocellulose/nitroglycerin) propellant that contains over 20 percent nitroglycerin in the mortar. There currently also exists a potential fire hazard for “bulk” stored propellant of unknown stability, which requires propellant testing prior to storage or shipment. This requirement is specific to downloading propellant and is clearly stated in Army standard, SB 742-1, and in the Propellant Management Guide (Defense Ammunition Center). Unstable, bulk stored propellant has the capability to auto-ignite and therefore the stability of the propellant must be determined to assess the condition of the material prior to storage or shipment.

The propellant in the M2/M2A1 is located in the fin of the mortar. The auto-ignition of propellants while contained in the munitions assembly is not be an issue of concern. The propellants due contain stabilizers as an added level of protection, however, the stabilizer is primarily added to prevent auto-ignition of propellant if downloaded and stored in bulk. Significant stabilizer degradation that may occur over the mortars’ lifetime would require added precautionary measures to insure propellant auto-ignition upon removal from mortar and storage in bulk containers. While in the mortar, the likelihood of propellant auto-ignition would remote or extremely improbable due to the relatively small amounts of propellant present in combination with the ignition neutralization effects of existing stabilizer and the mortar fin. (Herbst, D., 2003). The fin and the other major mortar components are shown in the drawing to the right.



**Mortar (M2/M2A1)**

Some mortars may contain an M2 propellant, black powder, in the ignition cartridge. That would need to be verified at download. The M2 propellant contains 1.1C material which under the right conditions poses both an auto-ignition and a possible subsequent explosive hazard. The M8 and M2 propellant will require testing to determine stabilizer content prior to bulk shipment.

Although the design concentration of stabilizer in the propellant varies, it typically is between 0.3% to 0.5% by weight. The specific Army requirements dealing with the propellant stability issue are addressed in SB742-1. If the stabilizer concentration is less than 0.2% it poses a very high auto-ignition fire hazard that would prohibit transportation (e.g., cannot be shipped off-site). The propellant would have to be destroyed on-site within 60 days. If the stabilizer concentration is between 0.2 and 0.29%, off-site transportation would not be prohibited but the propellant would have to be destroyed within six months. The contracted TSDf receiving the energetics would need to be notified (most appropriate as a condition of the Army and TSDf contract agreements for receiving the energetics waste) of required Army six month period for destruction. In addition, the DOT requirement for flammable substances would likely require specification of the potential auto-ignition hazard on the HW manifests and also require that the TSDf facility managers be alerted of the Army’s requirement for propellant destruction within 6

months (i.e., from the date of removal from the mortars and packaging for shipment from the PCD).

Before shipping the chemical stockpile mortar propellant at PCD, laboratory measurements of stabilizer concentration using High Performance Liquid Chromatography (HPLC) equipment is the standard procedure. These tests are taken at the Picatinny Arsenal laboratory facility in NJ. A portable propellant stability tester, recently certified under the U.S. Army's Ammunition Peculiar Equipment (APE) program would be available for use in testing propellant stabilizer concentrations before packaging and shipment. The stability tester uses near-infrared scanning technology to measure propellant stabilizer concentrations. Rigorous certification was done testing and comparing propellant sample with laboratory measurements using HPLC equipment. The results from the portable tester showed high correlation with the laboratory measurements for stabilizer concentration between 0.35% and 0.45%, sole certification of safe levels to allow off-site shipment without HPLC confirmation (Michaud, J., 2003). The near-infrared portable tester is certified, as APE-1985, for 7 different types of propellant. Comparative results from tests of a second portable tester (chemical reagent method, using thin-layer chromatography) are also being evaluated and compared with measurements from the lab. If certified, the second instrument would allow the testing of all types of propellants used in both the demilitarization and operational munitions stockpile. This technology will allow the QASAS (Quality Assurance and Ammunition Surveillance) program team at PCD to conduct field testing to certify the safe levels of stabilizer in the mortar propellant before bulk packaging and off-site shipment.

The numbers and unit weights of energetics components targeted for shipping are summarized in Table 5. The weights for the explosive material and the other energetics components (e.g., bursters, fuzes) were derived from data reported in the Army's Munitions Items Disposition Action System (MIDAS) database (U.S. Army 2002). The number of van-truck and railcar shipments that would be required in transporting energetics was determined on the basis of the required packaging and packaged cargo material (size and weight), and the space and weight limitations of the shipment vessel (2002). The assumptions used in determining the packaging are summarized in Appendix C. Energetics and components are to be packed, marked, and prepared for shipment according to Army Pamphlet 385-61 (U.S. Department of the Army 2001) and current drawings and specifications for the item involved. The packaging and shipping requirements are determined in compliance with federal regulations (49 CFR Parts 100-199) and the relevant and appropriate state and local regulations. These requirements include considerations not limited to packaging approval and interim hazard classification, for example. On the basis of these considerations, in order to eliminate compatibility issues, the recommendation from the Defense Ammunition Center (DAC) was to ship the disassembled energetics components as separate packages (e.g., fuzes, propellants, bursters). The M8 fuzes and M14 bursters in the M2/M2A1 mortars (4.2-in. cartridges) would be the exception. Since these munitions have cemented fuzes and bursters, these would be shipped as assembled components. The total number of van-truck and railcar shipments was estimated to be 41 and 16, respectively. The number of truck and rail shipments involving Division 1.1 explosives would be slightly less, 38 and 15, respectively. The basis for this assumption is discussed in greater detail below.

The M6 propellant for the M2/M2A1 mortars contains a primer mixture of explosive material designated as Division 1.3 under DOT regulations. This group of explosives has a

minor blast or projectile hazard but does have a fire hazard. The fire hazard is relatively small compared with the mass or blast hazard imposed by Division 1.1 explosives. Therefore, three fewer highway shipments (38 rather than 41) and one less railway shipment (15 rather than 16) would be required in assessing explosive cargo risk versus the noncargo risk. See Appendix C for the breakout of the munitions-specific packaged component shipment numbers.

With the packaging requirements determined, the risk of public injury or fatality from transportation accidents involving explosive cargo, in this case the shipment of explosives, in the energetics components of chemical munitions, can be calculated. The cargo-related risk is the

**TABLE 5 Unit Shipment Weights of the Chemical Munitions Energetics**

| Munitions Type                                    | 155-mm Projectiles    | 105-mm Projectiles |                      | 4.2 in. Mortars | Stockpile Inventory Totals |
|---|-----------------------|--------------------|----------------------|-----------------|----------------------------|
|   | (M104/110)            | (M60)              |                      | (M2/M2A1)       |                            |
| PCD Munitions Stockpile                           | 299,554               | 28,375             | 355,043 <sup>a</sup> | 97,106          | 780,078                    |
| Energetics Component                              | Unit Weight (lb/unit) |                    |                      |                 | Weight Totals (lb)         |
| Fuzes (M17/M8) <sup>b</sup>                       | 0                     | 2.12               | 0                    | 1.40            | 196,103                    |
| Bursters (M6/M5/M14)                              | 0.83                  | 0.51               | 0.51                 | 0.62            | 504,379                    |
| Propellant (M51A5/M6)                             | 0                     | 8.82               | 0                    | 0.41            | 290,081                    |
| Detonator/ignition cartridge (M22)                | 0                     | 0                  | 0                    | 0.1             | 9,711                      |
| Explosive material (tetryl/tetrytol) <sup>c</sup> | 0.414                 | 0.308              | 0.308                | 0.144           | 256,156                    |
| Weights totals (lb)                               | 1.24                  | 11.75              | 0.82                 | 2.67            | 1,256,430                  |

<sup>a</sup> The M60 stockpile of chemical munitions with fuzes and propellants removed.

<sup>b</sup> The munitions nomenclature in parentheses refers to the munitions type columns from left to right (e.g., the M17 fuzes are in the M60 projectiles and the M8 fuzes are in the M2/M2A1 mortars).

<sup>c</sup> The Division 1.1 explosives are incorporated into the energetics components, predominately in the bursters.

product of transportation and cargo-related accident probabilities times the consequences of the explosion event.

Division 1.1 explosives are of most concern in terms of hazard because of explosive damage that could occur during transportation. This is the only group of explosives within the six DOT Divisions that can detonate and explode (49 CFR 173.50). Of the half-dozen or so explosive compounds contained in the chemical munitions at PCD, only tetryl and tetrytol are Division 1.1 explosives. The mass of these two explosives is contained within the energetics components listed in Table 4. Most of the mass of the Division 1.1 explosives (84% for the 105-mm projectiles to 100% for the 155-mm projectiles) is contained in the bursters.

Although the Army does not currently use tetryl or tetrytol as a burster explosive in any of its conventional munitions (Nguyen 2002), these two explosives are common to the chemical stockpile's booster/burster components. This is mainly because tetryl and tetrytol are

sufficiently insensitive when compressed so as to be considered relatively safe in storage and when being moved on munitions pallets (Little 2002). However, either of these explosives can be initiated from flame and can burn readily, making them quite likely to detonate and explode if burned in large quantities. An explosive detonation can also be initiated from friction, shock, or sparks.

## 4.2 Explosion Probabilities and Effects

The probabilities of explosion events used in these analyses are based on historical frequencies of explosions from shipments of explosive materials. To determine the risk, the explosion probability is multiplied by the resulting consequence. The consequence is estimated as the product of blast overpressure or fireball hazard zone times the associated population density, typically estimated within an 800-m buffer zone, along the designated shipment route. The computed explosion effects are the number of people potentially injured or killed by blast overpressure (2.5 psi for injury and 7 to 20 psi for fatality)<sup>6</sup> and thermal radiation effects (e.g., injury from skin burns and fatalities from exceedances of specified thermal dosage threshold levels). The Chemical Accident Stochastic Risk Assessment Model (CASRAM) results provide the sum of the thermal and blast overpressure effects.



In a vehicle accident, a cargo explosion could result from either a fire that accompanies the accident or from the crash-impact of the vehicle. Although Division 1.1 explosives can detonate as a result of the impact and associated accident crush forces, explosions resulting from impact initiators are rarer than fire-initiated events. The probability of an explosion given a truck-cargo explosive shipment accident, with a fire, can be calculated by multiplying the probability of a fire given an accident by the probability of an explosion given a fire ( $P(E_f/A) = P(F/A) \times P(E/F)$ ). On the basis of the analysis of accident reports filed by commercial carriers, Dennis et al. (1977) estimated  $P(F/A)$  to be 1.6%. On the basis of the analysis of some limited data by Clarke et al. (1976), the probability of explosion given a fire ( $P(E/F)$ ) was estimated to be around 40%. The probability of an explosion given an accident with a fire is thus equal to 0.64%, or one chance per 160 accidents. The probability of impact or crush-initiated explosions is only 0.25%. For fire-initiated events, 100% of the explosive load would be involved in the explosion about 50% of the time.

Damage that comes from cargo detonations caused by a truck or rail accident depends on a number of factors, including the mass quantity and characteristics of explosive material being shipped. The hazard to people and the damage to nearby structures from an explosion are basically caused by the formation and rapid propagation of a shock wave and by the thermal radiation emanating from the explosive discharge. The blast-generated shock wave and radiated heat, typically in the form of a fireball, move rapidly away from the explosion source and produce an “overpressure burden” or cause thermal stress upon reaching a person and/or structure. Depending on the magnitude of the created overpressure and the released heat, injury, severe damage or destruction, or death can result. The thermal effects of blast-generated

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<sup>6</sup> These are the injury and fatality thresholds used in the DOT’s National Transportation Risk Assessment (NTRA) (Brown 2000). The NTRA used a blast overpressure of 7 psi for 50% fatality and 20 psi for 100% fatality. The 100% fatality level was set to reasonably account for the combination of direct, secondary, and tertiary blast effects that would make survival very unlikely.

fireballs are usually associated with explosions involving the transportation of liquefied or pressurized gases, such as propane. However, explosions involving the shipment of relatively stable explosive solid materials, such as TNT or tetryl, can also produce a significant thermal hazard in excess of that produced by the blast overpressure. The hazard dominance of secondary blast overpressure effects or thermal effects depends on the explosion size.

When the explosive mass is relatively large, thermal effects tend to be more important. For example, for explosions involving a mass of more than 10,000 kg, thermal effects are dominant in terms of injuries and they are slightly more important in terms of fatalities. However, for smaller explosions, secondary blast effects become more important. For 1,000-kg mass explosions, secondary blast effects dominate the fatalities, and thermal effects and blast effects contribute equally to injuries. For 100-kg explosions, secondary blast effects dominate over thermal effects for both injuries and fatalities. The shipment weights for the PCD energetics components range from about 2,000 lb to more than 12,000 lb for truck shipments and from about 5,000 lb to more than 31,000 lb for rail shipments.

### **4.3 Modeling and Analysis Approach**

Damage resulting from the blast overpressure of an explosion can produce direct injury or fatality effects due to blast-induced pressure on human tissue and can produce indirect injury or fatality from blast-generated debris or projectiles. The principal human hazard effect associated with explosions is internal organ damage (e.g., lung damage), perforation of human tissue (e.g., eardrum failure), or blunt trauma. A commonly employed approach in estimating blast overpressure-caused injuries and fatalities is a method based on “Sachs scaling” and also referred to as the Baker or the Baker-Strehlow method (Baker et al. 1983; Strehlow et al. 1979). The method relies on calculations of scaled nondimensional distances to generate graphical readings of scaled peak pressure and impulse. The scaled pressures are typically estimated from curves generated from experimental data. The use of scaling laws is also common in estimating the thermal effects of explosions (Baker et al. 1983). The thermal radiation from explosions can contribute to explosion-produced injuries or fatalities by adding minor to severe skin burns to the resulting overpressure burden effects.

These scaling methods have been adopted in a stochastic consequence model (CASRAM) that is used in estimating explosion injury and fatality risk from the shipment of explosive materials. CASRAM has also been used in estimating risk from chemical exposures and fires due to hazardous cargo shipments (Brown et al. 2000). CASRAM is capable of estimating explosive hazards that include (1) direct effects from the blast overpressure, (2) secondary effects of blast overpressure due to projectiles from blast-generated debris, (3) tertiary effects of whole-body blast displacement, and (4) direct thermal heat stress effects due to air explosion-generated fireballs.

The CASRAM/WebTRAGIS-estimated explosion risk for a specific route was calculated using the CASRAM explosion event algorithms (including associated probabilities of explosion events, such as P[F/A] and the 50% chance of a full explosive load detonation), along with input from WebTRAGIS of calculated route segment distances and populations, and user inputs of explosive mass and blast energy. The explosive’s blast energy or blast-specific energy (in MJ/kg) and the estimated total explosion energy (in MJ) are used by CASRAM in computing blast

overpressure and thermally generated blast effects. The theoretical mass-specific energy or blast energy for tetryl is 6.07 MJ/kg, with an experimental value of 4.56 MJ/kg (Little 2002). The CASRAM simulations used the mass-specific energy value for TNT (4.68 MJ/kg), which is slightly more conservative than the experimentally derived tetryl value. CASRAM also interpolates meteorology for time and location from a tabulated historical surface National Weather Service meteorological database. The model uses the meteorological data to estimate the propagation and degradation with distance of the blast pressure wave and thermal radiation. The route-specific CASRAM/WebTRAGIS analysis also accounts for the along-route population densities, with data obtained from the 2000 census.

The maximum cargo weight of tetryl or tetrytol per shipment was determined from the packaging and shipping requirements for each of the energetics components. The weight of Division 1.1 explosive material (tetryl and tetrytol) per shipment was determined for each of the separately packaged munitions energetics components. Shipments can be assembled into seven groups of energetics components with Division 1.1 explosive content, and by the specific energetics components to be shipped, as specified in Appendix C. The number of shipments and maximum truck explosive cargo shipment weights for each munitions type are summarized in Table 6. The shipments of 155mm projectile bursters (M104s) have the largest weight of explosives per shipment. Since these shipments are also the largest in number, they represent the greatest risk among the three energetics component munitions groups to be transported under Option C.

**TABLE 6 Explosive Mass per Shipment and Number of Truck and Rail Shipments<sup>a</sup>**

| Munitions<br>(component<br>nomenclature) <sup>a</sup> | Truck Shipments |     |                     |        |                      |         | Rail Shipments |     |                     |        |                      |         |
|---|-----------------|-----|---------------------|--------|----------------------|---------|----------------|-----|---------------------|--------|----------------------|---------|
|   | Shipment        |     | Weight per Shipment |        | Total Weight Shipped |         | Shipment       |     | Weight per Shipment |        | Total Weight Shipped |         |
|   | Group           | No. | lb                  | kg     | lb                   | kg      | Group          | No. | lb                  | Kg     | lb                   | kg      |
| M60 (M5 bursters)                                     | 1               | 9   | 10,955              | 4,969  | 98,595               | 44,722  | 1              | 3   | 32,865              | 14,907 | 98,595               | 44,722  |
| M60 (M51A5 fuse/booster)                              | 2               | 5   | 3,768               | 1,709  | 18,841               | 8,546   | 2              | 2   | 9,421               | 4,273  | 18,842               | 8,547   |
| M60 (detonator)                                       | 3               | 3   | 22                  | 10     | 66                   | 30      | 3              | 1   | 66                  | 30     | 66                   | 30      |
| M60 (primer)  | 4               | 1   | 203                 | 92     | 203                  | 92      | 4              | 1   | 203                 | 92     | 203                  | 92      |
| M2 (M14 burster/M8 fuzes)                             | 5               | 8   | 1,741               | 789    | 13,928               | 6,318   | 5              | 3   | 4,643               | 2,106  | 13,929               | 6,318   |
| M2 (charge relays)                                    | 6               | 2   | 14                  | 6.4    | 28                   | 13      | 6              | 1   | 28                  | 12.7   | 28                   | 13      |
| M104 (M6 charge burster)                              | 7               | 10  | 12,410              | 5,629  | 124,100              | 56,291  | 7              | 4   | 31,025              | 14,073 | 124,100              | 56,291  |
| Shipment Totals                                       |                 | 38  | 29,113              | 13,204 | 255,764              | 116,012 |                | 15  | 78,251              | 35,494 | 255,763              | 116,013 |

<sup>a</sup> The shipments involving the M8 propellant in the M2/M2A1 mortars are not included for the reason given in Section 4.3.1.

<sup>b</sup> M60s = 105-mm projectiles, M2/M2A1 = 4.2-in mortars, and M104s = 155-mm projectiles.

#### 4.4 Risk Results

The stochastic model (CASRAM) was applied in estimating the cargo risks in conjunction with using the routing analysis generated by WebTRAGIS. As mentioned above, there would be three fewer highway shipments (38 rather than 41) and one less railway shipment (15 rather than

16) required in assessing explosive cargo risk versus the noncargo risk. This difference is because of the absence of Division 1.1 explosive material in three of the truck and one of the rail shipments of the M8 propellant that would be removed, cleaned/decontaminated, and packaged for shipping. The difference is only relevant to the analysis of the explosive shipment risk and not to the actual required number of shipments of the energetics components. The M8 propellants do have extremely flammable material (e.g., nitrocellulose mixture) but are not Division 1.1 explosives.

The risk modeling analysis was based on the shipment weights and shipment frequencies given in Table 6. The seven energetics packaging groups listed in Table 6 and used for the risk assessment are based on the packaging requirements provided by the DAC in McAlister, Oklahoma (see Appendix C). The weights of the energetics were calculated from the unit weight of each component from data obtained in the MIDAS database (U.S. Army 2002).

Table 7 summarizes the cargo explosion-related and vehicle crash-related injury and fatality risk results from the CASRAM calculations. These results represent the probability that an accident will result in injuries and fatalities because of physical trauma and the release of hazardous cargo (i.e., detonation and explosion). The vehicle crash impact and the cargo explosion risk per truck and rail shipment, and the total shipment risk for the PCD chemical munitions stockpile energetics under Option C, are evaluated for four alternative shipment locations: Hawthorne, Nevada; Sauget, Illinois; Joplin, Missouri; and Colfax, Louisiana. Although the truck shipment risk to Colfax<sup>7</sup> is provided, the TSDF venter at this location does have a restriction on waste manifests with explosive material containing lead azide. The munitions subcomponents containing lead azide, including the weights of the overall mixture, are identified in Table 8. Before shipment to Colfax, these subcomponents would have to be removed. Only the M2/M2A1 mortars and the M60 projectiles containing M557 fuzes would be affected. The total weight of the munition subcomponents containing lead azide is only 588 mg, and none of these components contain a Division 1.1 explosive. Considering none of the explosive weight and a relatively small fraction of the total energetics cargo weight would be involved, the overall number of shipments required would be smaller. Therefore, the total energetics shipment risks presented in this report (Table 7) for shipments to the Colfax facility should be viewed as being slightly more conservative in comparison with the projected risks reported for the other three energetics treatment alternative sites.

The risk analysis shows that crash fatality risk associated with a highway accident while shipping dunnage to Last Chance, Colorado, under Option C is 3 to 5 times more risky than the explosion fatality risk from energetics shipments to the four alternative disposal sites. This is because of the larger number of shipments and longer total distances required for the dunnage cargos compared with the number of shipments total distances required for energetics. For example, although the average transport distance to the four alternative sites is almost 6 times the transport distance to Last Chance, Colorado, the number of required highway shipments to Last Chance is 36 times the number required for moving the energetics to each of the alternative disposal sites. The total number of truck transport miles to Last Chance for the dunnage and metal parts shipments is greater than 14 times the total transport distance required for all of the

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<sup>7</sup> No rail shipments to Colfax are considered because a rail spur is not available at the Colfax TSDF. Source: adapted from Lunt, R., 2002, EXCEL spreadsheet, Arthur D. Little, Boston, Mass., Sept. 12., Transmitted by S. Susman, via email, May 14, 2002

energetics shipments to the closest alternative energetics site (Joplin, Missouri) and 7 times the total distance to the farthest energetics site (Hawthorne, Nevada).

As shown in Table 7, the relative contribution of explosive cargo risk to vehicle-related risk varies, depending on the shipment destination and the mode (truck versus rail) of transportation. In this study, the transportation risk attributable to accidents involving the energetics portion (i.e., explosive material) of the highway risk represents between 5 and 14% of the injuries from the shipment of the energetics cargo by truck. However, the fatality risk due to potential cargo explosions represents a larger percentage, between 30 and 70%, of the total truck shipment risk (cargo + vehicle). The injury risk due to a rail cargo explosion accident represents between 10 and 50% of the total rail shipment injury risk. However, the fatality portion of the rail risk only represents between 7 and 14% of the total rail shipment risk. The fatality risk dominance for hazardous material truck shipments and the injury risk dominance for hazardous material rail shipments shown here are not inconsistent with the findings for explosive and other “dangerous cargo” shipments analyzed in the NTRA (Brown 2002).

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**TABLE 7 Option C (only Energetics Shipments): Cargo- and Vehicle-Related Injury and Fatality Risks from Transportation for Disposal of Assembled Chemical Weapons Stored at Pueblo Chemical Depot<sup>a</sup>**

| TSDF Destination              | Ship Distance (No./km) | Average Injury/Fatality Risk per Munitions Type |                      |                      | Average Cargo Explosion Risk (Energetics) |                      | Crash Injury Risk per Shipment | Crash Fatality Risk per Shipment | Average Non-Cargo Risk (Vehicle) |                      | Overall Average Shipment Risk (Cargo and Noncargo) |                      | Explosive Cargo Risk Fraction |                   |                 |                   |
|-------------------------------|------------------------|---|----------------------|----------------------|---|----------------------|--------------------------------|----------------------------------|----------------------------------|----------------------|--|----------------------|-------------------------------|-------------------|-----------------|-------------------|
|                               |                        | No. of Injuries<br>No. of Fatalities            |                      |                      | No. of Injuries                           | No. of Fatalities    |                                |                                  | No. of Injuries                  | No. of Fatalities    | No. of Injuries                                    | No. of Fatalities    | No. of Injuries               | No. of Fatalities | (% of Injuries) | (% of Fatalities) |
|                               |                        | M60s  | M2/M2A1s             | M104s                |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| <b>Hawthorne, NV</b>          |                        |   |                      |                      |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| Highway Shipments             | 38                     | $5.1 \times 10^{-4}$                            | $6.0 \times 10^{-5}$ | $5.3 \times 10^{-4}$ | $1.1 \times 10^{-3}$                      | $4.0 \times 10^{-4}$ | $4.8 \times 10^{-4}$           | $1.9 \times 10^{-5}$             | $1.8 \times 10^{-2}$             | $7.1 \times 10^{-4}$ | $1.94 \times 10^{-2}$                              | $1.1 \times 10^{-3}$ | 5.7%                          | 36.1%             |                 |                   |
|                               | 1,948                  | $1.8 \times 10^{-4}$                            | $2.2 \times 10^{-5}$ | $1.9 \times 10^{-4}$ |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| Railway Shipments             | 15                     | $1.8 \times 10^{-4}$                            | $2.2 \times 10^{-5}$ | $1.9 \times 10^{-4}$ | $4.0 \times 10^{-4}$                      | $5.9 \times 10^{-5}$ | $2.8 \times 10^{-5}$           | $2.4 \times 10^{-5}$             | $4.2 \times 10^{-4}$             | $3.6 \times 10^{-4}$ | $8.2 \times 10^{-4}$                               | $4.1 \times 10^{-4}$ | 49.0%                         | 14.2%             |                 |                   |
|                               | 2,020                  | $2.7 \times 10^{-5}$                            | $3.2 \times 10^{-6}$ | $2.9 \times 10^{-5}$ |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| <b>Sauget, IL</b>             |                        |   |                      |                      |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| Highway Shipments             | 38                     | $6.3 \times 10^{-4}$                            | $7.4 \times 10^{-5}$ | $6.6 \times 10^{-4}$ | $1.4 \times 10^{-3}$                      | $4.9 \times 10^{-4}$ | $4.1 \times 10^{-4}$           | $1.2 \times 10^{-5}$             | $1.5 \times 10^{-2}$             | $4.7 \times 10^{-4}$ | $1.7 \times 10^{-2}$                               | $9.6 \times 10^{-4}$ | 8.1%                          | 51.0%             |                 |                   |
|                               | 1,423                  | $2.3 \times 10^{-4}$                            | $2.7 \times 10^{-5}$ | $2.4 \times 10^{-4}$ |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| Railway Shipments             | 15                     | $3.3 \times 10^{-5}$                            | $3.9 \times 10^{-6}$ | $3.4 \times 10^{-5}$ | $7.1 \times 10^{-5}$                      | $2.5 \times 10^{-5}$ | $3.1 \times 10^{-5}$           | $1.6 \times 10^{-5}$             | $4.7 \times 10^{-4}$             | $2.4 \times 10^{-4}$ | $5.4 \times 10^{-4}$                               | $2.6 \times 10^{-4}$ | 13.1%                         | 9.4%              |                 |                   |
|                               | 1,506                  | $1.2 \times 10^{-5}$                            | $1.4 \times 10^{-6}$ | $1.2 \times 10^{-5}$ |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| <b>Joplin, MO</b>             |                        |   |                      |                      |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| Highway Shipments             | 38                     | $7.7 \times 10^{-4}$                            | $9.1 \times 10^{-5}$ | $8.1 \times 10^{-4}$ | $1.7 \times 10^{-3}$                      | $6.0 \times 10^{-4}$ | $2.6 \times 10^{-4}$           | $6.5 \times 10^{-6}$             | $9.9 \times 10^{-3}$             | $2.5 \times 10^{-4}$ | $1.2 \times 10^{-2}$                               | $8.5 \times 10^{-4}$ | 14.4%                         | 70.8%             |                 |                   |
|                               | 969                    | $2.8 \times 10^{-4}$                            | $3.3 \times 10^{-5}$ | $2.9 \times 10^{-4}$ |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| Railway Shipments             | 15                     | $1.9 \times 10^{-5}$                            | $2.3 \times 10^{-6}$ | $2.0 \times 10^{-5}$ | $4.2 \times 10^{-5}$                      | $1.4 \times 10^{-5}$ | $2.5 \times 10^{-5}$           | $1.2 \times 10^{-5}$             | $3.7 \times 10^{-4}$             | $1.8 \times 10^{-4}$ | $4.2 \times 10^{-4}$                               | $1.9 \times 10^{-4}$ | 10.1%                         | 7.3%              |                 |                   |
|                               | 1,197                  | $6.4 \times 10^{-6}$                            | $7.8 \times 10^{-7}$ | $6.8 \times 10^{-6}$ |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| <b>Colfax, LA<sup>b</sup></b> |                        |   |                      |                      |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |
| Highway Shipments             | 38                     | $7.1 \times 10^{-4}$                            | $8.4 \times 10^{-5}$ | $7.5 \times 10^{-4}$ | $1.5 \times 10^{-3}$                      | $5.6 \times 10^{-4}$ | $6.8 \times 10^{-4}$           | $1.9 \times 10^{-5}$             | $2.6 \times 10^{-2}$             | $7.3 \times 10^{-4}$ | $2.8 \times 10^{-2}$                               | $1.3 \times 10^{-3}$ | 5.6%                          | 43.3%             |                 |                   |
|                               | 1,576                  | $2.6 \times 10^{-4}$                            | $3.1 \times 10^{-5}$ | $2.7 \times 10^{-4}$ |   |                      |                                |                                  |                                  |                      |  |                      |                               |                   |                 |                   |

<sup>a</sup> For completeness, nonexplosive cargo shipment and vehicle-related risks are also included. Values are rounded to two significant figures. See Table 4 for agent hydrolysate and solid waste shipment.

<sup>b</sup> Only highway shipments to this destination are considered because a rail spur is not available at the Colfax TSDF.

**TABLE 8 Munitions Components Containing Lead Azide, Per Component**

| <b>Munitions Type</b>                 | <b>Component<sup>a</sup></b>          | <b>Weight (mg)</b> | <b>Composition (% by weight)</b>   |
|---------------------------------------|---------------------------------------|--------------------|--|
| <b>M2/M2A1</b><br>(4.2-in. cartridge) | <b>Detonator, M22</b>                 | 50.0               | Overall Mixture:<br>33.4 Potassium chlorate<br>33.3 Antimony sulfide<br>28.3 Lead azide<br>5.0 Carborundum |
|                                       | Upper charge<br>(Primer Mixture AN-6) |                    |  |
|                                       | Intermediate charge                   | 140.0              | Lead azide   |
|                                       | <b>Fuze, M51A5</b>                    |                    |  |
|                                       | Booster, M21A4                        | 230.0              | Lead azide   |
|                                       | <b>Detonator, M24</b>                 | 68.0               | Overall mixture:<br>33.4 Potassium chlorate<br>33.3 Antimony sulfide<br>28.3 Lead azide<br>5.0 Carborundum |
|                                       | Upper Charge                          |                    |  |
| <b>M60</b><br>(105-mm cartridge)      | <b>Fuze, M557</b>                     | 100.0              | Lead azide   |
|                                       | Relay                                 |                    |  |

The analysis shows that overall, truck shipments of energetics to Colfax, Louisiana, would pose the largest injury and fatality risk, and shipments to Joplin, Missouri, and would pose the smallest injury and fatality risk of the four alternatives TSDF sites evaluated under Option C. The transportation alternative site posing the largest highway injury risk has a risk more than a factor of 2 larger than the lowest risk site. For the destination TSDF site posing the largest fatality risk that risk is about 50% larger than the lowest risk destination site. For rail shipments of energetics, the shipments to Hawthorne, Nevada, pose the largest injury and fatality risk, and shipments to Joplin, Missouri, pose the smallest injury and fatality risk of the four alternative TSDF sites evaluated under Option C. The Colfax TSDF site does not have a rail hub, thus, no rail transport risks are given for that site in Table 7. For rail transportation to the alternative site with the largest injury risk, that risk is about 40% larger than for the lowest rail injury risk site, and the risk for the largest rail transportation fatality risk alternative site is slightly more than a factor of 2 larger than for the lowest risk site.

Overall, the combined vehicle- and cargo-related risks contributed by the energetics shipments under Option C are small in comparison with the vehicle-related risks associated with the large numbers of shipments and/or large shipment distances for agent hydrolysate and metal parts/dunnage-ash (see Table 9). The agent hydrolysate shipments contribute from 65 to 85% of the injury risk and around 75% of the fatality risk under Option C. If Vernon, California and/or Dayton, Ohio are chosen for final agent hydrolysate disposal by truck, this would be the lowest overall risk alternative for highway injuries and fatalities, respectively. Alternatively, the overall highest risk would result if Deepwater, New Jersey and/or Detroit, Michigan were selected as the alternative hydrolysate TSDF sites. The upper and lower agent hydrolysate and overall risk values are shown in the ranges given in Table 9.

Overall, the total risks for Option C are very similar to those of Option B, and about 2 to 4 times those of Option A. However, all the transportation options are estimated to result,

statistically, in less than 1 fatality and less than 1 injury over the entire campaign, meaning that no fatality or injuries would be expected.

**TABLE 9. Option C Risk Summary**

| Shipment Type    | Risks <sup>a</sup>                          |                                   |  |                                |
|------------------|---|-----------------------------------|--|--------------------------------|
|                  | Metal Parts and<br>Dunnage/Ash<br>Shipments | Agent<br>Hydrolysate<br>Shipments | Energetics<br>(explosives )<br>Shipments | Option C<br>Range in<br>Totals |
| <b>Truck</b>     |   |                                   |  |                                |
| Total injuries   | 0.11  | 0.23–0.71                         | 0.012–0.028                              | 0.36–0.85                      |
| Total fatalities | 0.0041                                      | 0.015–0.022                       | 0.0009–0.0013                            | 0.02–0.03                      |
| <b>Rail</b>      | (No Rail Hub)                               |                                   |  |                                |
| Total injuries   | 0.11 (truck)                                | 0.01–0.026                        | 0.0004–0.0008                            | 0.12–0.14                      |
| Total fatalities | 0.0041 (truck)                              | 0.008–0.015                       | 0.0002–0.0004                            | 0.012–0.02                     |

<sup>a</sup> Risks for dunnage and hydrolysate shipments are vehicle-related risks (see Table 3); cargo-related risks are negligible for these shipments. Risks for energetics shipments are combined vehicle- and cargo-related risks (see Table 6).

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## **APPENDIX A:**

### **Pueblo Fast Path Assumptions<sup>1</sup>**

#### **Option A: Basic Assumptions**

1. Any and all construction (both inside and outside the fence) can begin based on a Consent Agreement (like at the Aberdeen Chemical Agent Disposal Facility [ABCDF]) with the regulators prior to the issuance of an approved Resource Conservation and Recovery Act (RCRA) Part B Permit.
2. Enhanced reconfiguration (propellant, bursters, and fuzes) is initiated as early as possible, in a separate building (other than the Munitions Demilitarization Building [MDB] housing the agent/dunnage processing trains) with its own utilities under a Consent Agreement prior to the issuance (if required) of an approved RCRA Part B Permit.
3. Enhanced reconfiguration (780,078 munitions) operations will require 36-month duration and will begin 22 months prior to the start of agent processing (Pilot Test).
4. Energetics (propellant, bursters, and fuzes) are treated on-site independent of agent processing (hydrolysis), in a separate building (other than the MDB housing the agent/dunnage processing trains) during agent processing (hydrolysis). No energetics components are shipped off-site for treatment/disposal.
5. The MDB housing the agent/dunnage processing trains will not require any explosive containment rooms (ECRs).
6. Dunnage (wood pallets) is decontaminated (Demilitarization Protection Ensemble XXX [DPE 3X]) on-site with 90% (by weight) shipped off-site for final disposal (landfill) and 10% (by weight) assumed to fail 3X and treated in a metal parts treater (MPT) on-site; all DPE will be treated on-site in the MPT.
7. Agent hydrolysate will be treated on-site in a biotreatment system.
8. Energetics hydrolysate will be mixed with the agent hydrolysate and treated on-site in a biotreatment system.

#### **Option A: Design Assumptions**

1. The Pueblo Chemical Depot (PCD) can deliver the necessary quantity of munitions to the Pueblo Chemical Agent Disposal Pilot Plant (PCAPP) during a normal work week (5 days, 8 hours/day). The PCAPP will have sufficient storage capacity so that the operating rates are not constrained during the periods of time when the PCD is not delivering munitions.

2. The facility will have an availability of 63%. The availability is based on the analysis that was conducted by Arthur D. Little for the General Atomics Total Solution (GATS) and presented in its June 8, 2001, report "Design, Safety, Schedule, and Cost Assessment of General Atomics Total Solution," and for the Parsons/Honeywell Total Solution and presented in its June 8, 2001, report "Design, Safety, Schedule, and Cost Assessment of Parsons/Honeywell WHEAT Total Solution."
3. Three agent-processing lines have been included in the Pueblo Fast Path Design (cryobath/cyropress, projectile rotary hydrolyzers, and heated discharge conveyors [HDCs]). This is the same design proposed in the GATS Engineering Design Package (EDP), with one additional line. Each cryopress can operate at a maximum rate of 60 155-mm projectiles/h, 80 105-mm projectiles/h, and 80 4.2-in. mortars/h. The peak rate through the agent-processing lines is 135 155-mm projectiles/h (the rate limiting step is the HDC), 240 105-mm projectiles/h, and 240 4.2-in. mortars/h (the rate limiting step for both the 105-mm projectiles and the 4.2-in. mortars is the cryopress); the design rate is 120 155-mm projectiles/h, 180 105-mm projectiles/h, and 180 4.2-in. mortars/h.
4. Upon award of the System Contract, the contractor will begin the design of the agent line in order to perform full-scale integration testing of the cryopress and rotary hydrolyzers as early as possible.
5. Six agent hydrolysate reactors (AHRs) have been included in the Fast Path Design. These are of the same design as those proposed in the GATS EDP, with two additional reactors. At the design rate for the three munitions types, there is an AHR cycle time of 9.6 to 26 hours. The Army's minimum required cycle time is six hours.
6. Each MPT is designed to process 10% of the wood pallets (assumed to fail the 3X decon) and 100% of the DPE suits. Ninety percent (90%) of the wood is assumed to be uncontaminated and shipped off-site for disposal.
7. Two energetics rotary hydrolyzers (ERHs) followed by energetics hydrolysis reactors (EHRs) will be installed in a separate building to treat all bursters. The fuzes and the propellant will be processed in the MPT, along with the contaminated wood and all DPE.
8. The immobilized cell bioreactor (ICB) has been replaced by three sequencing batch reactors (SBRs) for the treatment of the energetics and agent hydrolysates. The ICBs were not considered to be technically feasible or cost-effective, considering the increased operating rates. The Pueblo SBR design is based on the ABCDF SBR design. Three 1.3 million gal tanks will be used, and the hydraulic retention time (HRT) has been increased to 10 days from the 5 days for the ICBs.
9. A water purge will be taken off the SBR effluent and treated in the Brine Reduction System (BRS). The remainder of the SBR effluent will be recycled and used to dilute the incoming agent and energetics hydrolysates. The purge has been sized to maintain a 5% total dissolved solids in the SBR feed stream. The BRS is the same size as the GATS system proposed by Arthur D. Little in its June 8, 2001, report. The BRS will produce a salt cake that will be disposed of off-site as a nonhazardous waste.

10. The SBRs will produce more sludge than the ICBs were estimated to generate. Therefore, the sludge from the SBRs will not be processed in the BRS as proposed in the WHEAT design. Rather, the sludge will be dewatered in a filter press prior to being disposed of off-site as a nonhazardous waste. The sludge is considered a nonhazardous waste because it is anticipated to be delisted. In addition, the U.S. Department of Defense Program Manager for Assembled Chemical Weapons Assessment (PMACWA) Engineering Design Studies (EDS) I Testing showed that the biotreatment sludge did not exhibit the characteristics of a RCRA waste.

### **Option B: Basic Assumptions**

1. Any and all construction (both inside and outside the fence) can begin based on a Consent Agreement (like at ABCDF) with the regulators, prior to the issuance of an approved RCRA Part B Permit.
2. Enhanced reconfiguration (propellant, bursters, and fuzes) is initiated as early as possible, in a separate building (other than the MDB housing the agent/dunnage processing trains), with its own utilities under a Consent Agreement prior to the issuance (if required) of an approved RCRA Part B Permit.
3. Enhanced reconfiguration (780,078 munitions) operations will require duration of 36 months and will begin 22 months prior to start of agent processing (Pilot Test).
4. Energetics (propellant, bursters, and fuzes) are treated on-site; no energetics are shipped off-site for treatment/disposal.
5. Energetics (propellant, bursters, and fuzes) is treated independent of agent processing (hydrolysis), in a separate building (other than the MDB housing the agent/dunnage processing trains), during agent processing (hydrolysis).
6. The MDB housing the agent/dunnage processing trains will not require any ECRs.
7. Dunnage (wood pallets) is decontaminated (3X) on-site with 90% (by weight) shipped off-site for final disposal (landfill) and 10% (by weight) assumed to fail 3X and treated in the MPT on-site; all DPE will be treated on-site in the MPT.
8. Energetics and agent hydrolysates will be shipped off-site for disposal (biotreatment).

### **Option B: Design Assumptions**

1. The PCD can deliver the necessary quantity of munitions to the PCAPP during a normal work week (5 days, 8 hours/day). The PCAPP will have sufficient storage capacity so that the operating rates are not constrained during the periods of time when the PCD is not delivering munitions.

2. The facility will have an availability of 69%. The availability is based on the analysis that was conducted by Arthur D. Little for GATS and presented in its June 8, 2001, "Design, Safety, Schedule, and Cost Assessment of General Atomics Total Solution."
3. Three agent-processing lines have been included in the Pueblo Fast Path Design (cryobath/cyropress, projectile rotary hydrolyzers, and HDCs). This is the same design proposed in the GATS EDP, with one additional line. Each cryopress can operate at a maximum rate of 60 155-mm projectiles/h, 80 105-mm projectiles/h, and 80 4.2-in. mortars/h. The peak rate through the agent-processing lines is 135 155-mm projectiles/h (the rate limiting step is the HDC), 240 105-mm projectiles/h, and 240 4.2-in. mortars/h (the rate limiting step for both the 105-mm projectiles and the 4.2-in. mortars is the cryopress); the design rate is 120 155-mm projectiles/h, 180 105-mm projectiles/h, and 180 4.2-in. mortars/h.
4. Upon award of the System Contract, the contractor will begin the design of the agent line in order to perform full-scale integration testing of the cryopress and rotary hydrolyzers as early as possible.
5. Six AHRs have been included in the Fast Path Design. These are of the same design as those proposed in the GATS EDP, with two additional reactors. At the design rate for the three munitions types, there is an AHR cycle time of 9.6 to 26 hours. The Army's minimum required cycle time is six hours.
6. Each MPT is designed to process 10% of the wood pallets (assumed to fail the 3X decon) and 100% of the DPE suits. Ninety percent (90%) of the wood is assumed to be uncontaminated and shipped off-site for disposal.
7. Two ERHs followed by EHRs will be installed in a separate building to treat all bursters. The fuzes and the propellant will be processed in the MPT, along with the contaminated wood and all DPE.
8. The agent and energetics hydrolysates are assumed to be shipped off-site to DuPont's Chambers Works (biotreatment) in Deepwater, New Jersey. The hydrolysates will be shipped by tanker truck to a rail transfer facility (cost included in PCAPP capital cost estimate), approximately 20 mi from the PCAPP and from there by rail to DuPont.

### **Option C: Basic Assumptions**

1. Energetics (propellant, bursters, and fuzes) are shipped off-site to Hawthorne Army Ammunition Plant (AAP) for treatment/disposal<sup>8</sup>
2. Agent hydrolysate will be shipped off-site for disposal (biotreatment).
3. Any and all construction (both inside and outside the fence) can begin based on a Consent Agreement (like at ABCDF) with the regulators, prior to the issuance of an approved RCRA Part B Permit.

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<sup>2</sup> The transportation risk assessment assumed the energetics hydrolysate would be treated and disposed of on-site.

4. Enhanced reconfiguration (propellant, bursters, and fuzes) is initiated as early as possible, in a separate building (other than the MDB housing the agent/dunnage processing trains), with its own utilities under a Consent Agreement prior to the issuance (if required) of an approved RCRA Part B Permit.
5. Enhanced reconfiguration (780,078 munitions) operations will require duration of 36 months and will begin 22 months prior to start of agent processing (Pilot Test).
6. The MDB housing the agent/dunnage processing trains will not require any ECRs.
7. Dunnage (wood pallets) will be decontaminated (3X) on-site with 90% (by weight) shipped off-site for final disposal (landfill) and 10% (by weight) assumed to fail 3X and treated in the MPT on-site; all DPE will be treated on-site in the MPT.

### **Option C: Design Assumptions**

1. The PCD can deliver the necessary quantity of munitions to the PCAPP during a normal work week (5 days, 8 hours/day). The PCAPP will have sufficient storage capacity so that the operating rates are not constrained during the periods of time when the PCD is not delivering munitions.
2. The facility will have an availability of 69%. The availability is based on the analysis that was conducted by Arthur D. Little for GATS and presented in its June 8, 2001, report "Design, Safety, Schedule, and Cost Assessment of General Atomics Total Solution."
3. Three agent-processing lines have been included in the Pueblo Fast Path Design (cryobath/cyropress, projectile rotary hydrolyzers, and HDCs). This is the same design proposed in the GATS EDP, with one additional line. Each cryopress can operate at a maximum rate of 60 155-mm projectiles/h, 80 105-mm projectiles/h, and 80 4.2-in. mortars/h. The peak rate through the agent-processing lines is 135 155-mm projectiles/h (the rate limiting step is the HDC), 240 105-mm projectiles/h, and 240 4.2-in. mortars/h (the rate limiting step for both the 105-mm projectiles and the 4.2-in. mortars is the cryopress); the design rate is 120 155-mm projectiles/h, 180 105-mm projectiles/h, and 180 4.2-in. mortars/h.
4. Upon award of the System Contract, the contractor will begin the design of the agent line in order to perform full-scale integration testing of the cryopress and rotary hydrolyzers as early as possible.
5. Six AHRs have been included in the Fast Path Design. These are of the same design as those proposed in the GATS EDP, with two additional reactors. At the design rate for the three munitions types, there is an AHR cycle time of 9.6 to 26 hours. The Army's minimum required cycle time is six hours.
6. Each MPT is designed to process 10% of the wood pallets (assumed to fail the 3X decon) and 100% of the DPE suits. Ninety percent (90%) of the wood is assumed to be uncontaminated and shipped off-site for disposal.

7. The energetics is assumed to be shipped off-site to Hawthorne AAP for disposal (incineration).
8. The agent hydrolysate is assumed to be shipped off-site to DuPont's Chambers Works (biotreatment) in Deepwater, New Jersey. The hydrolysate will be shipped by tanker truck to a rail transfer facility (cost included in PCAPP capital cost estimate), approximately 20 mi from the PCAPP and from there by rail to DuPont.

## APPENDIX B:

### Health Hazards Associated with Products of Mustard (HD) and Energetics Hydrolysis

#### B.1 Mustard (HD) Hydrolysate<sup>1</sup>

The product of HD hydrolysis (i.e., hydrolysate) is tested to verify that all of the HD has been destroyed to below 200 ppb. At this level, a soldier could drink water contaminated with HD for 5 days without any immediate (acute) or long-term (chronic) adverse health effects. At levels below 200 ppb, HD is not considered an ingredient (per Occupational Safety and Health Administration [OSHA] hazard communication standard).

The liquid that results from the hydrolysis process is a mixture with a composition as shown in Table B.1.

**TABLE B.1 HD Hydrolysate Mixtures Constituents**

| <b>3.8 wt% HD Hydrolysate</b>             | <b>15 wt% HD Hydrolysate</b>              |
|---|---|
| Water 88–97 wt% (percent by weight)       | Water 68–80 wt%                           |
| Thiodiglycol 2.7 wt%                      | Thiodiglycol and sulfonium ions 10–20 wt% |
| Sodium chloride 1.5 wt%                   | Sodium chloride 10–12 wt%                 |
| Other sulfur containing compounds 0–2 wt% |   |

Thiodiglycol (TDG) is widely used in industry and is shipped throughout the country. It is recognized as an eye and skin irritant whose toxicological properties are not fully investigated. The lack of additional follow-up studies might be because of the relatively innocuous results from the initial studies. The initial toxicity studies results do not indicate a cause for concern that would warrant additional studies. In its pure form, TDG is not considered by the U.S. Department of Transportation (DOT) to be a hazardous material and hazard warning placards or labels are not required.

Although direct comparison of raw toxicological data between studies and compounds (Table B.2) does not provide a quantitative risk assessment without an in-depth examination of the respective studies, an examination of similar studies will provide a high-level or qualitative comparison of the relative hazards and risks posed by individual compounds.

ORL-RAT LD50 means the lethal dose of the chemical (mg) per unit body weight (kg) that kills 50% of rats fed orally. As expected, the toxicity of sugar is very low, and only a very large dose would be lethal. Alcohol is more toxic than sugar, followed by TDG, baking soda, salt, caffeine, nicotine, and strychnine. The following is a pictorial representation of the sliding scale.

<sup>1</sup> Sources for Section B.1: adapted from Mason (2002); Starnes (2002).

|                             |  |   |                         |
|-----------------------------|--|---|-------------------------|
| Slightly<br>Toxic<br>HR = 1 | Sugar  | Alcohol TDG Baking Soda Salt Caffeine Nicotine Strychnine | Very<br>Toxic<br>HR = 3 |
|                             | ←-----Decreasing toxicity/hazards/risk-----<         |   |                         |
|                             | >-----Increasing toxicity/health hazards/risks-----→ |   |                         |

**TABLE B.2 Comparison of Rat Toxicity Studies Data**

| Compounds (pure)                     | Toxicity Data (lethal rat dose) <sup>a</sup> | Hazard Rating (HR) <sup>b,c</sup> |
|--------------------------------------|--|-----------------------------------|
| HD Hydrolysate Ingredients           |  |                                   |
| Thiodiglycol (TDG)                   | ORL-RAT-LD50 = 6,610 mg/kg                   | 2                                 |
| Sodium chloride (salt)               | ORL-RAT-LD50 = 4,000 mg/kg                   | 2                                 |
| Common compounds people ingest daily |  |                                   |
| Sucrose (cane sugar)                 | ORL-RAT-LD50 = 29,700 mg/kg                  | 1                                 |
| Ethanol (alcohol)                    | ORL-RAT-LD50 = 7,060 mg/kg                   | 3                                 |
| Sodium bicarbonate (baking soda)     | ORL-RAT LD50 = 4,220 mg/kg                   | 1                                 |
| Caffeine                             | ORL-RAT-LD50 = 192 mg/kg                     | 3                                 |
| Nicotine                             | ORL-RAT-LD50 = 50 mg/kg                      | 3                                 |
| Known hazardous chemicals            |  |                                   |
| Strychnine                           | ORL-RAT-LD50 = 2.35 mg/kg                    | 3                                 |
| Gasoline                             | IHL-RAT-LC50 = 300 g/m <sup>3</sup> /h       | 3                                 |

<sup>a</sup> Source: Lewis (2000).

<sup>b</sup> Lewis (2000) uses a relative hazard rating (HR). HR = 1 is slightly toxic or is combustible; HR = 2 is moderately toxic or is flammable; and HR = 3 is highly toxic or flammable, explosive, or extremely reactive.

<sup>c</sup> Received a 2 rating because it is flammable, not because it is toxic.

In conclusion, on the basis of rat toxicity studies, TDG is not an inhalation or dermal hazard and presents only a slight ingestion hazard.

The DOT hazard classifications and evacuation zones for various substances (not regulated or classified by the DOT) are shown in Table B.3. Risks associated with HD hydrolysate shipment spills would be minor when compared to its concentrated ingredients or other commonly transported materials.

Because of the risks involved, shipments of HD hydrolysate through a community are expected to be less hazardous than gasoline shipments of gasoline to local dealerships.

## B.2 Energetics Hydrolysate

The Assembled Chemical Weapons Assessment (ACWA) program has characterized the main components of the liquid energetics hydrolysate through analysis of holding tank contents for hydrolysate of all the munitions types at PCD (i.e., 105-mm HD projectiles; 155-mm HD projectiles, 4.2-in. HD mortars; 4.2-in. HT projectiles). The highest concentration component is water, which is present at levels from 55 to 80%. Other components present at concentrations greater than 0.5% are ammonia, sodium hydroxide, acetate, chloride, cyanide, and formate. One

**TABLE B.3 Comparison of DOT Classification and Evacuation Zones**

| Material           | DOT Classification                         | Small Spill or Leak Evacuation Zone | Large Spill Evacuation Zone | Tanker Truck Fire Evacuation Zone |
|--------------------|--|-------------------------------------|-----------------------------|-----------------------------------|
| HD hydrolysate     | Corrosive Liquid (not otherwise specified) | 25–50 m<br>(80–160 ft)              | 25–50 m<br>(80–160 ft)      | 800 m <sup>a</sup><br>(1/2 mi)    |
| Thiodiglycol (TDG) | Not regulated                              | None                                | None                        | None                              |
| Ethanol            | Ethanol, flammable liquid                  | 25–50 m<br>(80–160 ft)              | 300 m<br>(1,000 ft)         | 800 m<br>(1/2 mi)                 |
| Gasoline           | Gasoline, flammable liquid                 | 25–50 m<br>(80–160 ft)              | 300 m<br>(1,000 ft)         | 800 m<br>(1/2 mi)                 |

<sup>a</sup> These are default values assigned by the DOT for this general category. Because of the high water content of HD hydrolysate (over 88%), the actual risk of a fire occurring would be low.

additional substance, dimethyl sulfate, could be of concern because of its high acute toxicity, although it is present at a low concentration (0.05%) in the hydrolysate. Other constituents are present at very low levels and are not of concern with respect to hazards from accidental releases during transportation.

Of the substances listed above, most have low toxicities and volatilities<sup>2</sup> and would not present a hazard in the event of an accidental spill during transport. Two possible exceptions would be ammonia and dimethyl sulfate, which are chemicals included on the U.S. Environmental Protection Agency's (EPA's) list of "Extremely Hazardous Substances." Ammonia is not listed because of its high acute toxicity, but rather on the basis of its large volume production and the fact that it is an irritating gas that can cause injury when released in pure form in quantities higher than about 100 lb. A spill of ammonia at the concentration found in energetics hydrolysate (less than 1%) would be very unlikely to cause injuries.

Dimethyl sulfate is an extremely toxic liquid; a small inhalation dose or skin contact could prove fatal. The EPA "Level of Concern" for human exposures to dimethyl sulfate corresponds to concentrations in air equal to or greater than 5 mg/m<sup>3</sup> (EPA, FEMA, and DOT 1987). However, at the very dilute concentration present in energetics hydrolysate (0.05%), an accidental spill would be very unlikely to cause injuries.

### B.3 References

Lewis, R.J. (editor), *Dangerous Properties of Industrial Materials*, 10th Ed., Culinary and Hospitality Industry Publications Services. Available at [www.chipsbooks.com/chipssl.htm](http://www.chipsbooks.com/chipssl.htm).

Mason, G., 2002, "Health Risks of HD Hydrolysis Relative to Everyday Exposures," personal communication from Mason to S. Susman, U.S. Department of Defense, SBCCOM, April 17.

<sup>2</sup> A chemical with a "low volatility" does not readily change from a liquid to a gas at a relatively low temperature (e.g., near room temperature).

Starnes, G., 2002, personal communication from Starnes (U.S. Army, SBCCOM), to H. Hartmann (Argonne National Laboratory, Argonne, Ill.), Nov.

EPA, Fema, and DOT (U.S. Environmental Protection Agency, Federal Emergency Management Agency, and U.S. Department of Transportation), 1987, *Technical Guidance for Hazards Analysis -- Emergency Planning for Extremely Hazardous Substances, Appendix D*, Office of Emergency and Remedial Response, Emergency Response Division, Washington, D.C.

## APPENDIX C:

### **Pueblo Chemical Depot Munitions Packaging Requirements for the Assembled Chemical Weapons Assessment Transportation Assessment<sup>1</sup>**

The information contained in this document is relative to the transportation of explosive components resulting from the disassembly of 4.2-in. mortars and 105-mm and 155-mm projectiles potentially to be performed at Pueblo Chemical Depot (PCD) in Pueblo, Colorado. Transportation options, including highway and rail shipment, are listed by item and quantity of van-trailers or railcars required to move each item in Table C.1.

The transportation of these components is based on the following assumptions:

1. All items are in a clean (uncontaminated) and “serviceable” condition (i.e., indicates that the explosive charge is safe to move and not in an unstable condition).
2. All items (except the 105-mm M67 propelling charges) are packed in 48 in. × 40 in. × 40 in. high, triple-wall fiberboard pallet boxes.
3. The 105-mm, M67 propelling charges are packed 100 per 55-gal steel drum (with water and alcohol if required to stabilize the charge).
4. The 4.2-in. fuzes, M8s with M14 bursters, will be shipped as an assembled component, because they are cemented together at assembly.
5. Van-trailers are 48 ft minimum length.
6. Load weight per van-trailer is based on 30,000 lb.
7. Load weight per railcar is based on 88,000 lb.
8. Only one type of item per vehicle to eliminate compatibility issues.
9. Compliance with federal, state, and local regulations to include but not limited to packaging approval and interim hazard classification.

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<sup>1</sup> Source: Adapted from Dougherty, P.E., 2002, personal communication from Dougherty (Defense Ammunition Center, Transportation Engineering Division, McAlester, Okla.) to M. Lazaro (Argonne National Laboratory, Argonne, Ill.), Aug. 8.

**TABLE C.1 Components and the Estimated Number of Van-Trailers or Railcars Required for Transporting**

| <b>4.2 in. Mortars</b>    |                 |             |
|---------------------------|-----------------|-------------|
| Fuze with burster         | 8 van-trailers  | 3 railcars  |
| Propellant                | 3 van-trailers  | 1 railcar   |
| Ignition cartridge        | 2 van-trailers  | 1 railcar   |
| <b>105-mm projectiles</b> |                 |             |
| Fuzes                     | 3 van-trailers  | 1 railcar   |
| Bursters                  | 9 van-trailers  | 3 railcars  |
| Propellant                | 5 van-trailers  | 2 railcars  |
| Primers                   | 1 van trailer   | 1 railcar   |
| <b>155-mm projectiles</b> |                 |             |
| Bursters                  | 10 van-trailers | 4 railcars  |
| Total                     | 41 van-trailers | 16 railcars |