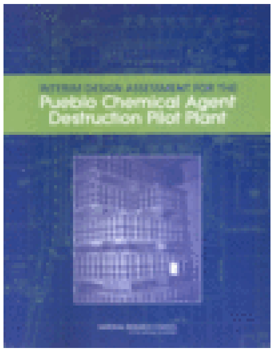

Interim Design Assessment for the Pueblo Chemical Agent Destruction Pilot Plant

Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants, National Research Council

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INTERIM DESIGN ASSESSMENT FOR THE Pueblo Chemical Agent Destruction Pilot Plant

Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants

Board on Army Science and Technology

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Preface

The Program Manager for the U.S. Army's Assembled Chemical Weapons Alternatives (formerly, Assembled Chemical Weapons Assessment) program requested that the National Research Council (NRC) form a committee to review and evaluate the facility design being developed for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) in Pueblo, Colorado. After an elaborate selection process, the Department of Defense (DOD) chose a hydrolysis (neutralization) process followed by a secondary biotreatment process to destroy the chemical agents and energetic materials in the chemical munitions at Pueblo Chemical Depot. The contract for the design for PCAPP was awarded to Bechtel National, Inc., which formed a group with subcontractors, and together they are known as the Bechtel Pueblo team.

This interim report highlights issues that the Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants (referred to as the ACWA Design Committee) has identified on the basis of a review of the information for the initial PCAPP design made available to the committee. Although the committee first met in November 2003, the subsequent delivery of sufficiently detailed information concerning the initial design for the Pueblo facility was seriously delayed because new security regulations were instituted by the Army. The NRC is subject to Federal Advisory Committee Act and Freedom of Information Act regulations established by Congress regarding public access to the information used in developing its reports. Since the Army's chemical stockpile is considered a possible terrorist target or source of munitions for terrorists, information about sites where these stockpiles are located is subjected to an operations security (OPSEC) clearance process to prevent the publication of information that might benefit any terrorist activity. This procedure requires that all of the design documentation, as well as related reports and briefings provided to the committee, must first be scrutinized by the appropriate Army authorities. Any sensitive material used by the committee must be exempted from public access requirements. Thus, material not cleared by OPSEC could not be used in this report. This impasse is gradually being resolved, and possible means to improve the timely availability of information for future studies by the ACWA Design Committee are being investigated.

In the meantime, the contractor has been proceeding with the facility design. Thus, while the committee has received only the initial design plans, the contractor has already completed the intermediate design. However, the committee has availed itself of all information that it could in preparing this report. The committee was briefed regularly on the design, members paid site visits to locations where the testing and construction of machinery are under way, and certain members attended the periodic design reviews given by the Bechtel Pueblo team.

The committee is indebted to both the Program Manager for Assembled Chemical Weapons Alternatives and the Bechtel Pueblo team for their complete openness, sincerity, and cooperation during the committee's data-gathering sessions and resultant discussions. The committee believes that the overall process has been

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effective and constructive and that it will lead to an improved plant design. Appreciation is extended to Joseph Novad and Yu-Chu Yang from the Army Program Office and to Craig Myler from the Bechtel Pueblo team, who have been primary points of contact during this study.

A study such as this always requires extensive logistics support. The committee is indebted to NRC staff for their assistance, particularly to the study director for this report, Donald L. Siebenaler, and Nancy T. Schulte, who courageously assumed responsibility for this study during Mr. Siebenaler's leave of absence. Invaluable contributions were also made by Harrison T. Pannella, who provided suggestions for organizing the report, coordinated initial text submissions by committee members into a first draft of the report, and edited subsequent drafts. Considerable assistance was also provided by the senior project assistant Carter W. Ford and research associate James C. Myska.

Robert A. Beaudet, *Chair*
Committee to Assess Designs for Pueblo
and Blue Grass Chemical Agent
Destruction Pilot Plants

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Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Richard J. Ayen, Waste Management, Inc. (retired),
Judith A. Bradbury, Battelle Patuxent River,
John B. Carberry, E.I. DuPont de Nemours & Company,
Peter B. Lederman, Peter Lederman Associates,
Richard S. Magee, Carmagen Engineering,
James F. Mathis, Exxon Corporation (retired),
Ray McGuire, Consultant, and
Janice Phillips, Centocor, Inc.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Hyla S. Napadensky, Napadensky Energetics, Inc. (retired). Appointed by the National Research Council, she was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Acronyms

ACWA	Assembled Chemical Weapons Alternatives
ANR	agent neutralization reactor
APB	agent processing building
ATS	agent transfer system
BGCAPP	Blue Grass Chemical Agent Destruction Pilot Plant
BRS	brine recovery system
CAM	cavity access machine
CATOX	catalytic oxidation
CDC	Centers for Disease Control and Prevention
CDPHE	Colorado Department of Public Health and Environment
COD	chemical oxygen demand
CST	continuous steam treater
CSTR	continuously stirred tank reactor
DCD	Deseret Chemical Depot
DOD	Department of Defense
DPE	demilitarization protective ensemble
DSC	differential scanning calorimetry
ECR	explosion containment room
EDS	engineering design study
ENR	energetics neutralization reactor
EPA	Environmental Protection Agency
EPB	energetics processing building
ERH	energetics rotary hydrolyzer
ETS	energetics transfer system
HD	distilled mustard agent
HDC	heated discharge conveyor
HEPA	high-efficiency particulate air
HT	mustard agent containing mustard-T
HVAC	heating, ventilation, and air conditioning
ICB	immobilized cell bioreactor
IPT	integrated product team
JACADS	Johnston Atoll Chemical Agent Disposal System
LEL	lower explosive limit
MCRT	mean cell retention time
MPT	metal parts treater
MWS	munitions washout system
NEPA	National Environmental Policy Act
NRC	National Research Council
OPSEC	operations security
OTS	offgas treatment system
PCAPP	Pueblo Chemical Agent Destruction Pilot Plant
PCD	Pueblo Chemical Depot
PMACWA	Program Manager, Assembled Chemical Weapons Alternatives
PMD	projectile/mortar disassembly

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PPE	personal protective equipment
RCRA	Resource Conservation and Recovery Act
RD&D	research, development, and demonstration
RFP	request for proposal
SRT	solids retention time
SSPP	system safety program plan
STEL	short-term exposure limit
SUPLECAM	Surveillance Program for Lethal Chemical Agents and Munitions
T	bis[2-(2-chloroethylthio)ethyl] ether
TAP	toxicological agent protective
TDS	total dissolved solids
TNT	trinitrotoluene
TOC	total organic carbon
TRA	technical risk assessment
TRRP	technical risk reduction program
VOC	volatile organic compound
WHEAT	water hydrolysis of agent and energetics treatment

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Executive Summary

The Program Manager for the Assembled Chemical Weapons Alternatives (ACWA) program of the Department of Defense (DOD) requested the National Research Council (NRC) to review and evaluate the designs for pilot plant facilities to destroy the chemical weapons stored at Pueblo Chemical Depot in Colorado and the Blue Grass Army Depot in Kentucky. To accomplish this task, the NRC established the Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants (referred to as the ACWA Design Committee). This interim report presents the committee's assessment of the design for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP). It is based on the initial design documentation, test plans, and various test reports and trade studies that were available to the committee. This documentation is cited throughout the report.

An interim report was necessary in order that the Program Manager, Assembled Chemical Weapons Alternatives (PMACWA) and the PCAPP contractor could benefit from the committee's assessment before the PCAPP design was finalized. This report focuses on significant issues that have come to the attention of the committee so far, in order that these concerns might be addressed as soon as possible by the Army.

HISTORICAL BACKGROUND

The DOD established the Assembled Chemical Weapons Assessment program (since renamed the Assembled Chemical Weapons Alternatives program) in response to Public Laws 104-201 and 104-208, enacted in 1996, mandating that the DOD assess and demonstrate technology alternatives to incineration for the destruction of chemical weapons at Pueblo Chemical Depot and Blue Grass Army Depot. In response to Public Law 104-201, which required the DOD to coordinate with the NRC, the PMACWA requested that the NRC form a committee to evaluate the seven technologies originally selected as candidates for demonstration.

The NRC's Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons (referred to as the ACW I Committee) produced two reports, the first evaluating the seven selected technologies and the second reviewing the results of the demonstration testing of three of the candidate technologies. The ACW I Committee was dissolved in March 2000.

The PMACWA subsequently requested that the NRC evaluate the demonstration testing results for three more technologies from the originally selected seven. The PMACWA also requested assessments of the site-specific engineering design studies that were selected as candidate technologies for each of the two sites—Pueblo and Blue Grass. To accomplish these tasks, the NRC formed the ACW II Committee (the Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: Phase II). This committee produced a total of five reports—one on the second set of technologies to be demonstrated, and a full report and a supplemental letter report on the engineering design studies conducted for each of the two sites.

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In August 2003, the Army requested the NRC to form another committee to assist in evaluating the designs for the pilot plant facilities at Pueblo and Blue Grass. The present committee—the Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants (referred to as the ACWA Design Committee)—was established in October 2003. The present report is the first prepared by this committee.

The statement of task for the ACWA Design Committee is as follows:

> The Program Manager for Assembled Chemical Weapons Alternatives (PMACWA) has awarded contracts for the design, construction, systemization, pilot testing, operation and closure activities aimed at destroying the assembled chemical weapons stockpiles at Pueblo Chemical Depot and Blue Grass Army Depot. Chemical neutralization-based technologies form the basis for destroying the agent and energetics associated with both stockpiles, along with new or adapted processes for preparing weapons for disposal and treating secondary waste streams generated during the primary neutralization processing step. These facilities differ from previously constructed baseline incineration facilities and from those constructed for bulk chemical agent disposal. To assist the PMACWA, the NRC will initially examine planning documentation and designs for the Pueblo and Blue Grass facilities and provide comments and recommendations. Separate reports will address the specific issues for each facility.
>
> The NRC will:
>
> - Assess planning documentation for design and construction of the Pueblo and Blue Grass facilities.
> - Assess process and facility designs of the Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants.
> - Consider design issues raised by permitting considerations and public acceptability (e.g., design aspects of facility closure).
> - Produce reports within three months following the date the initial and intermediate designs are provided to the NRC for Pueblo and Blue Grass.

Although the committee first met in November 2003, new Army security regulations significantly delayed the delivery of detailed information concerning the initial design for the Pueblo facility. Because the design development was continuing at a rapid pace, the Army requested an interim report based on the information that was available to the committee at the time this report was prepared.[1] Thus, this report focuses on significant issues that have come to the attention of the committee in order that they may be addressed as soon as possible by the Army and its contractors. The full initial design plans were only made available to the committee in May 2004. The limitations in available information necessarily mean that the committee's work has not yet been completed. The omission of a particular topic should not be taken to suggest either approval or disapproval by the committee. A subsequent report on the PCAPP design is planned when the intermediate and final design plans become available.

BRIEF DESCRIPTION OF DESIGN DEVELOPMENT FOR PCAPP

The PMACWA awarded the contract for a chemical weapons destruction facility at Pueblo Chemical Depot to Bechtel National, Inc., which has teamed with several subcontractors; collectively they are designated as the Bechtel Pueblo team. The Bechtel Pueblo team is expected to design, construct, operate, and eventually close the facility upon completing its mission. In order to manage the risk associated with this first-of-a-kind facility, the contractor has instituted a technical risk reduction program (TRRP) to identify and mitigate sources of technical risk that have been identified through a technical risk assessment. The committee believes that this initial technical risk assessment has identified the major technical risk issues and that the TRRP has developed appropriate plans to address them, but believes that the process by which risks have been ranked could be further refined. For example, whereas some scenarios employed in the initial technical risk assessment describe health, safety, and environmental impacts, the probability and consequence weightings ascribed to these scenarios are not always consistent with the scenario description.

The destruction processes to be used at the Pueblo Chemical Agent Destruction Pilot Plant can be summarized as follows (see Figure ES-1): (1) transfer and disassembly processes that precede the core processes and that are necessary to acquire and access the chemical agent and energetic materials, (2) core processes that destroy the agent and the energetic materials in the munitions, and (3) residuals treatment processes following the core processes to decontaminate the munition bodies and other materials associated with the munitions. These processes are to be accomplished in the major steps described below.

In the transfer and disassembly processes, the munitions on their storage pallets are transported to the destruction facility. There they are uncrated or unpacked, and the packaging material or dunnage is separated from the munitions. The 4.2-inch mortar rounds are in

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[1] The nature of the data available to the committee can be seen from an examination of the reference list at the end of the report and from the footnotes throughout the report concerning unpublished sources of information.

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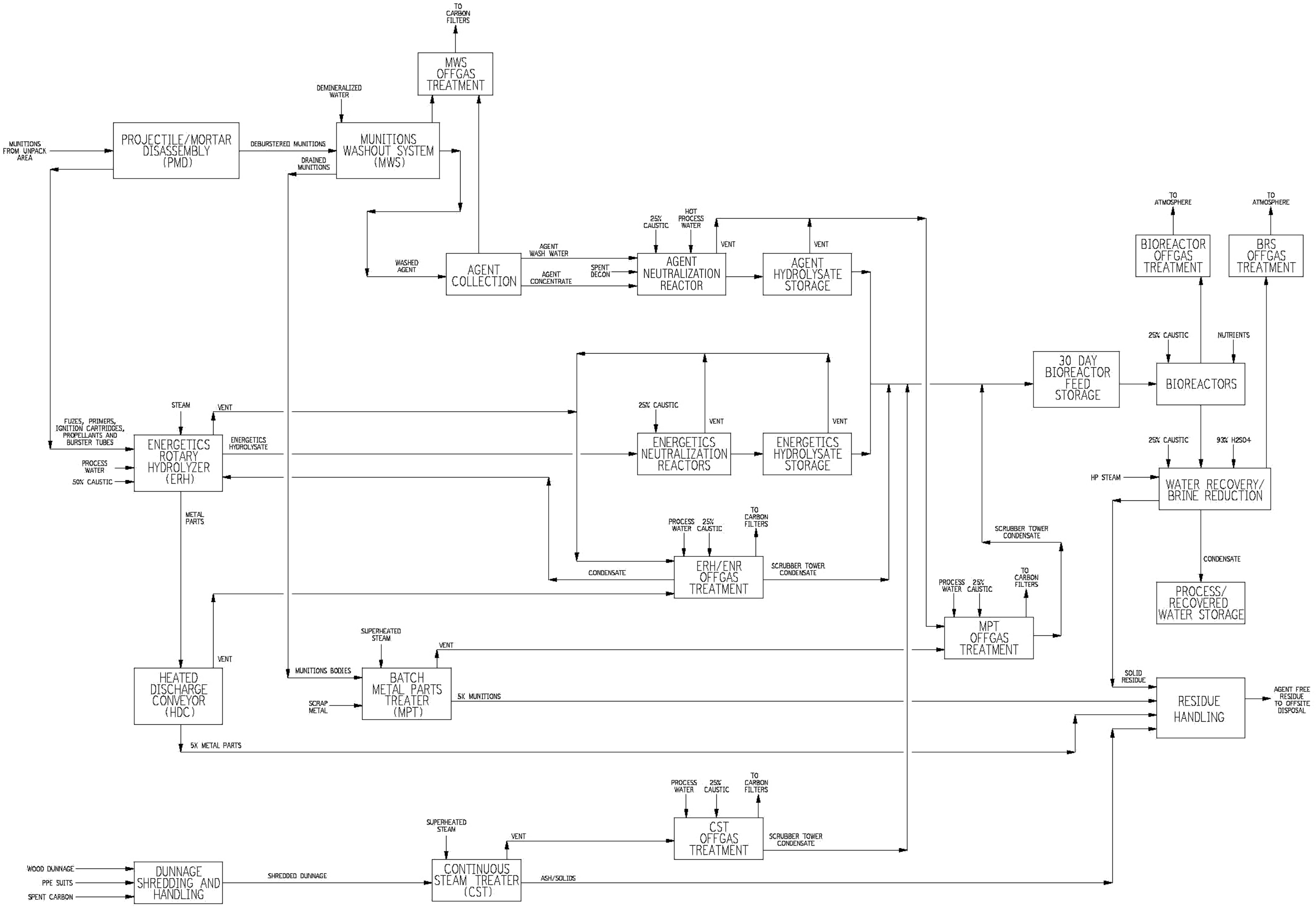

FIGURE ES-1 PCAPP process flow diagram. SOURCE: U.S. Army, 2004b.

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boxes with the propellant. The 105-mm and the 155-mm projectiles are palletized. Some of the 105-mm projectiles are boxed with the propellant and casings. In the reconfiguration room, propellants and igniters (not contaminated with agent) are removed from the boxed munitions.

Next, the munitions are conveyed to the projectile/mortar disassembly (PMD) area. The plant is designed with three PMD machines in separate explosion containment rooms (ECRs). Initially, each PMD line will treat a different type of munition. In the ECRs, the bursters are removed. As the processing of each munition type is completed, the PMD line will be converted to processing the remaining types. The Bechtel Pueblo team has selected a commercially available robotic machine to replace the PMD machines used at baseline incineration facilities. The committee believes that when up-to-date, off-the-shelf robotic units are used, the new PMD machines are an effective, reliable, and maintainable means of removing the energetics from the projectiles and mortars at Pueblo Chemical Depot.

Next the energetics from the munitions, which include the burster charges, fuzes, and the contaminated propellants, are placed in bins and sent on overhead conveyors to an energetics rotary hydrolyzer (ERH) for treatment according to the initial design. However, the overhead conveyor energetics transfer system was undergoing reconsideration as this report was being prepared. The use of an alternative, pneumatic system was being investigated. The committee considers the lack of a resolution with respect to the means of energetics transfer at this point in the design development to be of concern, since whatever means are chosen may impact downstream processes and might even change the footprint of the building layout.

Steps in the core processes that will destroy the agent and energetic materials are as follows. There are two ERHs in the PCAPP design. Each ERH is a continuous-feed unit, 6 ft in diameter and 20 ft long, with an inclined feed mechanism. In the ERHs, the energetics and associated metal parts are reacted with 35 percent caustic at 120°C. It requires about 2 hours for this material to move through an ERH, being carried along by the internal helical flights in the rotating ERH. The output stream from the ERH is passed over strainers, where undissolved metal parts are separated from the liquid and collected. These metal parts are then sent to the heated discharge conveyor (HDC), where they are heated to at least 1000°F for 15 minutes before being sent to storage awaiting disposal.

During the time that information was being gathered for this report, heating to 1000°F for 15 minutes was the only criterion for unrestricted release of material potentially contaminated with agent (this process is known as 5X decontamination). Subsequently, the Army established additional criteria for unrestricted release of material and abandoned the 5X terminology. The old 5X designation is still used in this report, however, because it is too early to determine implications of the newer criteria for the PCAPP design.

During the next step in the core processing, the treatment solution from the ERH is transferred to one of four energetic neutralization reactors, where the hydrolysis of the energetic materials is completed. In view of the extent of hydrolysis expected to take place in the ERHs, the committee believes that a review of the sizing of the post-ERH components of the energetics hydrolysis system may be warranted, and that this possibly offers a means to reduce plant costs.

The munition bodies still containing the agent, but without any energetics, are conveyed to the agent processing building. Here, a pedestal-mounted robotic arm similar to that used in the PMD machines is used to move each munition from a tray to a weighing station, and then to a cavity access machine (CAM), which is the main component of the munitions washout system (MWS). To access agent in the 4.2-inch mortar rounds, the bottom of each round is cut off and the agent and any heels (solidified agent) are washed from the munition casing with high-pressure water in the MWS. For projectiles, the munition is turned nose down, and an arm rams the burster well into the casing. The well is crimped so that it is out of the way, and the agent and any heels can be washed out with high-pressure water jets. The committee believes that the new MWS/CAM units are an effective and reliable approach to accessing and removing the chemical agent, including agent heels, from the munitions bodies. The design should also be able to handle munitions that contain frothing agent.[2]

The munition bodies, including their internal metal parts, are conveyed to one of two metal parts treaters (MPTs) for 5X decontamination. The MPT consists of

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[2] Hydrogen gas pressurization can result when mustard agent degrades, thereby forming hydrochloric acid. The acid in turn reacts with the iron of the munition casing to produce ferrous chloride and hydrogen gas. The hydrogen pressurization can cause foaming or frothing of the agent during disassembly, causing it to overflow from the casing. This is sometimes denoted as a *champagning* effect.

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an entry air lock, process chamber, and exit air lock. Metal parts are transported in carts on tracks through the MPTs. The inner wall surface of each MPT is maintained at 1200°F by electrical heating coils. Superheated steam at 1200°F is introduced into the process chamber of the MPT as a carrier gas to move vaporized agent and other gases produced from the 5X decontamination process into the MPT offgas treatment system. The committee has some concern that the use of superheated steam (instead of nitrogen) as a carrier gas may adversely affect MPT performance in terms of optimal throughput and potentially lead to reforming reactions that could initiate the formation of explosive mixtures in the catalytic oxidation unit of the MPT offgas treatment system.

The agent concentrate from the cavity accessing and washout process is stored in agent storage tanks until it is ready for hydrolysis. Then, the agent is sent to one of two agent neutralization reactors (ANRs). Mustard agent (HD or HT) will be hydrolyzed with hot water and then neutralized with caustic solution. The ANRs are kept at 194°F. After reaction, the hydrolysate is sent to an agent hydrolysate tank, where it is stored until being combined with the energetics hydrolysate for further processing in one of the continuous-feed immobilized cell bioreactors (ICBs).

The primary hydrolysis steps for the destruction of the agent and energetic materials at PCAPP are followed by a secondary biotreatment process in ICBs to transform the combined streams resulting from the hydrolysis of the agent and energetics into environmentally acceptable wastes. Storage tanks provide 30 days' storage capacity for agent and energetics hydrolysates in order to continuously feed the twenty-four 40,000-gallon ICBs, which have a 3.6-day residence time. Each reactor has three sections. The bacteria are immobilized on a plastic foam support material impregnated with activated carbon. The agent and energetic hydrolysates, together with nutrients, are fed to the ICBs.

Uncontaminated wood pallets are expected to be sent off-site for disposal. However, all contaminated pallets and other wastes—including used demilitarization protective ensemble (DPE) suits and other materials—will be treated on-site in one of three continuous steam treaters (CSTs). Before being fed to a CST, these materials will be shredded and then mixed with carbon carrier material. In the CST, the contaminated material is contacted with superheated steam to raise its temperature to 1000°F for at least 15 minutes to achieve 5X decontamination. A prototype CST consists of two chambers, an upper horizontal chamber and a lower horizontal chamber inclined slightly upward from the feed end to the discharge end. Each chamber has an internal auger shell to hold the material being treated, and a rotating auger to move the material through the auger shell. Propellant and dunnage (pallets and other packing materials) that are not contaminated with agent will be sent to an appropriate off-site disposal location or landfill without further treatment if permission is given by the regulators and if the Colorado Chemical Demilitarization Citizens Advisory Commission does not strongly oppose this course of action.

The CST will be tested at the Parsons Fabrication Facility in Pasco, Washington, in late 2004. The committee has a number of concerns about this unit, especially because alternative and less complex means for treating and handling these waste streams could be considered. Issues concerning the CST design include the following: (1) there is potential for jamming from the formation of tars, and (2) the planned testing may not be adequate to discern problems with maintenance of the equipment, as well as problems occurring during actual operating conditions. All offgases from PCAPP processes must be treated before being released to the atmosphere. Similarly, all ventilation air from process areas must be treated before release to the atmosphere. Offgas from processes will be treated in systems containing combinations of particulate separators, two-stage catalytic oxidation (CATOX) units, and scrubbers to ensure that the offgas streams are at or below approved levels for agent and other contaminants before release to the atmosphere.

PUBLIC INVOLVEMENT

The committee also reviewed public involvement in Pueblo. Over a period of several years, in preparation of an Environmental Impact Statement (for which a Record of Decision was issued in August 2002), the Army worked with regional and national stakeholders, the local community, and the State of Colorado to agree on the location of the facility at Pueblo Chemical Depot and on the choice of technology. This interaction was called the ACWA Dialogue, and it has been dubbed the "new style of doing business." It contrasts with the more traditional "public outreach" efforts that emphasize first selecting a technology and then informing or educating the public, rather than involving it in any significant way during the program design and implementation.

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The Army has tasked the Bechtel Pueblo team to implement the public involvement program for PCAPP. The ACWA Dialogue has been widely viewed as successful because it produced consensus on the choice of technology to be developed and implemented at the Pueblo facility. In addition to selecting a site and confirming a choice of technology, the ACWA Dialogue also led to public endorsement of an accelerated approach to Resource Conservation and Recovery Act (RCRA) permitting. The committee recommends that the public involvement program be continued and reviewed regularly to maintain it at its highest effective level.

A phased approach to permitting is being used to accelerate the construction process for the Pueblo facility. The Colorado Department of Public Health and Environment agreed to allow the Army to begin construction operations before the entire permit was issued for PCAPP. Thus, the permit will be issued in the three phases described in the report (see Chapter 4). The phased approach to an RD&D (research, development, and demonstration) RCRA permit appears to be advantageous to public review and involvement in the permitting process.

Also, the committee notes that the award of the contracts for the PCAPP design and for the public involvement program to the same contractor could lead to a perceived conflict of interest. Thus, the committee recommends that the Army and its contractors regularly review, with community groups and citizens, the ongoing effectiveness of the “new way of doing business.” Detailed information is provided in Chapter 4 of this report.

GENERAL FINDINGS AND RECOMMENDATIONS

Specific findings and recommendations on the component processes for PCAPP are presented in Chapters 1 and 3, in which the rationale for each finding or recommendation is provided. The general findings that follow are from Chapter 5. They summarize the committee’s overall assessment of the PCAPP design and public participation at the time this report was prepared.

General Finding 1. On the basis of the initial design documentation for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP), along with the results from completed technical risk reduction program (TRRP) studies and tests, as well as presentations on the intermediate design, the committee believes that the PCAPP can effectively and safely destroy the chemical agent and the energetic materials in the chemical munitions at Pueblo Chemical Depot. This assessment must be qualified by the limitations in available information and time constraints under which the committee operated, as described in this report. The committee remains concerned with the ability of the continuous steam treater to process dunnage effectively. The basis for the committee’s assessment can be summarized as follows:

- The hydrolysis of HD (distilled mustard agent) is a mature technology whose chemistry has been extensively studied. The chemical mechanisms and kinetics are well established. The chemistry of the hydrolysis of HT (mustard agent containing mustard-T) has not been as extensively studied to date, but the committee does not foresee any major problems with the hydrolysis of HT mustard.
- Although the hydrolysis of energetic materials through the use of hot caustic solutions is not as mature as mustard agent hydrolysis, testing during the earlier engineering design phase of the Assembled Chemical Weapons Assessment program indicates that the energetic materials at Pueblo Chemical Depot in Colorado can be effectively and safely destroyed by this process.
- The successful biotreatment of agent and energetics hydrolysates has been demonstrated both during the engineering design phase of the Assembled Chemical Weapons Assessment program and in the more recent TRRP activities to confirm that the microorganisms transform the hydrolysates to products that are environmentally acceptable.
- The newly designed systems for disassembling the projectiles and the mortars and for accessing the chemical agent in these munitions are up-to-date approaches that appear to be effective. Both use modern, commercially available robots to handle the munitions. The high-pressure water washout of the munitions bodies removes all of the solids as well as the liquid agent from the munitions bodies, thus reducing the chemical agent load on the metal parts treater (MPT). The projectile/mortar disassembly (PMD) machine has not been tested. However, a trade study has been conducted for the

new design to replace the PMD machines used in the baseline (incineration) system.

- Although the MPT is still undergoing developmental testing, it should be capable of decontaminating metal parts to a 5X condition.
- The continuous steam treater (CST) for processing dunnage and wastes and the complexity of the CST offgas treatment system constitute an area of great concern to the committee. The fabrication and testing of the CST will not be completed until late 2004, when the entire PCAPP design is supposed to be in the final stages. The processing of wood in an oxygen-free atmosphere will lead to charring and to the formation of tars. Only wood, activated carbon, and demilitarization protective ensemble suit materials are planned as feeds during TRRP testing; other wastes to be treated in the CST are not being tested.

General Recommendation 1. Alternative approaches for treating the dunnage at the Pueblo Chemical Agent Destruction Pilot Plant should be considered by the Army, with involvement by the public. One such alternative is to send all uncontaminated dunnage and wastes off-site for disposal. Another is to develop a low-temperature system for the treatment of contaminated dunnage to reduce the contamination to levels acceptable for public release in accordance with new Army standards.

General Finding 2. After reconfiguration of the 4.2-inch mortars and 105-mm projectiles, the propellants, fuzes, and igniters that are not contaminated with agent could be sent for off-site disposal to facilities already equipped to treat energetic materials from conventional munitions. This would greatly reduce the energy and process-chemicals requirements for energetics hydrolysis.

General Recommendation 2. The wastes listed in General Finding 2—reconfigured 4.2-inch mortar and 105-mm projectile propellants, fuzes, and igniters not contaminated with agent—should be sent off-site for disposal. The Army should seek guidance from both the permitting agencies and the public on possible approaches to off-site disposal of all uncontaminated wastes from the Pueblo Chemical Agent Destruction Pilot Plant.

General Finding 3. The unit operations in the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) design have never been operated as a total, integrated process. As a consequence, and notwithstanding the throughput analysis that has been performed, a prolonged period of systemization will be necessary to resolve integration issues as they arise, even for apparently straightforward unit operations. For example, the lack of resolution at the intermediate design stage on the means for transferring agent and energetics following munitions disassembly presents major challenges to completing the PCAPP design.

General Recommendation 3. Adequate time should be scheduled during the design of the Pueblo Chemical Agent Destruction Pilot Plant for the contractor team, the Bechtel Pueblo team, to address integration issues. Addressing these issues should include a major effort to define a safe, efficacious, and acceptable method for transferring agent and energetics to destruction processes following munitions disassembly. Whatever method is implemented should continue to keep the energetics and agent separated.

General Finding 4. Public participation and involvement in the design of the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) have been strong—starting with the Assembled Chemical Weapons Assessment Dialogue (called the ACWA Dialogue) and continuing through the Colorado Chemical Demilitarization Citizens Advisory Commission and the working groups, whose participants have included volunteers, local government representatives, stakeholder groups, the Army, and others. Public interest in the design of PCAPP remains high. Although there is substantial agreement on the choice of core technologies (hydrolysis and biotreatment), there is not necessarily agreement on all aspects of the plant design—for example, the continuous steam treater and the metal parts treater designs. Thus, there continue to be opportunities for public involvement in the design.

General Recommendation 4. The Army and its contractor should continue to inform and offer meaningful opportunities to involve the public and state and local government officials in relevant Pueblo Chemical Agent Destruction Pilot Plant design decisions and the technical risk assessment process. Also, the Army and its contractor should encourage public scrutiny and be cautious about taking community consent for granted.

1

Introduction

BACKGROUND

Chemical Agent Demilitarization in the United States

For the past two decades, the U.S. Army has been engaged in activities aimed at destroying its aging stockpile of chemical agents and munitions, which are located at eight sites in the continental United States.[1] Approximately 29 percent of the original stockpile of more than 30,000 tons of nerve and blister (mustard) agents has been destroyed to date.[2]

As a signatory to the international treaty known as the Chemical Weapons Convention, which was ratified by the international community on April 29, 1997, the United States had 10 years to destroy its stockpile, with an allowable extension of 5 years. It recently has been acknowledged that the United States will need the additional 5 years to complete destruction operations, that is, until April 29, 2012.

At four of the disposal facility locations, the destruction process is based on incineration, which is how most of the stockpile has been destroyed to date. Two of the other sites not using incineration (that is, other than the sites at Pueblo, Colorado, and Blue Grass, Kentucky) store chemical agents only in bulk ton containers: mustard agent at the Aberdeen, Maryland, site and VX nerve agent at the Newport, Indiana, site. These stocks are to be destroyed by a neutralization process (hydrolysis), followed by secondary treatment of the products of the hydrolysis treatment. Destruction operations are under way at Aberdeen and pending at Newport. At Aberdeen, secondary treatment of hydrolysate is being performed at the DuPont industrial wastewater treatment facility in Deepwater, New Jersey.

Assembled Chemical Weapons Alternatives Program

In 1996, in response to local opposition to the use of incineration for destroying the stockpile of chemical agents and munitions, the U.S. Congress passed Public Laws 104-201 and 104-208 that (1) froze the funds for construction of destruction facilities at Pueblo Chemical Depot in Colorado and at the Blue Grass Army Depot in Kentucky, (2) required the Army to demonstrate at least two alternatives to incineration to destroy assembled chemical weapons, and (3) required the Army to coordinate with the National Research Council. This program became known as the Assembled Chemical Weapons Assessment program and has since been renamed the Assembled Chemical Weapons Alternatives (ACWA) program.

After an elaborate selection process in which the public was extensively involved, six technologies received acceptable technology grades, and the Army chose three of these for demonstration (Demo I) of their

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[1] The Army completed destruction of munitions stored at a ninth site, on Johnston Island in the Pacific Ocean, in November 2000.

[2] As of May 30, 2004, 28.7 percent of the original stockpile comprising 9,036 tons of agent and 1.4 million munitions and containers had been destroyed (DOD Chemical Demilitarization Program Briefing by Patrick Wakefield (Office of the Secretary of Defense) to the National Defense Industry Association Executive Round Table Breakfast Meeting, Washington, D.C., June 16, 2004).

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technical viability to meet destruction objectives. Two of these technologies were found acceptable after demonstration testing, and they proceeded to engineering design studies (EDSs) for assessing their acceptability for implementation to destroy the chemical stockpile at Pueblo, which comprises nearly 800,000 projectiles and mortar rounds filled with mustard agent.

Subsequently, in 1999, the Congress passed Public Laws 106-79 and 106-52, requiring the Army to demonstrate the remaining three technologies (Demo II) and to consider all viable technology alternatives for destroying the chemical weapons at Blue Grass Army Depot in Kentucky, where both mustard agent and nerve agent munitions are stored. Two of the technologies demonstrated in Demo II and one of those in Demo I were selected to undergo EDS as candidates for destroying the weapons at Blue Grass.

A final, site-specific Environmental Impact Statement to satisfy National Environmental Policy Act (NEPA) requirements was completed in April 2002. The Department of Defense's (DOD's) Defense Acquisition Board issued a Decision Memorandum in July 2002 that approved neutralization followed by biotreatment for full-scale pilot testing at Pueblo and directed acceleration of the destruction of the stockpile. The Record of Decision was signed in July 2002. The Request for Proposal (RFP) to design, build, operate, and close a chemical agent destruction facility at Pueblo was issued in July 2002. Although the RFP specified that hydrolysis followed by biotreatment was to be used in the process, the selection of all other unit operations was left to the RFP respondents. The only other requirement was that the process design should include the destruction of all hazardous materials onsite. The system contract was awarded to Bechtel National, Inc., in September 2002, and work to develop a full-scale pilot plant design began in December 2002.[3,4]

Involvement of National Research Council in Assembled Chemical Weapons Alternatives Program

In accordance with congressional guidance, the National Research Council (NRC) formed the Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons (referred to as the ACW I Committee) in 1997 to evaluate the candidate technologies and to assess the three technologies chosen for Demo I. After producing two reports evaluating these technologies, the ACW I Committee completed its tenure in February 2000. However, the Army requested the NRC to evaluate the remaining three technologies that were to be tested during Demo II and to assess the engineering design studies of the first two technologies selected from Demo I.

Thus, a second NRC committee, the Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: Phase II (ACW II Committee) was formed, with largely the same membership as that of the ACW I Committee. The ACW II Committee produced three full-length reports, one evaluating engineering design studies for technologies considered for implementation at the Pueblo site, a report on the three technologies tested in Demo II, and a report evaluating the second set of engineering design studies for technologies considered for implementation at Blue Grass. Because the committee had to terminate data gathering before all of the tests were completed, two letter reports were also issued to update the committee's analyses and findings for the full-length reports. The ACW II Committee was dissolved in March 2003.[5]

In August 2003, the Army requested the NRC to form another committee to assist in evaluating the designs for the pilot plant facilities for the sites at Pueblo, Colorado, and Blue Grass, Kentucky. The present committee—the Committee to Assess Designs for Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants (referred to as the ACWA Design Committee)—was established in October 2003.

STATEMENT OF TASK

The ACWA Design Committee was requested to review and evaluate both the Pueblo Chemical Agent

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[3] The Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) is not a "pilot plant" in the traditional sense of the term. This pilot plant is intended to destroy the entire stockpile of chemical agent and to perform all associated treatment processes. This is also true for the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP).

[4] A Resource Conservation and Recovery Act (RCRA) permit application for preliminary construction activities was made in December 2003 and a Phase 1 RCRA permit was issued by the state in July 2004. The remainder of the facility will be permitted using a phased permitting approach in which portions of the design are approved as they are designed.

[5] The technologies referred to have all been described in detail in earlier NRC reports (NRC, 1999a; 2000; 2001a; 2001b; 2002a; 2002b; 2002c).

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Destruction Pilot Plant (PCAPP) and the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) design plans. However, this report only covers the committee's interim evaluation of the PCAPP design. The committee's statement of task is as follows:

> The Program Manager for Assembled Chemical Weapons Alternatives (PMACWA) has awarded contracts for the design, construction, systemization, pilot testing, operation and closure activities aimed at destroying the assembled chemical weapons stockpiles at Pueblo Chemical Depot and Blue Grass Army Depot. Chemical neutralization-based technologies form the basis for destroying the agent and energetics associated with both stockpiles, along with new or adapted processes for preparing weapons for disposal and treating secondary waste streams generated during the primary neutralization processing step. These facilities differ from previously constructed baseline incineration facilities and from those constructed for bulk chemical agent disposal. To assist the PMACWA, the NRC will initially examine planning documentation and designs for the Pueblo and Blue Grass facilities and provide comments and recommendations. Separate reports will address the specific issues for each facility.
>
> The NRC will:
>
> - Assess planning documentation for design and construction of the Pueblo and Blue Grass facilities.
> - Assess process and facility designs of the Pueblo and Blue Grass Chemical Agent Destruction Pilot Plants.
> - Consider design issues raised by permitting considerations and public acceptability (e.g., design aspects of facility closure).
> - Produce reports within three months following the date the initial and intermediate designs are provided to the NRC for Pueblo and Blue Grass.

SCOPE OF THE REPORT

Although this committee first met in November 2003, new Army security regulations significantly delayed the delivery of detailed information concerning the initial design for the Pueblo facility. Because the design development was continuing at a rapid pace, the Army requested an interim report based on the information that was available to the committee at the time this report was prepared.[6] Thus, this report focuses on significant issues that have come to the attention of the committee in order that they may be addressed as soon as possible by the Army and its contractors.

The full initial design plans for the Pueblo facility were only made available to the committee in May 2004. Other sources of information included test plans and various test reports and trade studies that had been completed and made available. The committee also attended the intermediate design review at Bechtel headquarters in San Francisco on May 19–21, 2004. Although the committee members could attend all sessions and were given presentations during the intermediate design reviews, they were not allowed to have either paper or electronic copies of the presentation slides nor of the intermediate design package, since these items had not yet undergone operations security (OPSEC) review. Thus, neither the presentation slides from this review nor the complete intermediate design package was available to the committee when this report was prepared.

This report attempts to provide a general overview of the technical risk assessment program and of certain potential difficulties with the unit processes that are associated with the PCAPP design. The limitations in available information described above necessarily mean that the committee's work has not yet been completed. The omission of a particular topic should not be taken to suggest either approval or disapproval by the committee. A subsequent report on the PCAPP design is planned when the intermediate and final design plans become available.

ORGANIZATION OF THE REPORT

Chapter 1 provides concise background information on the ACWA program, an introduction to the committee's task, the rationale for preparing an interim report, and the PCAPP contractor's design approach. Prior NRC reports on the ACWA program are noted for the reader who may wish to have more detailed information.

Chapter 2 describes the overall process and the unit operations being designed for PCAPP. These descriptions are based on the initial design plans and on the intermediate design presentations given at the contractor's design review meeting on May 19–21, 2004, in San Francisco. Certain unit operations are also evaluated in Chapter 2.

Chapter 3 discusses in detail areas of concern identified by the committee. It does not include any subsequent design modifications that may have been made since the May 19–21, 2004, presentations by the contractor. Detailed concerns as well as findings and recommendations on specific unit processes and related issues are also included in Chapter 3.

Chapter 4 reviews briefly the public involvement program for PCAPP. General findings and recommen-

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[6] The nature of the data available to the committee can be seen from an examination of the reference list at the end of the report and from the footnotes throughout the report concerning unpublished sources of information.

dations on the PCAPP design activities and related issues are given in Chapter 5.

DESCRIPTION OF PUEBLO CHEMICAL DEPOT STOCKPILE

The projectiles and mortar rounds stored at Pueblo Chemical Depot contain either HD, which is distilled mustard agent (bis (2-chloroethyl) sulfide), or HT, which contains nominally 60 weight percent HD and 40 weight percent residual that contains T (bis[2-(2-chloroethylthio)ethyl] ether) and related homologues. HT has the advantage of a lower freezing point than that of HD (U.S. Army, 2004a). The inventory of munitions at Pueblo is given in Table 1-1. The physical properties of field-grade liquid HD and liquid HT are given in Table 1-2. However, the composition of the agent in these munitions has changed in the four or five decades since the munitions were manufactured and placed in storage. A typical composition of the HD and the HT found in the old mortars is given in Table 1-3. Diagrams and technical specifications of the munitions to be destroyed are provided in Appendix A.

CONTRACTOR DESIGN STRATEGY FOR PUEBLO CHEMICAL AGENT DESTRUCTION PILOT PLANT

The Army procurement request for the Pueblo Chemical Agent Destruction Pilot Plant called for bidders to propose an integrated approach to the full scope of necessary activities, from design through construction, operations, and eventual decommissioning or closure. In response, the selected contractor has used a design-build strategy that is described in the Design-Build Plan for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) project (U.S. Army, 2003a). This approach can save both time and money for plants using well-developed processes. Under this approach, construction is begun before certain unit operations are designed and tested.

The selected contractor team, called the Bechtel Pueblo team, includes Bechtel National, Inc., as the systems contractor, together with several teaming subcontractors: Battelle Memorial Institute, Parsons Infrastructure and Technology, and Washington Demilitarization Company. In turn, the latter two companies have subcontractors—General Atomics and General Physics, respectively—complementing them. Appendix B indicates the responsibilities of each of these participants.

As required under the contract, the activities of the contractor team include all design, procurement, facilities construction, fabrication and testing of process components, installation, systemization, operations, and eventual closure. Included in these activities are safety analysis, licensing and environmental permitting, technical risk assessment, the use of lessons learned from previous chemical weapons disposal pro-

TABLE 1-1 Chemical Weapons Stockpile of HD- or HT-Filled Munitions at Pueblo Chemical Depot

Munition Type	Model No.	Chemical Fill	Energetics	Configuration
105-mm cartridge	M60	1.4 kg HD	Burster: 0.12 kg tetrytol Fuze: M51A5 Propellant: M1	Unreconfigured: semifixed, complete projectile: includes fuze, burster. Propellant loaded in cartridge. Cartridges packed two per wooden box.
105-mm cartridge	M60	1.4 kg HD	0.12 kg tetrytol	Reconfigured: includes burster and nose plug, but no propellant fuze. Repacked on pallets.
155-mm projectile	M110	5.3 kg HD	0.19 kg tetrytol	Includes lifting plug and burster but no fuze. On pallets.
155-mm projectile	M104	5.3 kg HD	0.19 kg tetrytol	Includes lifting plug and burster but no fuze. On pallets.
4.2-inch mortar	M2A1	2.7 kg HD	0.064 kg tetryl Propellant: M8	Includes propellant and ignition cartridge in a box.
4.2-inch mortar	M2	2.6 kg HT	0.064 kg tetryl Propellant: M8	Includes propellant and ignition cartridge in a box.

NOTES: The terms "unreconfigured" and "reconfigured" are defined in the column labeled "Configuration." The M1 propellant present in 105-mm cartridges that have not been reconfigured is present in M67 propelling charges, that is, granular propellant contained in bags as specified in MIL-DTL-60318C.

SOURCE: Adapted from U.S. Army, 2004b.

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TABLE 1-2 Physical Properties of Mustard Agents at Pueblo Chemical Depot

Agent Characteristic	HD	HT[a]
Chemical name	Bis(2-chloroethyl) sulfide or 2,2′-dichlorodiethyl sulfide	Same as HD, with 20 to 40 wt % agent T, bis[2-(2-chloroethylthio) ethyl] ether
Chemical formula	$C_4H_8Cl_2S$	Not applicable
Molecular weight	159.07	188.96 (based on 60/40 wt %)
Vapor density (relative to air)	5.5 (calculated)	6.5 (calculated based on 60/40 wt %)
Boiling point, °C	218 (extrapolated)	No constant boiling point
Decomposition temperature, °C	180	165 to 180
Freezing point, °C	14.45	1.3 (measured as melting point)
Vapor pressure, torr (mm Hg) at 25°C	0.106	7.7×10^{-2} (calculated based on Raoult's law equation)
Volatility, mg/m^3 at 25°C	9.06×10^2 (calculated from vapor pressure)	7.83×10^2 (calculated from vapor pressure)
Diffusion coefficient for vapor in air (cm^2/sec)	0.060 at 20°C (68°F)	0.05 at 25°C (77°F)
Flash point, °C	105	Flash point range: 109 to 115
Surface tension, dynes/cm	43.2 at 20°C (68°F)	42.01 at 25°C (77°F)
Viscosity, cSt	3.52 at 20°C (68°F)	6.05 at 20°C (68°F)
Liquid density, g/cm^3	1.2685 at 25°C	1.263 at 20°C
Solubility, g/100 g of distilled water	0.092 at 22°C (72°F); soluble in acetone, carbon tetrachloride, chloroform, tetrachloroethane, ethyl benzoate, ether	Slightly soluble in water; soluble in most organic solvents
Heat of vaporization, Btu/lb (J/g)	190 (82)	Not available
Heat of combustion, Btu/lb (J/g)	8,100 (3,482)	Not available

[a] HT is prepared by a chemical process that synthesizes the HT directly in such a way that it contains both the HD and T constituents without further formulation.

SOURCES: Abercrombie, 2003; adapted from U.S. Army, 1988.

grams, and interaction with the local community concerning all of these activities.

There are many challenges involved in controlling cost and schedule for the PCAPP project. These challenges stem from the PCAPP being a first-of-a-kind facility that will require the integration of many subsystem process components that have yet to be designed, built, or tested at a scale consistent with the anticipated throughput of the facility. These technical and scheduling issues appear to be understood by the contractor team, which has developed specific steps, plans, and procedures in its preliminary design documents in order to obtain the necessary data.

Ultimately, the as-built drawings of the facility itself, the installed equipment, the piping, the electrical equipment and wiring, and the control instrumentation are mandatory components for conducting operations and maintenance. To acquire and manage these design components, the PCAPP contractor team has organized the design packages into 11 elements that are mostly centered on the various processes and the buildings that encompass the six major unit operations. These design

TABLE 1-3 Compositions of Liquid HD and Liquid HT Agent Drained from 4.2-inch Mortars at Pueblo (Excluding the Composition of Any Solids in the Munitions)

		Area % by GC/MS-Cl	
Chemical Name/Abbreviations	Chemical Structure	HD	HT
Bis(2-chloroethyl) sulfide, HD	$(ClCH_2CH_2)_2S$	95.7	62.6
1,2-Dichloroethane	$ClCH_2CH_2Cl$	0.7	0.3
1,2-Bis(2-chloroethylthio) ethane	$ClCH_2CH_2SCH_2CH_2SCH_2CH_2Cl$	2.1	3.6
1,4-Dithiane	$S(CH_2CH_2)_2S$ (six-member ring)	0.7	2.0
1,4-Oxathiane or 1,4-thioxane	$O(CH_2CH_2)_2S$ (six-member ring)	0.04	0.7
Bis(2-chloroethyl) disulfide, HS_2	$(ClCH_2CH_2)_2S_2$	0.02	0.04
Bis(3-chloropropyl) sulfide, BCPRS	$(ClCH_2CH_2CH_2)_2S$	0.08	
2-Chloropropyl 3-chloropropyl sulfide	$(CH_3CHClCH_2)S(CH_2CH_2CH_2Cl)$	0.07	
2-Chloroethyl 4-chlorobutyl sulfide, CCBS	$(ClCH_2CH_2)S(CH_2CH_2CH_2CH_2Cl)$	0.3	
2-Chloroethyl 3-chloropropyl sulfide, CECPRS	$(ClCH_2CH_2)S(CH_2CH_2CH_2Cl)$	0.07	
Bis[2-(2-chloroethylthio) ethyl] ether	$(ClCH_2CH_2SCH_2CH_2)_2O$		23.5
2-(2-Chloroethylthio) ethyl 2-chloroethyl ether	$ClCH_2CH_2SCH_2CH_2OCH_2CH_2Cl$		5.1
Bis(2-chloroethyl) ether	$(ClCH_2CH_2)_2O$		0.2
Polythioethers (4 compounds tentatively identified)			2.0
Total		99.8	100.0

NOTE: HD mortars contained an average of 80 weight percent liquid and 20 weight percent solid.

SOURCE: Chemical Compositions of Liquid HT, Solid HT, Liquid H, and Solid H. Briefing by Yu-Chu Yang, ACWA Chief Scientist, to the Mustard Working Group Meeting, September 23, 2003.

packages are complemented by a full three-dimensional computer model for PCAPP that includes all civil structures, equipment, piping and electrical infrastructure, control instrumentation, and interfaces, and provides considerable detail on the installation process and operational parameters.[7]

An important element of any design-build activity is configuration control. This effort entails keeping track of changes necessitated as the design and process details change and as equipment is manufactured and installed.

Finding 1-1. The three-dimensional computer model for the Pueblo Chemical Agent Destruction Pilot Plant is a key element in the formal configuration control program that has been developed by the Bechtel Pueblo team. All design and procurement documentation is maintained in its most current form and related via the three-dimensional model.

Recommendation 1-1. It is essential that the Bechtel Pueblo team, the contractor team for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP), follow through on procedures to ensure that field changes are incorporated back into the three-dimensional computer model for PCAPP so that as-built drawings reflect the actual installation.

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[7] PCAPP Design Overview Briefing by Craig Myler, PCAPP Chief Scientist, to the ACWA Design Committee, Aberdeen Proving Ground, Md., November 6, 2003.

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2

Description of the Pueblo Chemical Agent Destruction Pilot Plant Process

OVERVIEW OF THE PROCESS

In this chapter, the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) process being designed by Bechtel National, Inc., to destroy the chemical weapons stockpiled at Pueblo Chemical Depot (PCD) is described according to the configuration information available to the committee when this report was being prepared.[1]

Destruction processes for chemical munitions typically involve the following: (1) transfer and disassembly processes that precede the core processes and which are necessary to acquire and access the chemical agent and energetic materials,[2] (2) core processes that destroy the agent and the energetic materials in the munitions, and (3) residuals treatment processes that follow the core processes and decontaminate the munition bodies and other materials associated with the munitions. These processes are accomplished in the following major steps (details on the individual steps are provided in the sections below).

First, during the transfer and disassembly steps, the munitions on their storage pallets or in boxes are transported in ammunition transport vehicles from the depot's storage igloos to the agent destruction facility. There they are uncrated or unpacked, tested for leakage, and, if the munitions are safe, the pallets and other packing materials are separated from them.

Next, the munitions are disassembled to separate the agent-containing portions from the energetic materials. At PCAPP, propellant that is stored with the projectiles and mortar rounds and not contaminated with agent is to be separated before disassembly of the munitions and prepared for destruction on-site or for shipment to appropriate off-site destruction and disposal facilities.

During disassembly of the munitions, five separate waste streams are produced for further processing: (1) the toxic chemical agent from the munition cavities; (2) the energetic materials, which may include propellants, bursters, igniters, and fuzes, and their associated metal parts; (3) metal munitions casings and their associated metal parts; (4) ancillary wastes or dunnage such as the wooden pallets and boxes and packing materials, most of which are not contaminated with agent; and (5) process offgas streams and air from the facility's heating, ventilation, and air conditioning (HVAC) system. Ancillary wastes also include demilitarization protective ensemble (DPE) suits, waste lubrication and hydraulic oils, spent activated carbon, and other trash and debris that may be contaminated with agent.

In the core disposal operations that follow disassembly, the chemical agents and the energetic materials are destroyed by hydrolysis processes. At Pueblo, HD or HT mustard agent will be hydrolyzed with hot water and the resulting acidic solution then neutralized with caustic solution. The energetic materials will be hydrolyzed with a hot caustic solution. These primary steps

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[1] Except where otherwise noted, background material in this chapter is drawn from U.S. Army (2004b) and the PCAPP intermediate design review in San Francisco, May 19–21, 2004.

[2] *Energetic materials* or simply *energetics* are general terms that refer to propellants and explosives as a group.

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will be followed by secondary treatment processes to transform the streams resulting from the hydrolysis (hydrolysates) into environmentally acceptable wastes. At Pueblo, biotreatment in immobilized cell bioreactors (ICBs) will be used to treat the agent and energetic hydrolysates.

In the residuals treatment processes, metal parts such as the projectile casings, fuze cups, nose closures, and metals separated from dunnage streams are treated by being heated to at least 1000°F for 15 minutes to decompose any residual agent and energetics. This process is called decontamination to a 5X condition.[3] The 5X-treated metal parts are considered safe to be released for subsequent disposal or recycling. Low-pressure (<25 pounds per square inch gage (psig)), superheated 1200°F steam will be used as a sweep gas for gases generated during thermal treatment of the metal parts in an inductively heated metal parts treater chamber.

Wooden pallets, worker protective suits, and all other nonmetallic wastes that may be contaminated with agent are treated to a 5X condition to destroy the agent and then sent to a suitable disposal site. The decontamination of these materials takes place in a continuous steam treater (CST). The CST is inductively heated and uses low-pressure, superheated 1000°F steam and inert gas to sweep out gases generated during thermal treatment. The Bechtel Pueblo team requested that the Colorado Department of Public Health and Environment (CDPHE) permit sending propellant and dunnage that is not contaminated with agent offsite for appropriate destruction and disposal, provided the Citizens Advisory Commission does not strongly oppose this course of action.

All offgases from PCAPP processes, including the offgases from storage vessels used during these processes, are treated before release to the atmosphere. Similarly, all ventilation air from process areas is treated before release to the atmosphere. Offgases from both core processes and residuals treatment processes are treated to ensure that the offgas streams are at or below regulated levels for agent and other contaminants before release directly to the atmosphere. In the following sections, each of the processes being designed for PCAPP is described in further detail. This description is largely based on the initial 30 percent design for PCAPP, along with supplementary information that subsequently became available as this report was being prepared. A process flow diagram is given in Figure 2-1.

TRANSFER AND DISASSEMBLY OF MUNITIONS

At Pueblo Chemical Depot, chemical munitions are stored on pallets in igloos and are periodically checked for leakers (i.e., leaking munitions). Pallets found to contain leakers are overpacked in specially designed containers and will be processed in a separate campaign after all other munitions have been processed.[4] Because PCAPP will operate 24 hours a day, sufficient pallets of munitions will be brought from the PCD storage igloos to the unpack area of the PCAPP energetics processing building (EPB) during daylight hours to permit continued operation at night. Transport from the storage igloos at night or during inclement weather is prohibited. Pallets retrieved from the igloos by forklift are placed in ammunition transport vehicles. These vehicles will be used on a daily basis to transport munitions from igloos to the EPB unpack area, where the transport vehicle airspace is monitored for agent prior to the vehicles being opened. The committee expects that if agent is detected, special procedures and protective equipment will be used to access the vehicle interior, locate and overpack the leaker(s), and decontaminate the vehicle.

If it is verified that no agent can be detected in its airspace, the vehicle is opened and the palletized munitions are removed by forklift and delivered to the unpack area, where they are removed from the storage pallets. The 4.2-inch mortar rounds are in boxes with the propellant; the 105-mm and 155-mm projectiles that have been reconfigured (i.e., the propellant has been removed) are palletized. There are also 105-mm projectiles that have not been reconfigured and are packed in boxes with the shell body and the propellant. See Table 1-1 in Chapter 1 and Figure A-4 in Appendix A for a description of the unreconfigured and reconfigured munitions. The unreconfigured 105-mm projectiles and the 4.2-inch mortars in their boxes are moved to the reconfiguration room, where chemical agent detectors are used to verify that the propellant

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[3] Treatment of solids to a 5X decontamination level is accomplished by holding a material at 1000°F for 15 minutes. This treatment results in material that can be released for general use or sold (e.g., as scrap metal) to the general public in accordance with applicable federal, state, and local regulations.

[4] The Bechtel Pueblo team is considering dedicating the disassembly line for 4.2-inch mortars to processing all of the projectile leakers after the mortar campaign, including leakers, is completed.

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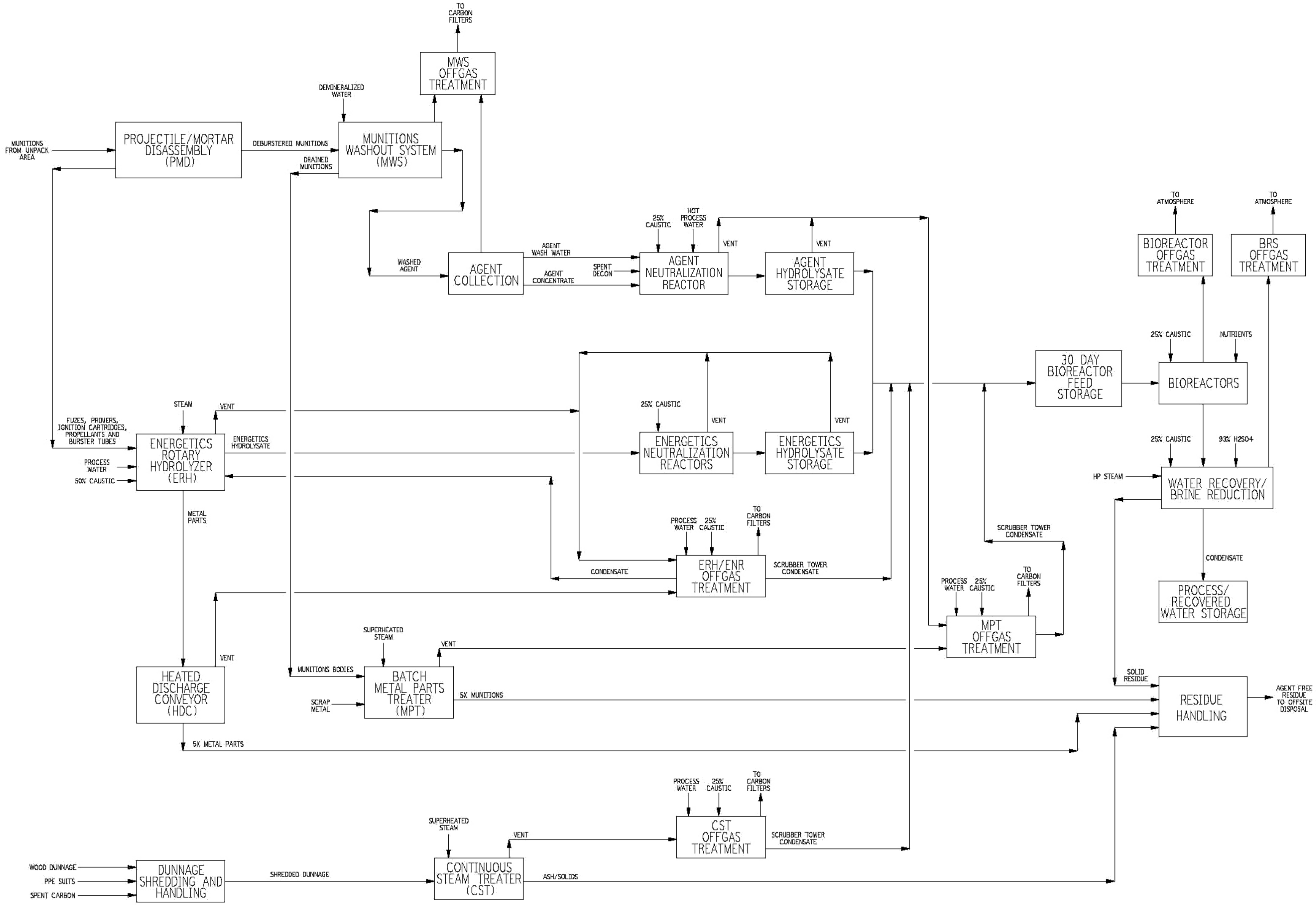

FIGURE 2-1 PCAPP process flow diagram. SOURCE: U.S. Army, 2004b.

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does not release agent at concentrations that exceed the short-term exposure limit, in accordance with new criteria for unrestricted release.[5]

In the reconfiguration room, the uncontaminated propellant, igniters, and primers are removed and, if allowed, will be prepared for off-site disposal. Otherwise, they will be placed in trays for transfer to the energetics destruction processes. At the time that this report was prepared, the Army had not yet obtained a permit to send the propellant off-site for disposal. If a permit is obtained, the uncontaminated propellant will be shipped off-site, but the igniters and primers will be processed on-site. Contaminated propellants and associated munitions will be overpacked and returned to storage for processing with all other contaminated munitions after the processing of all uncontaminated munitions is completed.

Following reconfiguration, the unpacked munitions are moved by a horizontal conveyor system from the reconfiguration room to the entrance of one of three explosion containment rooms (ECRs). Munitions that do not require reconfiguration are unpacked and placed on conveyors and moved to the entrance of one of the three ECRs.

If a pallet is found to contain a leaker, the pallet will be containerized at the storage igloo in a special overpack that is yet to be designed. The Army estimates that about 0.1 percent (~30) of the unreconfigured stockpile and 0.01 percent (~40) of the reconfigured stockpile will be found to be vapor leakers.[6]

After processing of the uncontaminated munitions, the overpacked pallets containing leaking munitions will be brought to the EPB unpack area and refrigerated to 0°C for HD and –20°C for HT before processing. Refrigeration at these temperatures will maintain the agent in a frozen state for a minimum of 3 hours to prevent leakage during disassembly (U.S. Army, 2003b).[7] The refrigeration unit is to be installed in the EPB unpack area before the processing of contaminated munitions begins. Processing of refrigerated munitions will take place with the same steps as those for uncontaminated munitions, but the necessary additional personal protective gear and agent monitoring will be used.

The next step in disassembly takes place at the projectile/mortar disassembly (PMD) machines. The plant is designed with three PMD machines, each in a separate ECR. At the beginning of PCAPP agent operations, one ECR will be dedicated to processing each of the three types of munitions: 4.2-inch mortars, 105-mm projectiles, and 155-mm projectiles.

Nose assemblies, fuzes, and bursters are removed by each of the three PMD machines. The PMD machines consist of a commercially available, pedestal-mounted robotic arm and disassembly stands, one for each step in the disassembly process. The robotic arm is used to move the munition from the input conveyor through the disassembly stands, to a tray on the output conveyor. The robotic arm, which permits precise positioning, is computer-controlled, allowing the arm to be walked through the disassembly steps and thereby to "learn" the movements and positions needed. Parts removed from the munitions bodies are placed in trays that are moved from the ECR via conveyors.

The newly designed PMD machine, selected as a replacement for the PMD machines used at baseline incineration facilities, is composed of smaller components (robotic arm and disassembly stations). These smaller components can fit through ECR entryways that are in turn smaller than those used at baseline incineration facilities. This change in turn further reduces the required concrete wall thickness and reinforcing necessary for ECR explosion resistance, particularly around ECR openings. This modular design also simplifies maintenance and replacement operations and will simplify the closure of the plant because the modules can be removed from the ECR.

As noted above, the key element of the PMD machine design is a pedestal-mounted, multiaxis robotic arm similar to those used in automotive assembly and other manufacturing operations. The disassembly stations are adaptations of technology developed for baseline facilities.

AGENT AND ENERGETICS TRANSFER SYSTEMS

The agent transfer system (ATS) and energetics transfer system (ETS) are located in the transfer corri-

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[5] This verification step may be unnecessary if the method of detecting the presence of agent in the storage igloos is deemed adequate.

[6] PCAPP briefing by Craig Myler, PCAPP Chief Scientist, to the ACWA Design Committee, Aberdeen Proving Ground, Md., April 13, 2004.

[7] Hydrogen gas pressurization can result when mustard agent degrades, thereby forming hydrochloric acid. The acid in turn reacts with the iron of the munition casing to produce ferrous chloride and hydrogen gas. The hydrogen pressurization can cause foaming or frothing of the agent during disassembly, causing the agent to overflow from the casing. This frothing is sometimes called "champagning" (NRC, 2004).

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dor of the energetics processing building. They are intended to move the agent-filled munitions bodies and the removed energetics from the explosion containment rooms to separate processing areas. In the current design, the 4.2-inch mortar round propellant sheets and the propellant bags containing M1 propellant separated from the projectiles in the munitions reconfiguration area adjacent to the ECRs also will be moved by the ETS to the energetics processing area.

The ATS will receive munitions free of energetic materials in trays through a dedicated explosion-resistant door in the ECR that opens into the transfer corridor of the energetics processing building (EPB). The ATS then transfers the munitions to a buffer storage room for feed to the agent processing building munitions washout systems (MWSs) via roller conveyors. The agent-filled munitions are transferred from the ECR to the buffer storage area (tentatively by a remotely operated forklift, but this mode of transport is subject to change depending on the design of the ETS and further design evaluation).

In the current design, the energetics separated from munitions in each ECR (bursters, fuzes, and nose assemblies) are placed in trays that are moved on conveyors through an explosion-resistant door dedicated to energetics transfer. Once in the EPB corridor area, the tray is picked up by the ETS. The ETS has elevator mechanisms outside the energetics discharge door of each ECR. These mechanisms raise the tray with energetics to a position for pickup by the ETS elevated monorail system. The tray is then moved to the opposite side of the corridor to the feed chute of one of the two energetics rotary hydrolyzers (ERHs), where the tray is tipped and the energetics are discharged into the ERH. A similar tray elevator and monorail pickup position are provided for trays of mortar propellant and propellant bags containing M1 propellant discharged from the munitions reconfiguration area. The ETS is designed to handle all of the propellants produced in the munitions reconfiguration room, but the PCAPP design team is requesting a waiver from the Army and the CDPHE to permit shipment of all uncontaminated propellant material (propellant bags containing M1 propellant and sheet propellant from the mortars) off-site.

At the time this report was being prepared, explosives safety considerations were requiring blast-resistant structures in the transfer corridor and complicating the overhead monorail design of the ETS. Therefore, alternative ETS designs such as pneumatic tubes are being considered. Because both the ETS and ATS operate in the same transfer corridor, the ATS may also be affected by the final choice of the ETS.

HYDROLYSIS OF ENERGETIC MATERIALS

Hydrolysis of energetic materials begins in either of two ERHs. Each ERH is a continuous-feed unit, 6 ft in diameter and 20 ft long, with an inclined feed mechanism. The ERH rotates at a rate of 4 revolutions per hour and is similar to a rotary kiln in configuration. In the ERH, the feed materials (burster tubes filled with energetics, fuzes, sheet propellant, propellant bags containing M1 propellant, and nose assemblies) are brought in contact with 35 percent caustic (NaOH) at 120°C, which is just below the boiling point (U.S. Army, 2003c). Parts and materials that are not dissolved in the caustic solution move through the ERH in about 2 hours, carried along by the internal helical flights in the rotating ERH. High-pressure water spray from nozzles on a spray bar located on the axis of the ERH washes undissolved materials from the ERH walls and flights. Aluminum in the burster tubes or fuzes is also dissolved by the caustic solution, thereby generating hydrogen gas.[8]

The output stream from the ERH passes over strainers, where undissolved metal parts and propellant bags are separated from the liquid, dropped on a vibrating conveyor, and then moved to a heated discharge conveyor (HDC), where they are heated to at least 1000°F for 15 minutes for 5X decontamination before being dropped into discharge hoppers for cooling and storage prior to disposal. The HDC and ERH ventilation system feeds all of the reaction gases to the energetics offgas treatment system (OTS). Any undissolved fuzes exiting the ERH are expected to deflagrate on the HDC, which is designed to withstand detonations of these items.

The treatment solution that passes through the ERH discharge strainers contains dissolved energetics and some sodium aluminate as well as unreacted caustic. This solution is transferred to energetics neutralization reactors (ENRs), where the hydrolysis of the energetic materials is completed. The hydrolysate is sampled and analyzed for residual energetics before being transferred to buffer storage and then to the immobilized cell bioreactor units. A differential scanning calorim-

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[8] The Bechtel Pueblo team is considering sending the aluminum-containing parts not through the ERH but directly to the heated discharge conveyor.

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etry (DSC) method has been developed by the Bechtel Pueblo team to determine whether there is any energetic material remaining in the hydrolysate. The absence of an exotherm in the DSC thermogram indicates that there is no component of the hydrolysate that will react exothermically. The detection of any unreacted energetic material, as indicated by an exotherm in the DSC, requires that the hydrolysate be recycled through the ENR. The unreacted energetic materials would not be in sufficient concentration to harm the ICBs. Treatability studies have been performed with TNT and tetryl, and neither should be toxic at concentrations that might be inadvertently released to the ICBs.

AGENT PROCESSING

All agent processing is performed in a separate building, the agent processing building (APB), to lower the risk of agent's being released if there were a catastrophic explosion in the energetics processing area. Processing the agent in a separate building is expected to lower closure costs by requiring that only one building undergo major decontamination.

The munitions bodies, still containing the agent but now devoid of energetics following disassembly in the energetics processing building, are conveyed in trays from the explosion containment rooms through the transfer corridor to the input air locks at the APB-EPB transfer corridor interface. Trays containing either energetics or munitions bodies still filled with mustard agent will be present in the transfer corridor, but the agent and energetics will be handled on separate transfer systems, as previously described. The amount of energetics and agent in the transfer corridor will be limited by operational controls.

Removal of Agent from Munitions

After arriving in the APB, the munitions (with the bursters and fuzes removed, but the chemical agent still sealed in the body by the burster well) are moved in their trays to one of three munitions washout systems. At each MWS, a pedestal-mounted, robotic arm similar to that used in the PMD machines is used to move each munition from the tray to a weighing station, and then to a cavity access machine (CAM) located in its dedicated containment booth.

Each CAM is designed to operate on one of the three different munition types stored at Pueblo Chemical Depot. At the beginning of agent operations, one MWS will be dedicated to each type of munition. The 155-mm projectile MWS will have two operating CAMs and one installed spare. The 105-mm projectile MWS will have three operating CAMs and one installed spare. The 4.2-inch mortar MWS will have four operating CAMs and one installed spare. As the destruction of one type of munition is completed, the MWS dedicated to that munition (as with the PMD machines noted earlier) will be reconfigured to handle 105-mm projectiles. Eventually, all three MWSs will process 105-mm projectiles. The MWS and the associated CAMs were designed to address problems that had been encountered with gelled agent during the processing of mustard agent munitions at the Johnston Island facility (the Johnston Atoll Chemical Agent Disposal System, or JACADS).

Munitions are brought in to the MWS stations in trays on a conveyor with the shells pointed upward. For projectiles, the robot picks up a shell and moves it to a weighing station, where its weight is automatically recorded. The shell is then picked up again, turned nose down, and placed in the jaws of a gripper on the CAM. The gripper holds the projectile against a stop on the base end of the projectile while a ram rises up from the bottom of the CAM agent collection cavity to force the burster tube back into the shell. This causes the burster tube to buckle into a "Z" shape, and thus it will not interfere with the draining of agent through the open nose of the projectile. The seal around the nose is designed to contain agent if the agent "champagnes," or froths, when the cavity is accessed. The agent is gravity-drained from the shell, and the ram is then inserted back into the cavity for washout using a nozzle in the ram head. Warm, high-pressure wash water at 10,000 psi jets through the ram nozzle into the cavity as the shell is rotated to rinse out any gelled agent or residue (FOCIS, 2003a).

After completion of this rinsing step, the robot picks up the projectile, tips it to ensure maximum drainage prior to weighing, and then places it in an upright position in the weighing facility to record the weight change resulting from the removal of agent. Finally, the projectile is moved to a tray on the outlet conveyor for removal to a metal parts treater (MPT). If the weight loss of the projectile does not meet or exceed target values, the projectile would be returned to the CAM for further washout, or placed in a reject stand in the MWS area for further evaluation.

To access the agent in 4.2-inch mortar rounds, the round is weighed and then inserted into the CAM,

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which cuts off the base of the round just above the bottom plate. This is done by holding and rotating the body over wheel cutters similar to those in a pipe cutter. The cut-off bottom is dropped into a collection tray, and the liquid agent drains by gravity into a collection tank. Then, residual agent and heels are washed from the munition casing with high-pressure (~10,000 psi at 108°F) water spray through a wand inserted in the munition body cavity (FOCIS, 2003b). Each emptied mortar round is weighed, and the cut-off bases are collectively weighed and the weight averaged to determine the amount of agent removed per shell. The mortar rounds and the collected bases are then placed on a tray on the outlet conveyor for removal to the metal parts treaters. The drained agent from the mortar rounds and projectiles is sent to a settling tank, where the agent, which is only slightly soluble in water, will settle out into an agent concentrate. From the settling tank, the agent and the separated wash water are fed to the neutralization system for processing through different pipelines. Several committee members traveled to the contractor fabrication facility in Pasco, Washington, in May 2004 to view the prototype testing of the munitions washout system.

Decontamination of Munitions Bodies

The munitions bodies (including internal metal parts and cut-off bottom plates of mortar rounds) are placed in trays and conveyed from the MWSs to one of three metal parts treaters for decontamination to a 5X condition. Other potentially contaminated metal parts are also treated to a 5X condition in the MPTs by being placed in baskets or trays designed to move through the MPTs.[9] Each MPT consists of an entry air lock, a process chamber, and an exit air lock. The munitions and metal parts in the trays move on tracks through the MPTs. The interior wall surface of the MPT process chamber is maintained at 1200°F by external induction heating coils. Low-pressure (<25 psig), superheated steam at 1200°F is introduced into the process chamber of the MPT as a carrier gas to move vaporized agent and other gases produced from the 5X decontamination process into the MPT offgas treatment system. The steam may react with the agent and other organics such as paint to form some hydrogen, but the primary means of achieving the 5X condition is through thermal decomposition. Both the entrance and exit air lock chambers are purged to the MPT offgas treatment system with nitrogen before the doors are opened to the process chamber, because the gas mixture in the process chamber could contain hydrogen or other combustible gases. The airspace in the exit air lock will be sampled for the presence of agent before the air lock is opened and the tray is moved out of the air lock. The decontaminated metal will be recycled or disposed of appropriately. If agent is detected in the exit air lock, the tray will be backed into the MPT process chamber for further treatment.

One of the MPTs will be larger than the other two (one will be 10 ft in diameter, the others 6 ft in diameter). The larger MPT will be used for big objects during closure of the facility (e.g., a CAM in its containment booth that requires 5X decontamination during facility closure).

Hydrolysis of Mustard Agent

After washout, the solution of agent and washout water is fed to one of two agent/water separators, where it separates into a lighter water phase and a heavier agent phase. The agent concentrate, normally more than 99 percent agent, is then sent to an agent-concentrate holding tank, and the washout water is pumped to wash-water holding tanks for recycling to the munitions washout system stations. The agent concentrate is fed to one of two agent neutralization reactors (ANRs), which are continuously stirred tank reactors (CSTRs), where hydrolysis with hot water (194°F) will be taken to completion. The outlet stream from the ANR is first collected in buffer storage tanks, which are also CSTRs, and checked for the completion of hydrolysis. Because the resulting hydrolysate is acidic and unacceptable for feed to the immobilized cell bioreactors, sodium hydroxide solution is added until the pH of the solution is in a neutral range. This process and the reaction conditions are identical to those used by the Aberdeen Chemical Agent Destruction Facility for the destruction of the bulk mustard agent stored at Aberdeen Proving Ground in Maryland.

After the neutralization is completed, the hydrolysate is sent to an agent hydrolysate tank, where it is stored until further processing in one of the continuous-feed ICBs. The hydrolysate is sampled and analyzed for the presence of residual mustard agent. If agent is detected, the hydrolysate will be returned to

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[9] These metal parts include strapping from dunnage, DPE metal connectors, and metal parts discarded from maintenance of contaminated equipment.

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Interim Design Assessment for the Pueblo Chemical Agent Destruction Pilot Plant
http://www.nap.edu/catalog/11213.html

the ANRs after hydrolysis of the next batch being processed is completed.

BIOTREATMENT OF AGENT AND ENERGETICS HYDROLYSATES

Biotreatment has been selected as the secondary treatment process at PCAPP for agent and energetics hydrolysates. The hydrolysates, various process condensates, and additional water are collected in 30-day storage tanks. After sampling to determine the composition of the tank contents, these contents will be mixed with required nutrients and fed to twenty-four 40,000-gallon ICBs for biotreatment. The average residence time in each ICB is expected to be approximately 3.6 days.[10] It will require approximately 30 days to acclimate each ICB at start-up. The design team has provided flexibility to accommodate this time period by allowing for the storage of feed water.

The bacteria used in this process are immobilized on a support material made of plastic packing rings and an elastomer foam impregnated with activated carbon. The reactor is arranged with three compartments in series. The solution is sparged with air at a flow rate of 600 cubic feet per minute. The ICBs can operate in temperatures ranging from 95°F to 41°F, but ambient temperatures in Pueblo, Colorado, range from 115°F down to –20°F. Therefore, the design will provide appropriate cooling and heating of air and water fed to the ICBs to ensure optimum operating temperatures.

Thiodiglycol, the only Schedule II component in the agent hydrolysate, has been reported from testing to be 99.9 percent destroyed (the goal was 90 percent).[11] The ICB design is the same as the system used for the earlier ACWA engineering design studies conducted for Pueblo.[12]

Normally, the bioreactor liquid effluent will be sent directly to the brine recovery system (BRS) for the recovery of most of the process water. Vapor from the bioreactors is collected and sent to the bioreactors' offgas treatment system for odor control.

The BRS consists of two 50 percent capacity trains of equipment. Each train contains a pretreatment steam stripper, a brine concentrator, an evaporator/crystallizer unit, and a solids-dewatering unit, along with related tanks, heat exchangers, and pumps and piping systems. Water conservation is an important consideration for the Pueblo community. The BRS recovers clean water from the ICB effluent for reuse in the process units and separates the solids in pressure filters or centrifuges. The BRSs are designed for a total flow rate of about 200 gallons per minute. Vapors from the evaporator/crystallizer vapor condensers on each train are combined and flow to the BRS offgas treatment system. The solids from the crystallizer will be sent to an appropriate off-site facility.

If necessary, the bioreactor liquid effluent can be fed to two clarifiers, where suspended solid materials (e.g., cells from the ICBs) are separated and collected by a sludge collector. It is expected that the clarifiers normally will not be required. This question is being studied at Battelle, which is a member of the Bechtel Pueblo team, and should be answered prior to facility construction. In each clarifier, a scraper-type sludge collector is provided to collect the underflow sludge and release it intermittently to the thickener. The underflow sludge is fed to two thickeners designed to capture 90 percent of the suspended solids. The thickened sludge is then pumped intermittently to one of two dewatering filter presses for solids removal. Filter cake from the presses is collected in dumpsters and sent for off-site disposal. Overflows from the thickeners and filter presses are sent to the BRS.

DUNNAGE TREATMENT

All contaminated wood pallets, used DPE suits, and other contaminated nonmetallic waste will be shredded in the dunnage shredding and handling system, and the shredded material will be decontaminated to a 5X condition in one of the three continuous steam treaters. Uncontaminated wood pallets will be sent off-site for disposal if a permit is granted and the Citizens Advisory Commission does not strongly oppose this course of action. Otherwise, the uncontaminated pallets will be treated in the same way that the contaminated pallets are.

Table 2-1 summarizes the expected quantity of waste feed to the dunnage treatment system. Potentially contaminated metallic waste will be processed in one of the three MPTs. As shown in Table 2-1, approxi-

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[10] PCAPP briefing by Craig Myler, PCAPP Chief Scientist, to the ACWA Design Committee, Aberdeen Proving Ground, Md., April 13, 2004.

[11] Schedule II components are those agent breakdown products that the Chemical Weapons Convention of 1997 requires to be destroyed because of the potential that they could be reconstituted into agent.

[12] See NRC, 2000; 2001b.

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TABLE 2-1 Estimated Quantity of Waste Feed to Dunnage Treatment

Waste Type	Composition	Waste Quantity (lb/round)
Wood pallets	Wood, both contaminated and uncontaminated.	2.4 (105-mm projectiles and 4.2-inch mortars) 5.0 (155-mm projectiles)
Miscellaneous dunnage from nonmunition sources	Glass, plastic, wood, paper, packaging materials. Assumed to be 60 percent wood and 40 percent plastic.	0.5
Demilitarization protective ensemble (DPE) materials	Chlorinated polyethylene, PVC, latex, butyl rubber.	0.15
Spent carbon from plant heating, ventilation, and air conditioning filters	Generated by filter building and offgas treatment systems.	0.3
Waste oils	Assumed to be heavy oil for lubrication. Heat content assumed similar to that of kerosene.	0.3
Trash, debris, protective clothing	Assumed to be solid, nonmetallic, nonplastic. Treated like wood.	0.2
Spent hydraulic fluid	Light oil for hydraulic machinery operation. Heat content assumed similar to that of kerosene.	0.2

SOURCE: Adapted from U.S. Army, 2004b.

mately 1.65 lb per round will arise from sources other than wood pallets, and when 105-mm projectiles and 4.2-inch mortars are being processed, these other sources constitute approximately 40 percent of the dunnage feed. The remaining 60 percent of the dunnage feed will be wood pallets, assuming no off-site disposal of uncontaminated pallets.

All solid dunnage materials will be shredded prior to being fed to the continuous steam treater. The shredded materials will be mixed with carbon carrier material—either similar to the activated carbon used in the HVAC filters or coconut shell activated carbon—and then fed to the CST. The liquid organic wastes (see Table 2-1) will be mixed with the shredded solid material or the carbon carrier material, presumably as the solid material is fed to the CST. Each CST is designed to process materials at a design rate of 160 lb/hr for wood, 50 lb/hr for plastic and rubber, or 300 lb/hr of granulated activated carbon from spent HVAC filters. Each CST processes only one of the preceding feed materials at a time. For wood and plastic or rubber, carrier carbon is added to maintain an overall feed rate of 300 lb/hr. Mixes of feed materials are not planned.

The design of the CST is still under consideration. A unit will be fabricated and tested at the Parsons Fabrication Facility in Pasco, Washington, in late 2004. However, the current CST design consists of two inductively heated chambers, one above the other, as shown in Figure 2-2. The upper chamber is horizontal from the feed end to the discharge end, while the lower chamber is slightly inclined upward from the feed end to the discharge end. As shown in Figures 2-3 and 2-4, each chamber consists of two concentric shells, a chamber shell and an auger shell. An electrical induction heater is mounted on the outside of the chamber shell. The annular space between the shells is filled with a gas, presumably inert or with very low oxygen content. The auger shell containing the auger and its end-mounted drive unit can be withdrawn from the chamber shell on racks (not shown in Figures 2-3 and 2-4). Material is fed to the upper auger shell, which uses a shaft with rotating paddles to move the material to the exit of the auger shell. The material leaving the upper auger shell drops into the inlet of the lower auger shell. The lower auger shell uses a rotating shaft with solid helical flights for material movement. The lengths of the two chambers and the speeds of the rotating auger shafts are set to ensure that 5X decontamination is achieved.

Low-pressure (<25 psig), superheated steam at 1000°F is fed countercurrent to the material flow in the upper auger shell. This steam serves as sweep gas for the removal of gaseous decomposition products. Expe-

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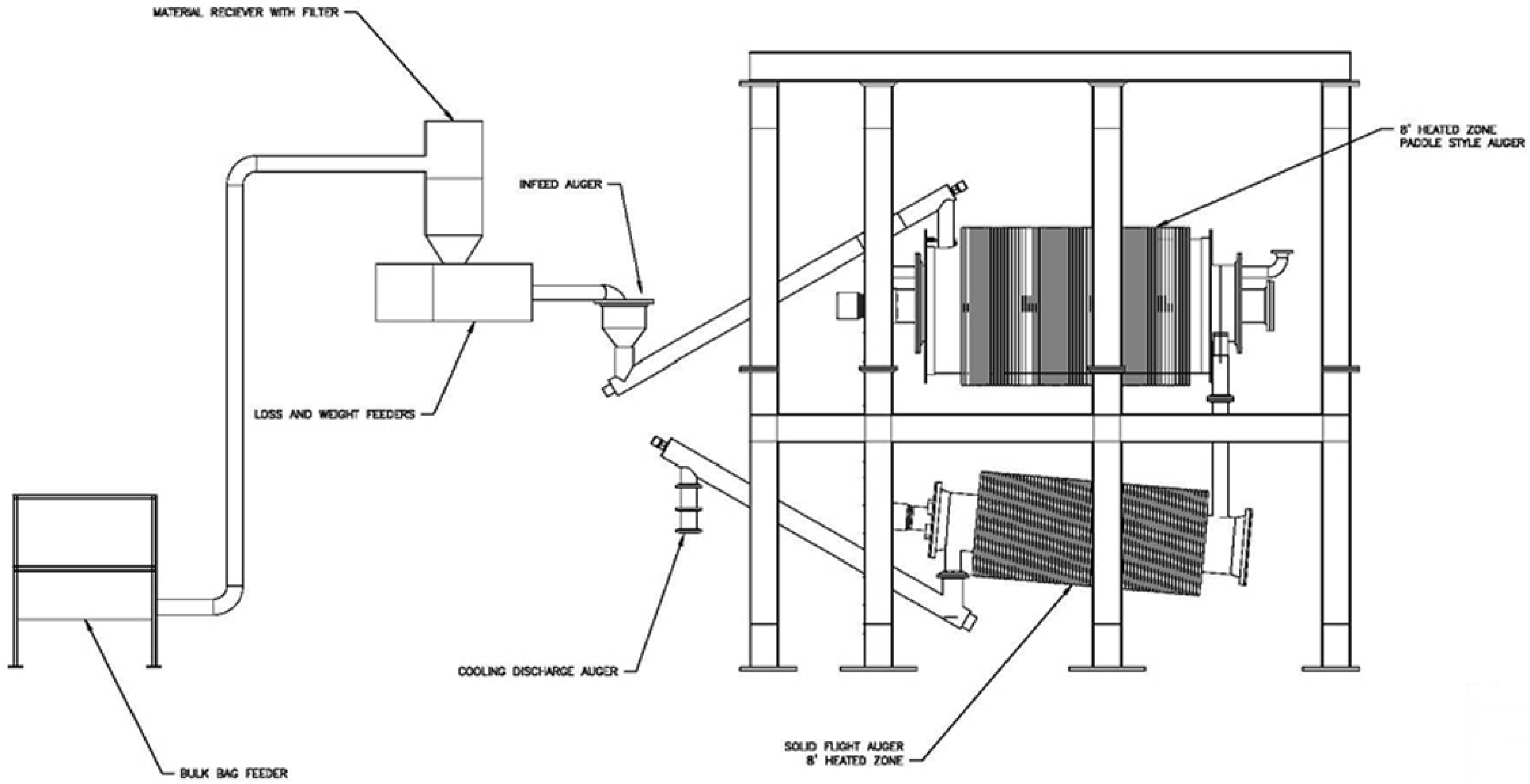

FIGURE 2-2 Two-cylinder continuous steam treater configuration. SOURCE: U.S. Army, 2003d.

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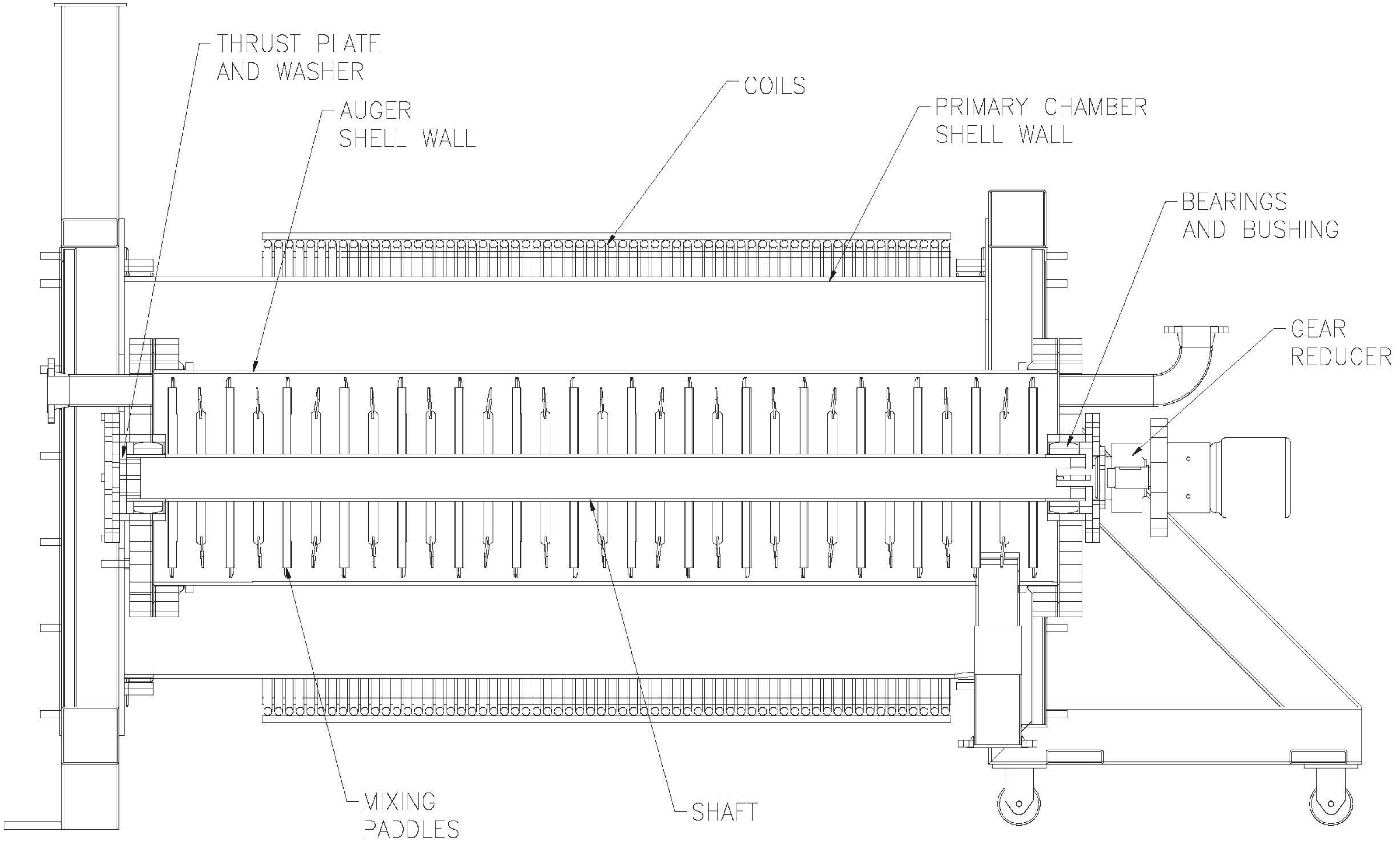

FIGURE 2-3 Primary chamber of the continuous steam treater. SOURCE: Provided by Yu-Chu Yang, ACWA Chief Scientist, July 26, 2004.

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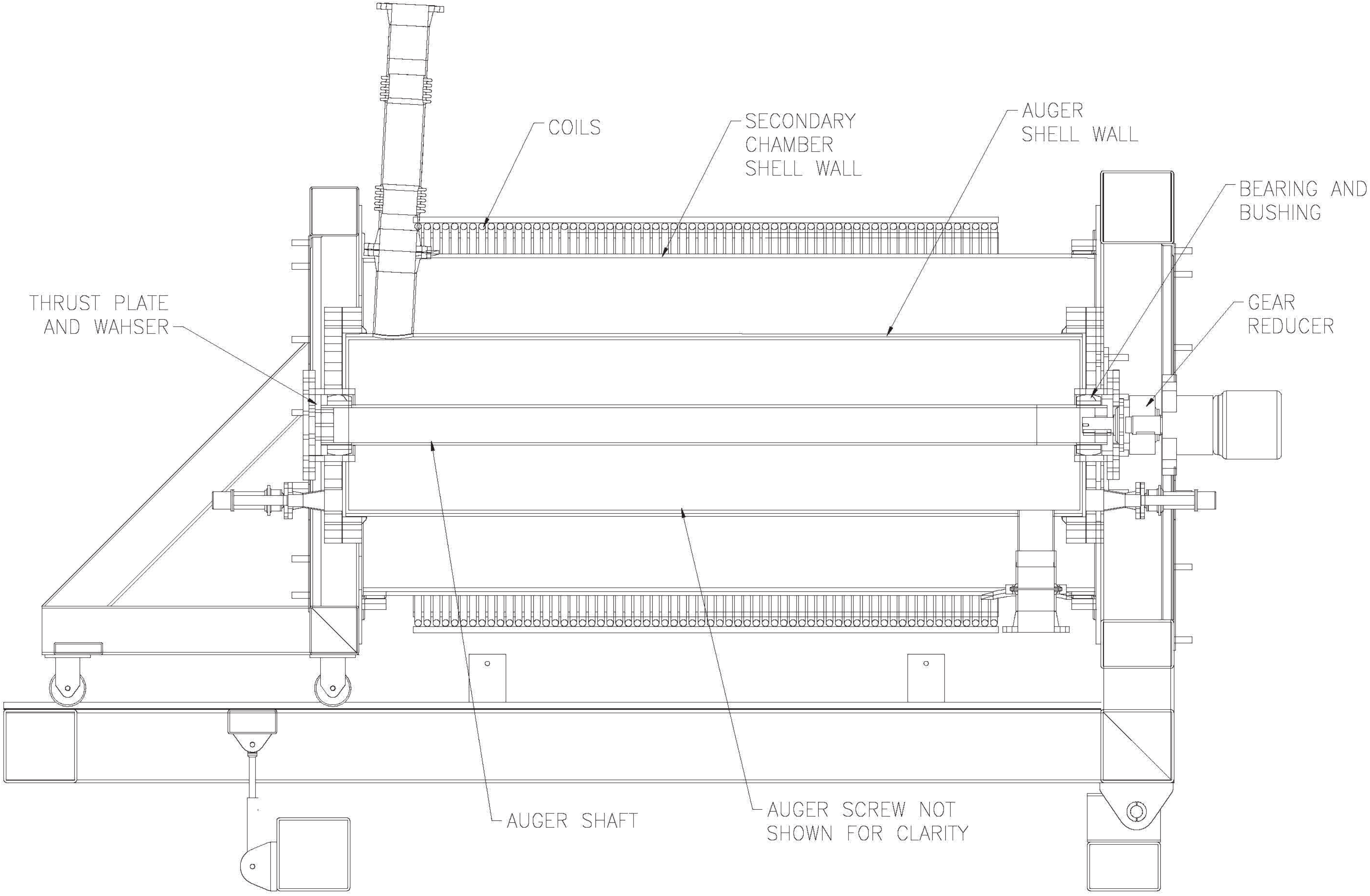

FIGURE 2-4 Secondary chamber of the continuous steam treater. SOURCE: Provided by Yu-Chu Yang, ACWA Chief Scientist, July 26, 2004.

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rience gained in prior CST testing suggests that steam may react with the wood, DPE suit material, and any agent and other organic materials present, in the first chamber of the CST (NRC, 2001b). However, air may have leaked into the system in prior tests.

A nitrogen sweep gas flows countercurrently through the lower auger shell into the upper auger shell and exits that shell with the superheated steam-gas mixture from the upper auger shell. The CST offgas flows to the CST offgas treatment system for the destruction of any remaining hazardous materials. Treated solid material, a mixture of char and tar, exiting the lower chamber is collected and cooled in an air-locked bin, where the vapor space is sampled to verify agent destruction. Subsequently, the treated material is released to a hazardous waste disposal site.

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3

Selected Pueblo Chemical Agent Destruction Pilot Plant Design Issues

This chapter presents a discussion of selected design issues that the committee has identified and that it believes require further study and possible changes.[1] In actuality, the Army and its contractors may already be making modifications and pursuing changes based partially on questions that the committee asked during meetings with the Army and its contractors. Also, it must be emphasized again that this review is based largely on the initial design for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP). Any information included on the intermediate design was obtained from notes taken during attendance by committee members at the May 19–21, 2004, intermediate design review meeting held at the offices of the contractor, Bechtel National, Inc., in San Francisco.

SIZING OF THE FACILITY

The Bechtel Pueblo team used iGrafx™ software to estimate the material flow in the PCAPP design and to determine the number of units and capacity of each unit operation within the total plant design. The model assists the design team in better understanding and evaluating design options and determining the rate-limiting steps. For example, this event-driven model can vary the input and output rates of items (e.g., munitions) in each step in the process, including the probabilities of encountering problems. Calculations include excursions in boxed munitions handling, leakers and rejects, munitions dismantling, agent washout, agent hydrolysis, energetics hydrolysis, metal parts treatment, biological treatment, and brine reduction. Because several of these processes are batch processes while others are continuous, the model can be used to evaluate buffer storage requirements between various operations. Buffer storage is needed for situations in which single-unit failure would limit throughput or shut down the plant completely, and to ensure that the desired throughput can be maintained.

The analysis indicates that the rate-limiting activity in the process design is the munitions disassembly step. As a result, in order to maintain the desired availability of munitions, the front-end process has a separate disassembly station for each of the three types of munitions to be treated. There is an unequal number of each type, with the number of 4.2-inch mortars being about one-third the number of either the 105-mm or the 155-mm projectiles. Therefore, after completion of the disassembly of all 4.2-inch mortars, including leakers, the 4.2-inch mortar line will be modified to disassemble the remaining types of leaking projectiles by retooling the projectile/mortar disassembly (PMD) station. However, Army safety regulations may require that all three PMD machines be shut down if maintenance is being performed on one, and thus the effective throughput capacity for the disassembly step would be reduced.

Finding 3-1. The rules for personnel safety during equipment repairs in the explosion containment rooms

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[1] Unless otherwise indicated, background material in this chapter is drawn from U.S. Army, 2004b, and information on the intermediate design is from the PCAPP intermediate design review in San Francisco, May 19–21, 2004.

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may require that all three stations must be shut down if maintenance is being performed on one station. In a worst case, the unavailability caused by the maintenance of a station would be nearly three times what would ordinarily be expected.

Recommendation 3-1. The Bechtel Pueblo team designing the Pueblo Chemical Agent Destruction Pilot Plant should seek clarification on the regulations for the safety of maintenance personnel during the repair of equipment in the explosion containment rooms (ECRs). If the regulations call for operations in all three ECRs to stop during maintenance on one station, the effects of such shutdowns should be examined by the event-driven iGrafx model, and performance and schedule impacts should be incorporated into the design. Design changes should be sought whereby operations in the other two projectile/mortar disassembly ECRs can continue while planned and unplanned maintenance is performed in the third station.

TECHNICAL RISK REDUCTION ISSUES

The core processes to be used at PCAPP for destroying chemical agent stored at Pueblo Chemical Depot (PCD) are neutralization (hydrolysis) followed by biotreatment. Neutralization is well proven for the destruction of neat mustard agent (HD or HT) and is currently being used successfully at Aberdeen Proving Ground, Maryland. As discussed in Chapter 2, however, multiple steps are required to separate the mustard agent from the projectiles and mortar rounds. Other materials obtained from the separation process include energetics; metal parts from bursters, fuzes, and munition casings; and dunnage, which includes wooden pallets, packing materials, personal protective equipment (PPE), rags, and other organic wastes (solid and liquid). Any of these other materials may be contaminated with agent. The practice in other chemical agent destruction facilities has been to consider these materials contaminated and to process them in a manner that ensures the destruction of the chemical agent. This practice also is being implemented in the PCAPP design.

The biotreatment process was originally planned to be used at Aberdeen Proving Ground for the secondary treatment of the hydrolysate, but after the events of September 11, 2001, the hydrolysate was sent off-site to accelerate the schedule. However, the biotreatment of the hydrolysate was demonstrated as a viable means to treat this secondary waste earlier in the Assembled Chemical Weapons Assessment program and further tested in a technical risk reduction program study (NRC, 2001a; U.S. Army, 2003a).

While these core processes being used for destroying mustard agent are well proven, many of the treatment processes for the other materials (noted above) are novel. Moreover, the PCAPP design is a first-of-a-kind pilot plant, and, consequently, overall integration of the unit processes presents additional challenges. In recognition of these technological challenges, the Bechtel Pueblo team assembled an integrated product team (IPT) to assess and select combinations of unit operations that would meet PCAPP requirements. The IPT also performed a technical risk assessment (TRA) of the proposed design concept to identify problem areas in meeting performance objectives. The IPT consisted of a team of recognized experts in the design and operation of chemical agent disposal facilities.

Although the selection process was subjective, it drew on lessons learned from the chemical agent disposal facilities at Johnston Island (in the Pacific Ocean); Aberdeen, Maryland; and Newport, Indiana; and on expertise from earlier ACWA engineering design studies.

After the unit operations were selected, the IPT initiated a TRA of the total design concept embodying these operations. The TRA process, thus initiated, will be continued and refined throughout the life of the project. The ultimate goal of the TRA, as stated in the PCAPP Design-Build Plan, is to "maximize the safety of workers and the public, minimize any adverse effects on the environment, and ensure a smooth process for obtaining the necessary regulatory permits" (U.S. Army, 2003a, p. 137). The Design-Build Plan also notes that the ongoing TRA process will include "measures for reducing risk for cost overruns and minimizing the overall project schedule" (U.S. Army, 2003a, p. 137).

The committee observes that the initial TRA focused almost exclusively on risks stemming from cost and schedule overruns. Based largely on engineering judgment, the IPT identified 90 different risks relating to major unit operations. These risks are listed in Appendix P of the PCAPP Design-Build Plan and are reproduced in this report as Appendix C (U.S. Army, 2003a). To prioritize the risks, the IPT adopted a semiquantitative approach, assigning two weighting factors, one to "probability of occurrence" and one to "technical, schedule, and cost consequence of occurrence." The total risk for each scenario was calculated by multiplying the two weighting factors together.

The probability of occurrence was scored on a scale of 1 to 5, where 1 is "remote," 2 is "unlikely," 3 is "likely," 4 is "not defined," and 5 is "near certainty." The consequence of occurrence was scored on a scale of 0.2 to 1.0, where 0.2 is "minimal or no impact," and 1.0 is "unacceptable." Multiplying probability and consequence provided the overall risk weight.

Each of the risks was then assigned to one of three overall risk-weight categories: low (overall weight equal to or less than 1.0); medium (overall weight between 1.0 and 3.0); and high (overall risk weight above 3.0). No risks with an overall weight equal to or greater than 3.0 were identified. This analysis identified the 10 distinct areas requiring either paper studies or testing that are listed in Table 3-1. Also, the PCAPP team identified other issues requiring testing or trade (paper) studies to resolve key design, construction, operation, or closure issues. Both the TRA issues and these other issues are listed in Table 3-2 (U.S. Army, 2003a).

The committee observes that the criteria in the TRA for assigning probability and consequence values could have been defined more precisely, but the overall risk-weight results seem reasonable. For example, whereas health, safety, and environmental impacts were considered in the description of some of the risk scenarios, the probability and consequence weightings ascribed to scenarios with health, safety, and environmental impacts are not always consistent with the scenario description. Cost and schedule impacts appear to have been the primary drivers of the probability and consequence scoring scheme. Some examples of such inconsistencies are as follows (U.S. Army, 2003a):

- Under "baseline/reconfiguration operations" (see Appendix C in this report), the probability of "inadequate design considerations for explosives handling" is considered to be remote, with a probability weighting of 1 out of 5. Under "energetics treatment processes," the probability of "inadequate explosive considerations" is considered to be unlikely, with a higher probability weighting of 2. The consequence weighting, however, is 0.8 for the former and only 0.4 for the latter, even though both could result in explosion. It would seem that the consequences of explosion in both instances or locations should be the same, since the impact of investigation delays would be similar.
- Under "metal parts treatment processes," one of the listed risks with a low overall rating is "explosive gas build-up/purging potential for explosion." The probability is given as unlikely (weighting of 2 out of 5). The consequences are described as follows: "explosion occurs, requires downtime, repairs, and minimal to moderate impact to cost and schedule." The relatively low consequence weighting of 0.45 out of 1.0 may stem from lumping the potentially catastrophic effects of an explosion with the minor impacts on cost and schedule. While it is quite possible that equipment could be repaired fairly quickly following an explosion, the project could be shut down for months while the explosion was investigated.
- Under "biotreatment of hydrolysate processes," one of the listed risks with a low overall rating is "odor not adequately controlled." The probability is unlikely (weighting of 2). The consequences are stated as "potential regulatory violation, resulting in fines and potential shutdown" and assigned a weighting of 0.3. The IPT may be optimistic in anticipating "minimal cost and schedule impacts." The same risk is also included under "environmental risks." There, the probability is weighted as likely (rating of 3), but the consequence remains at 0.3.

The committee believes that, despite the shortcomings in the rigorousness of the implementation of the TRA process, most of the major technical roadblocks to a successful design were identified. Tests are under way to acquire design data for unit operations with insufficient prior testing or operating experience, and studies have been undertaken to evaluate promising alternatives or to resolve design decisions for areas not requiring testing. As noted earlier, these tests and studies are listed in Table 3-2, along with reference to the TRA risk areas/scenarios that have been identified in Appendix P of the PCAPP Design-Build Plan. They are discussed in more detail in the subsequent sections of Chapter 3, along with other aspects of the design important to its success.

Finding 3-2. Although the implementation of the risk assessment methodology in the preliminary technical risk assessment for the Pueblo Chemical Agent Destruction Pilot Plant is sometimes inconsistent, the committee judges that the major technical risk issues have been identified and are being addressed by tests and studies.

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TABLE 3-1 Major Potential Risks and Proposed Mitigation Measures for the Pueblo Chemical Agent Destruction Pilot Plant Identified in the Technical Risk Assessment

Potential Risk	Proposed Mitigation Measure
Integration of material-handling units with process equipment may lead to more maintenance, increased operating time, and moderate increase in schedule.	Design in adequate buffer capacity. Develop and maintain interface control diagrams (ICDs) early in program, use three-dimensional computer-aided design and drafting models to assess impacts, and perform systems engineering, using iGrafx to model flows beginning early in the program to mitigate rework. Include repair/access, maintainability, construction tolerances, turnover, etc. in three-dimensional model.
Unknown agent and energetic characteristics impacting performance may lead to more maintenance, increased operating time, and moderate increase in schedule.	Use a broad design range for feed characteristics based on lessons learned from other chemical demilitarization programs.
Delays in obtaining the Certificate of Designation,[a] which is a new permitting requirement, may lead to delays in start of construction and all subsequent operations, with significant schedule impact.	Prepare a research, development, and demonstration permitting strategy using multiphases. Involve regulators in all phases of the program, and get their buy-in to the design. Form integrated product teams to support and resolve issues.
Unreliability of entire water-supply system requires facility to shut down, pending resupply, with moderate schedule impact.	Perform trade studies to enhance recovery and possible alternate sources (sanitary sewer, pink water, new wells). Determine overall system reliability and availability for water supply; perform well testing and upgrade pumping system, if found inadequate to meet demands.
Energetics rotary hydrolyzer (ERH)/heated discharge conveyer (HDC) throughput rates less than required, and minimal full-scale data may result in plant operational schedule not being maintained, causing impacts on other operations and moderate schedule delays.	Design for surge capacity and use a conservative rate (test data indicate higher achievable). Fabricate and perform extensive tests at fabrication shop prior to shipment to site.
Cotton fibers in propellants and bags impacting performance of ERH and energetics neutralization reactors from excess material plugging recirculation pumps, causing malfunction and requirement for maintenance, with moderate schedule impact.	Conduct trade study to consider separate reactor for propellants, with additional testing identify alternatives to adding bags to ERH.
Closure criteria not adequately defined, causing minimal to moderate impacts on closure costs and schedule due to extra time and equipment requirements.	Add experienced closure expert from Johnston Atoll Chemical Agent Disposal System to design-build team to participate and provide lessons-learned input into design, develop closure criteria early, and maintain the "design to close" approach throughout the entire program. Add closure in design reviews, and add closure data to the engineering procurement and construction design tool for the closure package.
Inability to deliver munitions within the facility at night, causing operations to stop when munition buffer inventory (4 hours) is depleted, with moderate schedule impact.	Design for munitions night transportation, using adequate lighting and covered areas. Perform trade study to determine transportation alternatives with covered passageways, ensure safety analysis in limiting conditions of operation. Work with customer to obtain permission to perform such night operations.
Aluminum dissolution in caustic causing downstream problems in immobilized cell bioreactors (ICBs) by aluminum hydroxide reducing the surface area of biomass and potential sluffing, which results in poor performance and moderate schedule impact.	Conduct trade study to determine impact on downstream equipment items. Consider adding pH adjustment and filter press upstream of the ICBs to remove precipitation, if warranted. Process used in industrial applications.
Verification of heat transfer for Pueblo tray configuration to validate metal parts treater throughput. If less effective heat transfer occurs, plant average operational schedule is not maintained; impacts other operations and results in moderate schedule delays.	Perform additional testing using prototype munition trays in the ACWA test unit to obtain additional data to confirm the heat-transfer model prior to scale-up. Design using model to full-scale unit, fabricate full-scale unit, perform tests using approved test plan with acceptance criteria and contingencies for failure.

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[a] A Certificate of Designation (CD) is a document issued by the local (county or municipality) governing body authorizing the siting of land for a solid waste disposal site or facility. The CD is issued if it has been determined that the standards are met and after local issues are satisfied.

SOURCE: U.S. Army, 2003a.

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TABLE 3-2 PCAPP Risk Issues Identified for Testing or Trade Studies

Test or Study	Design-Build Plan Appendix P, Risk Areas/Scenarios[a]
Testing	
Prototype Test (Design-Build Plan (DBP) Sect. 2.11.3)	
Prototype Continuous Steam Treater (CST)	43–45
Robotic Performance Coupled with Munitions Washout System (MWS)	23–27
Prototype Metal Parts Treater (MPT)	34, 35
Prototype Energetics Rotary Hydrolyzer (ERH)/Heated Discharge Conveyor (HDC) Interface	17
Laboratory/Bench-Scale Tests (DBP Sect. 2.11.4)	
Scale Testing of ERH	17
HT and Explosives Biotreatment	55
Propellant Bag and M8 Thread Processing (Laboratory Testing of Propellant Reaction)	22
Aluminum Hydroxide Solids	21
Other Identified Tests (Presentation, November 6–7, 2003)	
Personal Protective Equipment (PPE) Certification for HT Agent	None identified
Trade Studies (DBP App. J)	
Projectile/Mortar Disassembly (PMD) Machine	23–27
Explosion Containment Room (ECR)	None identified
Conveyor (for energetics and agent-filled munitions)	15
Munitions Refrigeration (leaking munitions)	None identified
On-site Munitions Transportation Alternatives (from igloos to unpack area)	1–7
Tetrytol Exudates Presence	16
Enhanced Water Recovery	49, 50
Optimize Process Modeling	Various

[a] Appendix P of the PCAPP Design-Build Plan can be found in Appendix C of this report.

SOURCES: U.S. Army, 2003a; PCAPP Design Overview Briefing by Craig Myler, PCAPP Chief Scientist, to the ACWA Design Committee, Aberdeen Proving Ground, November 6, 2003.

Recommendation 3-2. If use of the technical risk assessment (TRA) scoring process for the Pueblo Chemical Agent Destruction Pilot Plant is continued, the Army and the Bechtel Pueblo team should more clearly define each of the weighting factors used in the initial TRA for probability and consequences. Consideration should be given to separating cost and schedule, health and safety, and environmental impacts, if that is necessary to ensure consistency. Furthermore, the methodology for assigning risk reduction factors should be clarified. Additionally, a process should exist to verify that the implemented mitigation measures result in the same level of risk reduction that was assumed during the TRA.

The lay public or qualified representatives selected by the lay public were not involved in the initial TRA, even though the lay public often perceives risks differently from how the technical analysts perceive them. For example, higher risks in the public's perception may relate mainly to worker and public safety, whereas the Bechtel Pueblo team may see those risks as manageable and less of a challenge than other technical risks with greater probability of major cost and schedule impacts.

Involving the public early in the technical risk assessment activity can help alleviate overreaction to unpleasant surprises later on. The committee believes that the IPT may have been optimistic about the maturation rate for the new technologies. Moreover, apparently small problems can cause extensive delay and cost overruns—for example, the occurrence of crystals in the sarin in M55 rockets being processed at the Anniston baseline incineration facility caused extensive concern among both the technical and public communities.

The National Research Council previously reported the importance of involving members of the public, stakeholder group representatives, and local governmental officials, in addition to technical experts, in decision making about risks that are nonroutine and highly controversial, such as is the case with the PCAPP facility (NRC, 1996). The lay public and local officials have perspectives on hazards and risk issues that are both legitimate and important to consider. Involvement of participants from the lay public and local official communities should not diminish the scientific integrity of decisions, but should bring diverse concerns and considerations to bear in risk decisions. Past NRC reports have elaborated on the importance of involving all parties in every step of risk decision making, beginning with the definition of the problem.[2] This involvement is particularly important because there are public considerations of policy assumptions that are embedded in risk analysis activities.

Finding 3-3. The integrated product team (IPT) that initiated the technical risk assessment of the design concept for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) included only experts in chemical demilitarization selected by the PCAPP contractor. No involvement by the lay public or qualified representatives of the lay public was included in developing the technical risk assessment of the IPT, even though the assessment process was conducive to such involvement and would ensure that process efficacy, safety, and environmental concerns were addressed from the public's perspective.

Recommendation 3-3. Qualified representatives selected by the lay public should be included in any future technical risk evaluations for the Pueblo Chemical Agent Destruction Pilot Plant, not necessarily to identify the risks, but to provide an independent perspective on the rankings of probabilities and consequences.

DISASSEMBLY AND TRANSFER PROCESSES

On-site Munitions Transportation Alternatives (from Igloos to Unpack Area)

Palletized munitions are to be loaded by forklift onto ammunition transport vehicles from the storage igloos at Pueblo Chemical Depot, where the chemical munitions are stored. They will be transported to the PCAPP energetics processing building and then offloaded into a receiving vestibule at the unpack area of the EPB. The transfer of munitions from the storage igloos to the EPB unpack area is managed under the control of the PCD commander. The general intent is to have sufficient munitions available to provide for the plant throughput 24 hours a day, 7 days a week, while minimizing cost and ensuring safety.

The technical risk reduction program (TRRP) for PCAPP determined that the following alternatives would optimize the munitions delivery flow:

- *Transport vehicles.* Largely for reasons of depot familiarity, PCD intends to continue to use the current transport vehicles. New vehicles of this type purchased for this program will likely be a larger (18-ft bed) model that increases the capacity by about 50 percent. These new vehicles will be sufficient to provide the 24-hour per day feed requirements for plant operations. In a typical workday (daytime only), one vehicle can be expected to deliver four loads. Previously overpacked pallets in the igloos, which by virtue of their bulk will decrease the delivery capacity, were not considered.
- *Daytime operations.* PCD has required that all movement of munitions from storage to PCAPP be conducted during daylight hours.
- *Weather.* Historical data on average inclement weather events in the Pueblo area (extreme temperatures, precipitation, snow, wind, electrical storms) and on the frequency of extreme adverse weather were evaluated to determine limitations to the delivery of munitions. High or gusty winds (causing 43 percent of outages) were determined to have the major impact on weather-related downtime. A probability analysis for weather outage was then applied to the various scenarios for deliveries to determine the impact on throughput.
- *Storage limitations at the unpack area.* Army regulations restrict the quantity of munitions that can be stored to what can be processed during half of a work shift (U.S. Army, 1999). Recommendations from the TRRP indicated the best and least costly scenario—that a larger staging capacity be provided at the EPB unpack area. Deliveries will be made 7 days a week.

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[2] For example, see NRC, 1996; 1999b; 1999c.

> The presumption is that an Army waiver is possible and will be granted.

Finding 3-4. The Bechtel Pueblo design team presumes that a waiver will be granted for storage of a larger operational buffer capacity in the unpack area of the energetics processing building at the Pueblo Chemical Agent Destruction Pilot Plant. This waiver is pivotal to the implementation of the optimal scenario, and if not granted, will necessitate significant changes to the design.

Recommendation 3-4. The Bechtel Pueblo team should make immediate application for a waiver to obtain additional munitions storage in the unpack area of the energetics processing building at the Pueblo Chemical Agent Destruction Pilot Plant.

In a presentation of the transportation simulation of the munitions transfer process, the transport vehicles were shown moving one way throughout the PCD storage area. However, after passing through the security gate, the vehicles moved both ways on the roads in front of the EPB. This two-way traffic pattern introduces the possibility of collisions between the transport vehicles as they maneuver into position to unload the munitions and to return to the security gate to retrieve another load of munitions.

Finding 3-5. The two-way traffic pattern in the vicinity of the energetics processing building at the Pueblo Chemical Agent Destruction Pilot Plant introduces hazards associated with the movement of large vehicles in a limited area.

Recommendation 3-5. The Bechtel Pueblo team should evaluate the hazards associated with the two-way traffic pattern within the restricted area in the vicinity of the energetics processing building at the Pueblo Chemical Agent Destruction Pilot Plant and should consider revising this pattern to maintain a one-way flow of traffic throughout the site, or it should provide suitable separation barriers for traffic on the two-way portions of the munitions transport system.

Reconfiguration Room

Munitions stored at Pueblo Chemical Depot are either in their original packing or have been reconfigured. Reconfiguration involves removing propellant charges, igniters, associated packing materials, and mortar round fins that are usually attached before firing. Currently, 28,376 of the 105-mm projectiles and all of the 4.2-in. mortars (97,106 rounds) are still boxed with propellant and must be reconfigured before further processing.

The PCAPP initial design includes a reconfiguration room located east of the ECRs in the EPB unpack area. The boxed munitions (see Table 1-1 in Chapter 1) are moved to the reconfiguration room on carts. The boxes are then opened, and the contents are removed and placed on a conveyor, where they are disassembled manually. They are then palletized for later processing or sent directly to the appropriate ECR for disassembly. A key step in the reconfiguration is the removal of igniters (cartridges about the size of shotgun shells) from the mortars by using a pulling machine. Currently, Bechtel Pueblo team designers are developing methods and equipment for accessing the energetics contents of the igniters because the plastic casings of the energetics do not dissolve.

All metal parts that are not part of the reconfigured munition, such as fins and metal strapping, are collected in bins for transport to the metal parts treater. All energetic materials except the bursters are collected and placed in trays for transfer to one of the two energetics rotary hydrolyzers (ERHs). Bursters are removed later when the reconfigured munitions are processed through the projectile/mortar disassembly machines in the ECRs, where the appropriate mechanism for burster removal is available. Currently, the PCAPP design team is seeking permission to process uncontaminated propellant from the reconfiguration process off-site. Igniters would be processed in the ERHs. All nonmetallic packing materials, including box filler material, propellant cardboard cases, and the boxes, are collected in bins for transport to the dunnage shredding and handling system and continuous steam treater.

The reconfiguration room is designed so that personnel in the room can safely open and reconfigure the munitions. The operations conducted in the reconfiguration room would normally be performed in the field without further protection. Although the presence of propellant represents a potential flammability hazard to workers, an explosive hazard does not exist because the propellant is not confined (i.e., it is uncontained).

Finding 3-6. The reconfiguration process for munitions at the Pueblo Chemical Agent Destruction Pilot Plant does not contain positive controls to prevent the

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manual mixing of energetics and metallic and nonmetallic waste or dunnage in a manner that ensures that all energetics are properly collected for further processing. The bins for collecting the nonmetallic and metallic wastes that are sent to the dunnage shredding and handling system and metal parts treater, respectively, are located next to one another, thus increasing the likelihood of commingling the two types of wastes and upsetting the downstream processes. Furthermore, the method of ensuring that all energetic materials are collected and retained for further processing is not clearly defined at this time. Conceivably, these materials could end up in the bins.

Recommendation 3-6. Positive controls should be incorporated to prevent the mixing of waste streams for the metal parts treater and dunnage shredding and handling system/continuous steam treater processes during reconfiguration room operations at the Pueblo Chemical Agent Destruction Pilot Plant. For example, means should be provided to ensure that energetics removed in the manual disassembly will only be placed in the proper trays.

Robotic Performance Coupled with Munitions Washout System

The design for the munitions washout system (MWS) for accessing and removing agent from the mustard agent projectiles at Pueblo Chemical Depot is based on lessons learned from processing similar munitions at the Johnston Atoll Chemical Agent Disposal System (JACADS).

In tests of the MWS, the agent cavities of mortars and projectiles have been cleaned to a bright and shiny metallic surface. Based on preliminary testing, a high water temperature minimizes water usage and is more effective for the removal of agent heels from the projectiles. The design must optimize water wash temperature and volume for both the washout process itself and the downstream processing. Based on current design, the flow rates for washout of PCAPP munitions are the following: 3 gallons per minute (gal/min) at 140 seconds for 155-mm projectiles, 3 gal/min at 35 seconds for 105-mm projectiles, and 4.5 gal/min at 70 seconds for 4.2-inch mortars. These flow rates will be updated based on the TRRP test data.

Several issues are of concern with the design for the MWS, most of which have been identified by the Bechtel Pueblo design team. A key issue is the potential incompatibility of the settling process with downstream processing—that is, premature neutralization in the settling tank could lead to varying agent concentration in the feed. The design team may determine that additional testing, including the redesign of the settling process, may be warranted to adjust for variations in the feed concentrate and to avoid, to the extent possible, hydrolysis upstream of the reactors and the formation of difficult-to-hydrolyze sulfonium compounds from premature hydrolysis of the MWS agent concentrate in the settling tank (NRC, 2001b).

Another concern is the close mechanical tolerances for munitions placement by the robot. The MWS is a highly mechanized and somewhat complex design with narrow tolerances, having as a key element a multiaxis, floor-mounted robot specific for each of the three lines. The committee believes that it is not adequate to simply identify the need for precision, but to also articulate compensating methods in the event of misplacement or misalignment of munitions in trays. Also, the committee did not see a plan for what to do if one munition, for any reason, failed to show a sufficient difference in weight before and after washout.

Finding 3-7. The committee believes the munitions washout system (MWS) design of the Pueblo Chemical Agent Destruction Pilot Plant is an effective and reliable approach to accessing and removing the chemical agent, including agent heels, from the munitions bodies. This MWS design also promises the nearly complete removal of the mustard agent and the residual heels, thereby lowering the agent loading on munitions going to the metal parts treater.

Recommendation 3-7. Future testing and integration efforts for the munitions washout system design of the Pueblo Chemical Agent Destruction Pilot Plant should ensure that the design is forgiving of misalignment and misplacement of munitions in trays, and that procedures are in place to effectively deal with off-normal situations (such as when a munition fails to show a sufficient difference in weight before and after washout).

Treatment of Leaking Munitions

At Pueblo Chemical Depot, approximately one-tenth of 1 percent of the munitions may be leakers. The munitions are stored on pallets containing from 30 to 50 munitions each, and locating individual leakers can be

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very labor-intensive and time-consuming.[3] It can take as long as a week to locate a leaker in an igloo. Subsequent overpacking of the leakers is also a labor-intensive and hazardous process.

To enable safer and more efficient handling of leakers, several options employing refrigeration were considered, as reported in the PCAPP refrigeration study (U.S. Army, 2003b). These options were derived from consideration of JACADS experience with leakers and "frothing" while processing munitions containing mustard agent. Frothing of agent when accessing the agent cavity is similar to the foaming that can occur when opening a carbonated beverage bottle. The frothing results from dissolution of pressurized gases such as hydrogen that are produced by chemical degradation of the agent over time.[4] The operators at JACADS anticipated that this problem would be most severe with leakers and other munitions that were rejected because of difficulty in accessing their agent cavity during disassembly. Thus, they decided to freeze the leakers and the rejected munitions as a means of addressing the frothing issue.

The PCAPP refrigeration study, anticipating that the design and testing of the cavity access machines (CAMS) would be successful in demonstrating control of frothing without the use of refrigeration, recommended using a single refrigeration unit similar to the one used at JACADS for leakers and rejected munitions only. In subsequent development of the initial design for PCAPP, the Bechtel Pueblo team proposed that the normal practice for location and isolation of individual leakers at PCD be replaced with a procedure in which the entire pallet containing a leaker would be overpacked by using a container that is still to be designed. These overpacked pallets would later be refrigerated and processed during the campaigns for processing leakers and rejected munitions, which will occur after all nonleaking 4.2-inch mortars have been processed.

The committee understands that the PCAPP refrigeration unit, if used, would be installed in the unpack area of the EPB before the start of the campaigns for processing leakers and rejected munitions. The refrigeration unit would be used to freeze pallets containing known leakers. The pallets would be overpacked at the storage igloos. The pallet overpack would be a specially designed container, and after delivery to the EPB, it would be placed in a freezer to lower the agent temperature in the munitions to a point that would prevent thawing until after the agent cavity was accessed. Currently, no thawing would be expected for approximately 3 hours. The freezer unit would be a commercially available modular unit of about 640 cubic feet.

Refrigeration was applied at JACADS only to eliminate problems with frothing when accessing the munition cavity. Contamination associated with these munitions prior to processing was not addressed, but the control of frothing when accessing the agent cavity was. The control of frothing appears to be addressed successfully by the new MWS/CAM design to be used at PCAPP. Testing to date provides assurance that this design also should be able to handle munitions that contain frothing agent without the need for refrigeration because the nose of the munition is sealed to the receiving vessel as described in Chapter 2 (FOCIS, 2003a; 2003b).

Finding 3-8. Without resorting to refrigeration, the new munitions washout system/cavity access machine (MWS/CAM) design to be used at the Pueblo Chemical Agent Destruction Pilot Plant appears to satisfactorily address the problem of frothing mustard agent from munitions. On the basis of completed and planned testing (FOCIS, 2003a) and observation by committee members of the prototype mortar MWS, the committee believes that the CAM used to remove the base from 4.2-inch mortar rounds will be an effective means of accessing agent in these munitions.

Recommendation 3-8. If the tests of the munitions washout system/cavity access machine to be used at the Pueblo Chemical Agent Destruction Pilot Plant still indicate problems with frothing agent from munitions, the committee recommends solving these problems without the application of refrigeration for leakers and rejected munitions. Specifically, refrigeration should not be applied to leakers and rejected munitions.

The pallet overpack units, if used, would introduce additional contaminated material for processing in the continuous steam treaters (CSTs). This is material that has not been identified for inclusion in the CST test program. Furthermore, overpacking pallets means that

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[3] ACWA Design Committee meeting with Army and Bechtel National, Inc., participants at Irvine, Calif., February 11–13, 2004.

[4] This frothing of mustard agent, or "champagning," as it is sometimes called, resulted in increased maintenance of disassembly equipment, equipment modifications, and Resource Conservation and Recovery Act permit modifications during the processing of mustard agent munitions at JACADS (NRC, 2004).

most of the munitions on a pallet that are not leakers, and which could have been processed during the nonleaker campaign, might now have surface contamination from the leaker munitions as a consequence of the overpacking.

There is little evidence to show that the existing procedure for leaker overpacking presents unique safety or logistical problems. Furthermore, there are currently only 28 known leakers and 490 "suspected" SUPLECAM (Surveillance Program for Lethal Chemical Agents and Munitions) leakers at PCD (U.S. Army, 2003b).[5] This number would not be expected to increase significantly before the time when PCAPP begins to process leakers (NRC, 2004).

Finding 3-9. The proposed overpacking of entire pallets containing leakers adds to the number of munitions that must be handled during the leaker campaigns. There appear to be little advantage and some disadvantages with this approach and an added processing burden for the continuous steam treaters.

Recommendation 3-9. The procedure currently used to locate and overpack individual leakers at Pueblo Chemical Depot and other storage sites should be considered for continued use during operations of the Pueblo Chemical Agent Destruction Pilot Plant.

Agent and Energetics Transfer Systems

As noted in Chapter 2, the placement of both the agent transfer system and energetics transfer system in the transfer corridor of the energetics processing building requires structural blast protection elements to be added in the transfer corridor to prevent possible energetics explosions from dispersing agent from the munitions being transported by the ATS. However, the PCAPP design team found that the need for blast resistance complicated the design of the ETS overhead monorail transfer system. Because the ATS is in the same area as the ETS, the design of the ATS may also be impacted.

At the time that this report was prepared, a pneumatic conveyor system was under consideration for transferring energetics in capsules placed in pneumatic tubes. Two pneumatic tubes would be provided for each explosion containment room and for the munitions reconfiguration area to allow each of the ECRs and the munitions reconfiguration area to feed either of the energetics rotary hydrolyzers. Thus, eight tubes would cross the transfer corridor.

The committee has identified several concerns with the pneumatic tube design that must be addressed by the PCAPP design team, including the following:

1. Requiring blast/missile protection at both ends of each tube,
2. Addressing the mechanics of loading and unloading and catching the transfer capsules without severe deceleration loads,
3. Preventing static electricity discharges in the tubes from movement of the capsules and air through the tubes,
4. Ensuring a sufficiently large radius of curvature in the axial direction to permit capsules long enough to carry bursters, and
5. Achieving a rate of energetics transfer equivalent to the design rate established for the overhead monorail conveyor system.

Finally, regardless of the design chosen for the ETS, the ATS also will be affected because it uses the same corridor. The committee is concerned that the lack of firm choices for the ETS and ATS designs at this point may impact other design choices for interfacing systems and for the building footprint. The final design must ensure that problems with the ETS or ATS do not result in frequent shutdowns of both the ETS and ATS for repairs. This potential problem arises because the current layout places both the energetics and agent in the same space after effectively separating them in the ECRs.

Finding 3-10. The choice of design for the energetics transfer system (ETS) has a significant impact on the interfacing systems, and it is not obvious that desired processing throughputs can be achieved with the current design because the transfer corridor in the energetics processing building is used by both the agent transfer system and the ETS. The energetics transfer system contained in the initial design poses reliability and maintenance problems and may require additional design changes in order to address explosive safety issues—for example, limits on the amount of energetics

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[5] SUPLECAM, a program conducted in the 1980s and early 1990s, involved intrusive sampling of the agent cavity of selected munitions to investigate the physical and chemical condition of the agents.

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and the mix of energetics transferred in each tray. At the present time, any equipment problem in the transfer corridor may require shutdown of all disassembly processing.

Recommendation 3-10a. The choice of agent transfer system (ATS) and energetics transfer system (ETS) designs should be resolved as quickly as possible in order to minimize schedule and cost impacts on the design and construction of the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP). The PCAPP design team should accelerate its efforts to resolve both the ETS and ATS design selection while ensuring an acceptable level of reliability and explosive safety.

Recommendation 3-10b. As the Bechtel Pueblo team considers design alternatives for the Pueblo Chemical Agent Destruction Pilot Plant, reconfiguration of the building layout should be considered to allow the transfer of agent-filled munitions and of energetics through entirely separate pathways in order to minimize the synergistic impact of agent transfer system and energetics transfer system failures on processing throughput.

CORE PROCESSES

Scale Testing of Energetics Rotary Hydrolyzer

Energetics Hydrolysis System

Hydrolysis tests were performed in 2003 at Deseret Chemical Depot (DCD) in Tooele, Utah (U.S. Army, 2003c). The final report was expected to be available at the beginning of May 2004. Because testing prior to 2003 had been done at or below 105°C, the DCD tests were planned to verify that the bulk of the reaction of energetics would be completed during the residence time in the energetics rotary hydrolyzer.

One of the significant tests at DCD was the destruction of energetics in M14 boosters, which are long, narrow burster tubes that are closed at one end. The test results showed that in 45 to 55 minutes at 118°C to 124°C in 35 percent caustic, all of the tetrytol had been removed from the burster tubes. This was verified by visual inspection of the burster tubes. It was necessary to have excess caustic present (more than is required to react with the energetics) to prevent the hydrolysate from becoming too viscous. At one time, using twice the stoichiometric amount of caustic was thought to be sufficient, but a higher ratio of caustic to energetic is necessary to keep the hydrolysate sufficiently fluid.

The DCD tests were run for 1 hour. These tests showed that the burster explosives and the propellants (provided they are exposed to the hot caustic) are easily hydrolyzed in less than 1 hour in 35 percent caustic at 114°C to 120°C. Caustic readily penetrates the propellant bags, and the cotton threads holding the bags together decompose in the ERH, spilling the propellant out into the solution, where it is hydrolyzed.

Tests were performed with propellant that was sewn together in two-sheet bundles. It was unclear whether this represented the most sheets that could be encountered in a sewn stack. According to MIL-I-48086, the sheets may be packed in five-sheet bundles, so the tests do not represent the worst case for hydrolysis of the propellant (U.S. Army, 1972). Because the surface area will be smaller per unit mass of propellant, it should take longer to hydrolyze the propellant in a five-sheet bundle than in a two-sheet bundle.[6]

The design anticipates that hydrolysis of the energetics will be completed in the energetics neutralization reactors (ENRs), which are monitored for the presence of energetics by differential scanning calorimetry (DSC).[7] However, the bench-scale hydrolysis data indicate that the hydrolysis of the energetics in the projectiles stored at the Pueblo site is likely to be completed in the two energetics rotary hydrolyzers.[8] This likelihood reduces the need to include four ENRs in the design. It also reduces the need for a long residence time of the hydrolysate in the ENRs and the two holding tanks.

Finding 3-11. The hydrolysis of energetic materials at the Pueblo Chemical Agent Destruction Pilot Plant is expected to be substantially completed in the energetics rotary hydrolyzers.

Recommendation 3-11. The Bechtel Pueblo design team should review the number and sizing of the post-energetics rotary hydrolyzer components of the energetics hydrolysis system for the Pueblo Chemical Agent Destruction Pilot Plant.

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[6] ACWA Design Committee site visit to General Atomics, San Diego, Calif., April 6, 2004.

[7] The test protocol is still being developed.

[8] ACWA Design Committee site visit to Battelle Memorial Institute, Columbus, Ohio, March 19, 2004.

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A caustic solution of 35 percent NaOH at 120°C is to be used in the ERH, and the potential exists for further concentration of the solution by splashing and evaporation. The effects of this environment on the equipment warrant consideration. For instance, there is the possibility of stress corrosion cracking (also often called caustic embrittlement) in such environments. Austenitic and ferritic stainless steels are often used in what could be termed intermediate ranges of caustic service for reasons of economy and utility. Austenitic stainless steels, primarily types 304 and 316, are very resistant to caustic in concentrations up to 50 percent and temperatures to about 95°C (200°F). Stress corrosion cracking can occur in 304 or 316 stainless steel at temperatures as low as 120°C for 35 percent caustic solutions. As this is the approximate operating range of the ERH, the use of 304 or 316 stainless steel must be carefully evaluated (Nelson, 1987).

Another possible hazard is the presence of mercury as a contaminant. Mercury has been found in some mustard agent, and this may have contaminated some of the energetics. This contamination constitutes a potential hazard, since it can contribute to cracking or pitting of austenitic stainless steel with mercury concentrations as low as a few parts per million (Nelson, 1987).

Nickel or nickel-base alloys, although more expensive than 304 or 316 stainless steel, are extensively used in more severe caustic applications. The very low corrosion rates also ensure low metal-ion contamination. Nickel has the lowest corrosion rates—even in molten anhydrous NaOH up to 538°C (1000°F)—and is essentially immune to caustic stress corrosion cracking. Inconel 600, although excellent in caustic service, has higher corrosion rates than the nickel 200 and 201 metals (Hoxie, 1975).

Nickel-clad vessels and equipment are frequently fabricated to minimize the need for expensive high-nickel alloys. Typically, the nickel-clad thickness represents 20 percent or less of the base steel thickness. However, mercury contamination as previously discussed will also affect nickel and nickel alloys. One way to address this latter issue is to determine whether mercury contamination of the energetics to be processed through the ERH is a real issue. If it is determined that mercury could be present in parts per million quantities in the ERHs, then steps could be taken to ensure that this situation will not cause excessive downtime. Steps that might be taken include identifying the mercury-contaminated munitions and processing them in such a manner that the mercury concentration in an ERH does not exceed a certain level. Alternatively, the mercury might be removed from the munitions prior to processing, or inspection and repair intervals for the ERHs could take the possibility of the effects of mercury contamination into account.

Finding 3-12. The use of 35 percent caustic at 120°C in the energetics rotary hydrolyzer of the Pueblo Chemical Agent Destruction Pilot Plant could cause corrosion issues.

Recommendation 3-12. Design decisions for the Pueblo Chemical Agent Destruction Pilot Plant regarding the appropriate material for use in caustic service should take into account temperatures, concentrations of caustics, and contaminants. Consideration should be given to the possibility of lowering the operating temperature and concentration of the caustic in the energetics rotary hydrolyzer (ERH) reactor to guard against stress corrosion. Another alternative would be to consider the used of nickel-clad ERH vessels.

Biological Treatment of Hydrolysates

After neutralization, the agent and energetics hydrolysates will be combined for secondary processing via biotreatment.

Hydrolysis is a well-known process for destroying energetic materials and can reliably convert these materials to nonenergetic by-products (Bonnett and Elmasri, 2001). Hydrolysis likewise converts agent into by-products that are less toxic. The by-products can be biotreated after adjusting pH and establishing appropriate conditions. The success of biological treatment depends on knowing the hydrolysis by-products, their degradability and toxicity, and the mass rates at which they are produced.

The PCAPP design calls for the use of immobilized cell bioreactors (ICBs) (e.g., a fixed-film reactor). The bioreactors are a proprietary technology, patented by Honeywell. Previous piloting studies for a chemical demilitarization application were conducted on a full-scale unit during engineering design studies earlier in the ACWA program to determine operating parameters and throughput expectations. More recently, testing to optimize the performance of the ICBs was being performed at Aberdeen Proving Ground, Maryland, while this report was being prepared; the testing used a 4-liter-scale test unit on a blend of hydrolysates of

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HD/HT and tetryl and tetrytol (70 percent tetryl and 30 percent TNT). This testing was scheduled for completion in mid-2004. This study should reaffirm the suitability of the process for PCAPP and identify problems and areas for improvement.

The following subsections comment on specific aspects of the biological treatment system.

Energetic Materials

The complexity of hydrolyzing energetic materials depends on the chemical composition of the explosive (Heilmann et al., 1996). Propellant components such as nitrocellulose and nitroglycerine are easily hydrolysable (Newman, 1999). Destruction of energetics components of bursters such as tetryl and TNT by hydrolysis is complicated by the aromatic ring structure of these substances. It is well established that TNT loses its energetic properties when it undergoes base hydrolysis (Earley et al., undated). However, the organic by-products are less well known and quite complicated. Recently, Thorn et al. (2004) investigated base hydrolysis of TNT, and their findings illustrate the complexity of identifying the products. They concluded that the biodegradability of the products is still unknown.

Several investigators have treated mixed hydrolysis products, including TNT hydrolysis products, in biological reactors. Earley et al. (undated) have summarized previous work. The disappearance of TNT by-products was not documented by rigorous methods, but by the removal of chemical oxygen demand (COD) and total organic carbon (TOC). The processes appear successful.

Finding 3-13. While it has been demonstrated that TNT hydrolysate can be treated in a bioreactor, the nature of the decomposition products and the toxicity of the residual organic carbon in the bioreactor effluent from treatment of tetryl and TNT hydrolysate have not been established. Until there is conclusive evidence that the effluent from the bioreactors is not toxic, no final decision about the disposal of the sludge from the bioreactor can be made. The determination of the toxicity of the sludge is an important issue to the public and to state regulators.

Recommendation 3-13. In designing the Pueblo Chemical Agent Destruction Pilot Plant, the Bechtel Pueblo team should establish the toxicity of the effluent from biotreatment of TNT and tetryl hydrolysates, including any carcinogenic or mutagenic properties, so that an acceptable disposal plan for the sludge can be designed.

The ammonia produced during the hydrolysis of energetic materials is easily volatilized at the high pH. The residual ammonia can be nitrified to nitrate in the biological process. The nitrate is less toxic than ammonia or nitrite and does not express an oxygen demand. Removing nitrogen from wastewaters is a well-established technology that can be addressed by the Bechtel Pueblo design team should it become necessary. Various denitrification processes could be used. And, the processes that separate salts during the reclamation of biological reactor effluents will also separate nitrate.

Mustard Agent

Mustard agent is effectively destroyed by hydrolysis, as noted previously, and the by-products are well known and degradable. Earley et al. (undated) have reviewed previous studies which document bioreactors that successfully treated the main hydrolysis by-products, thiodiglycol and dithiane. Degradation was documented by the disappearance of COD and TOC.

Other Contaminants

In the process of hydrolyzing the mustard agent and energetic materials from the munitions stored at Pueblo, other substances will also come into contact with the high-pH, high-temperature hydrolyzing solutions. Materials such as aluminum are expected to completely dissolve. Low-carbon steel and stainless steels will be unaffected, although iron particles in agent heels, possibly from corrosion, have been noted. Some plastics will dissolve.

Additional contaminants may be present in small quantities. Earley et al. (undated) note that various volatile compounds were found in previous studies. These compounds may have been laboratory contaminants or contaminants in manufacturing or disassembly of the weapons (e.g., methylene chloride used in organic extractions, organics associated with lubricants, residual cleaning agents, and so on.). The design for the biological treatment process should be capable of handling these contaminants. As the pH of the hydrolysates is reduced to ranges suitable for biotreatment (i.e., pH 6 to 9), some compounds will precipitate, as

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discussed below, and may potentially create problems in the bioreactors.

The aluminum and suspended solids are of particular concern. Aluminum will not be toxic to the biological process, but will produce a voluminous aluminum hydroxide floc at the point of neutralization (the various aluminum hydroxide polymers are least soluble at pH 5.5). This floc will tie up suspended solids that are present in the hydrolysates. Any heavy metals that precipitate or that exist in particulate form will probably be incorporated in the aluminum hydroxide sludge.

Aluminum also reacts with phosphorus. Aluminum sulfate (alum) is typically used at wastewater treatment plants to precipitate phosphorus. Both phosphorus and nitrogen are essential nutrients for biological reactors. Nitrogen will be available in sufficient quantities from the explosives, but there is no natural source of phosphorus, and any that exists in the wastewater streams will be precipitated by the aluminum. The Bechtel Pueblo design team should demonstrate how they can avoid depletion of phosphorus in the PCAPP immobilized cell bioreactors.

Finding 3-14. Phosphorus is a required nutrient for the bacteria in the immobilized cell bioreactors (ICBs). Because of the precipitation of phosphorus by the aluminum, the wastewaters will be devoid of phosphorus, and the bioreactors will be phosphorus-limited. The bench-scale testing of the ICBs at the Battelle Memorial Institute in Columbus, Ohio, is not evaluating the effects of aluminum and will not observe the effects of phosphorus depletion.

Recommendation 3-14. The Bechtel Pueblo team should provide for phosphorus addition for the immobilized cell bioreactors in the Pueblo Chemical Agent Destruction Pilot Plant.

When aluminum hydroxide floc has been allowed to enter a biological process such as the activated sludge process, it has become enmeshed in the activated sludge flocs, which in turn overloaded the clarifier/thickener and required operation at reduced sludge age (mean cell retention time [MCRT] or solids retention time [SRT]).

The PCAPP process design calls for the use of a fixed-film growth (immobilized cells), and the bulk of the aluminum hydroxide floc will pass through the process and become part of the suspended solids in the effluent or, at very high concentrations, may coat or clog the bioreactor packing. In either case, it will be necessary to remove the aluminum floc from the bioreactors, or by a clarifier after the bioreactors.

Aluminum hydroxide floc is difficult to thicken and rarely can be thickened beyond 1 percent in a conventional gravity clarifier. The mass can be predicted from the mass of aluminum to be destroyed in the munitions (the mass of floc will be much greater owing to the hydroxide and waters of hydration). All of the aluminum can be expected to precipitate.

Aluminum hydroxide flocs are common in water treatment processes, since many if not most water treatment plants use aluminum sulfate as a primary coagulant. There are also examples of treatment of waste aluminum chloride solutions in wastewaters from chemicals manufacturing. In developing a design for PCAPP, the Bechtel Pueblo team must anticipate the problem presented by the aluminum hydroxide floc. A screening for other dissolution or precipitation problems, such as the issue with phosphorus, should also be made part of this analysis. The flow diagrams presented at an earlier meeting (see Figure 2-1 in Chapter 2) showed a hydrolysate neutralization tank prior to biological treatment.[9] It may be necessary to add a clarifier/thickener after this tank, depending on the mass of precipitates.

Finding 3-15. There is a significant potential problem with aluminum hydroxide precipitates and other precipitates and their effect on the biotreatment process at the Pueblo Chemical Agent Destruction Pilot Plant. The Bechtel Pueblo team is addressing the problem, but has yet to provide a satisfactory solution.

Recommendation 3-15. The Bechtel Pueblo team, in designing the Pueblo Chemical Agent Destruction Pilot Plant, should include a process to remove the aluminum hydroxide precipitates prior to biological treatment, or demonstrate that the biological process can be operated successfully in spite of the precipitates.

Controls

At the committee meeting in April 2004, the Bechtel Pueblo team seemed to be knowledgeable of biological treatment technology, such as start-up time

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[9] ACWA Design Committee site visit to Battelle Memorial Institute, Columbus, Ohio, March 19, 2004; and PCAPP briefing by Craig Myler, PCAPP Chief Scientist, to the committee, Aberdeen Proving Ground, Md., April 13, 2004.

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and acclimation and nutrient requirements.[10] Biological processes generally require a minimum of three cell retention times to approach steady state. During this acclimation period, loading rates need to be reduced, and efficiencies will be low. These issues are not unique to the treatment of hydrolysates but are concerns for any industrial biological wastewater treatment.

RESIDUALS TREATMENT PROCESSES

Prototype Metal Parts Treater

As part of the technical risk reduction program (TRRP), the Bechtel Pueblo team is fabricating a two-thirds-scale metal parts treater (MPT) at the Parsons Fabrication Facility, located in Pasco, Washington. The Parsons facility will also build the actual MPTs to be used for PCAPP.

This TRRP activity will not test the offgas treatment system because the Bechtel Pueblo team believes that it was successfully tested as part of the earlier engineering design study (EDS) phase of the ACWA program for PCAPP.

According to Parsons, the scope of the TRRP for the MPT is to develop "system design and fabrication data for a full-scale, fully automated treatment system using modified ACWA water hydrolysis of explosives and agent technology (WHEAT) EDS equipment to mitigate TRA risks."[11] The scope encompasses activities to design, fabricate, and test a mock-up prototype unit (single train), validate the heat-transfer model and test the configuration for the three sizes of projectiles to be processed through PCAPP, validate the throughput rates, and develop timing and availability data on tray handling and the induction heating system.

The targeted heat-up rates for all three munitions types is less than 90 minutes with a throughput rate of 1 tray per hour. Part of the test objective is also to verify that typical maintenance activities can be performed within a reasonable time period and within the allowable period (about 2 hours) for a worker to be in a demilitarization protective ensemble (DPE) suit.

The main thermal treatment chamber of the prototype MPT is 11 ft long and 4 ft 8 in. in diameter and will be inductively heated to 1350°F ± 50°F. The power supply is a 600-kW unit running at 3 kHz. The fabricators at the Parsons facility planned to use only 200 kW of the available power and may shift to a 10-kHz power supply if coil noise becomes excessive. The chamber of the prototype MPT is about 3 ft shorter than the 14-ft-long chamber of the PCAPP MPT design because the fabricators used a shell for the inductively heated chamber that was available from earlier ACWA engineering design study tests. This shell is made from 316L stainless steel, whereas the shells for the PCAPP MPTs will be manufactured from Hastelloy C276. The differences between the planned design for the MPT and the design used for the TRRP test performed at Pasco could allow some potential design deficiencies to be untested. For instance, since the planned MPT furnace shell is larger than the one being used for the TRRP, there may be some problems discovered at full scale that were not found at the lower scale of the TRRP. Some of these factors may include (1) the time required to reach 1000°F at certain munitions locations; (2) high-temperature creep, distortion, or sag of the MPT furnace shell and other components subjected to large cyclic thermal gradients; and (3) the effect of a superheated steam temperature on the soak time required for each batch.

The committee members who observed the prototype MPT had some concerns about the temperature drop within the unit and the heating of adjacent components when the doors were opened for inserting and pulling the trays through. Although munitions trays have been enhanced over earlier versions to reduce the risk of cracking and misalignment, the opening and closing of the MPT chamber doors generate cyclic heating of the munition trays and other MPT components located near the doors. In addition, the conveyer used to move the trays will also be cyclically heated and cooled. However, the testing campaign is probably not long enough to detect any mechanical or thermal fatigue problems.

Finding 3-16. Repeated thermal cycling of the trays and other components of the metal parts treater (MPT) in the egress chamber may cause distortion and thermal fatigue cracking, resulting in excessive needs for repair or replacement of parts. The testing planned at Pasco regarding the technical risk reduction program for the MPT will be of insufficient duration to determine if the proposed design will suffer from distortion

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[10] PCAPP briefing by Craig Myler, PCAPP Chief Scientist, to the ACWA Design Committee, Aberdeen Proving Ground, Md., April 13, 2004.

[11] Personal communication of committee member with Mark Rieb, Parsons Project Manager, Pasco, Wash., site visit, May 7, 2004.

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and thermal fatigue cracking that could affect time to repair or maintain, which in turn could affect overall unit availability.

Recommendation 3-16. Thermal stress modeling, using a computational fluid dynamics model developed by Bechtel for the metal parts treater (MPT) of the Pueblo Chemical Agent Destruction Pilot Plant, should be used to determine if repeated cycles of parking hot trays on the MPT exit hardware will cause excessive creep fatigue and cracking of the trays. Similar modeling should evaluate the potential for creep and warpage of MPT chamber door seals and the Hastelloy C276 shell.

Prototype Continuous Steam Treater

The use of a continuous steam treater is proposed for 5X decontamination of potentially contaminated nonmetallic wastes at PCAPP. These wastes include shredded wood from pallets; shredded plastic from DPE suits; waste lubrication and hydraulic oils; mixed glass, plastic, wood, metal, and paper packaging materials; spent activated carbon; and other trash and debris.

The 5X designation "indicates an item that has been decontaminated completely of the indicated agent and the material may be released for general use or sold to the general public . . ." (U.S. Army, 2002a, Section 5-1. c. (3)). From the time that the request for proposal for PCAPP was issued to the end of data gathering for this report, the only approved method for decontamination to 5X was heating the item to 538°C (1000°F) for 15 minutes. On June 18, 2004, following the advice of the Centers for Disease Control and Prevention (CDC), the Army issued revised health-based criteria for exposure to airborne agents (U.S. Army, 2004a). The Army also eliminated the use of 0, X, 3X, and 5X decontamination terminology to be in conformance with existing laws and regulations.[12] The concept of a material that has been completely decontaminated of agent is obsolete, because it is impossible to verify that every molecule of agent has been removed. The Army has retained the fundamental criterion of 5X, which is that the material is sufficiently decontaminated that it may be released for general use or sold to the general public.

Under the updated rules, a material can be released unconditionally under any of the following three circumstances (U.S. Army, 2004a):

- Documented evidence is available to prove that the material has never contacted liquid agent and has never been exposed to airborne agent at concentrations exceeding the short-term exposure limit (STEL) of 3×10^{-3} μg/m^3 time-weighted average over a 15-minute period.
- The material is heated to a surface temperature of 538°C (1000°F) for at least 15 minutes.
- The material is cleaned in accordance with an approved equipment decontamination plan and certified by the mission commander to the selected health-based criteria for the reasonably anticipated use environment of the public owner. The selected health-based criterion may be the worker population limit, the STEL, the immediately dangerous to life and health limit, or the general population limit, depending on how the decontaminated material will be used.

Finding 3-17. The decision by the Army to adopt the recommendations of the Centers for Disease Control and Prevention on airborne exposure limits to chemical agents provides possible new options for the treatment of dunnage, such as the following: (1) maintaining good documentation to prove that the material has never contacted liquid agent and has never been exposed to airborne agent at concentrations exceeding the short-term exposure limit so that it can be released to a commercial disposal facility without further treatment, and (2) low-temperature treatment that meets one of the new health-based criteria for unrestricted release and is acceptable to the regulatory agency and to the intended disposal facility.

Recommendation 3-17. The Army and the Bechtel Pueblo team designing the Pueblo Chemical Agent Destruction Pilot Plant should develop alternative conceptual designs for the decontamination of dunnage on the basis of the three allowable criteria and should en-

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[12] At the 3X decontamination level, solids are decontaminated to the point that agent concentration in the headspace above the encapsulated solid does not exceed the health-based, 8-hour, time-weighted average limit for worker exposure. The level for mustard agent is 3.0 mg/m^3 in air. Materials classified as 3X may be handled by qualified plant workers using appropriate procedures but are not releasable to the environment or for general public reuse. In specific cases in which approval has been granted, a 3X material may be shipped to an approved hazardous waste treatment facility for disposal in a landfill or for further treatment; 0 and X designate lesser degrees of decontamination (U.S. Army, 2002a).

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gage the local public, interested stakeholder groups, and state and local government officials in a dialogue about the most appropriate decontamination approach.

Prior to issuance of the new guidance by the Army, the Bechtel Pueblo team was constrained to treat dunnage to 5X by heating the material to 1000°F for 15 minutes. Accordingly, the team redesigned the continuous steam treater for PCAPP to correct problems identified with an earlier design during the engineering design study phase of the ACWA program. The Bechtel Pueblo team planned to test a full-scale prototype of the redesigned unit at the Parsons Fabrication Facility in Pasco, Washington, during the latter half of 2004. Three similar units are to be installed at PCAPP.[13]

Heating of agent-contaminated metals to 1000°F in the absence of air or oxygen would only attack the agent and any other organic material—for example, paint associated with the metal. The treated material would then be suitable for sale to commercial scrap dealers. In contrast, heating of agent-contaminated nonmetallic wastes to 1000°F would attack both the agent and the substrate in a complex set of reactions including pyrolytic decomposition. The treated material would be totally different in form and composition from the feed and would only be suitable for disposal in a commercial incinerator or landfill. The problems of treating wood are illustrative. In the presence of air or oxygen, wood catches fire and burns when it reaches a temperature of about 400°C to 500°C (752°F to 932°F). Since this effectively would be incineration, the wood would have had to be heated to 538°C (1000°F) for 15 minutes in the absence of air in order to be releasable to a commercial facility under the old rules.

When wood is heated in the absence of air, moisture is driven off first. The wood temperature remains at about 100°C to 110°C (212°F to 230°F) until drying is complete. After that, the temperature of the wood rises. At about 270°C (518°F), the wood begins to decompose with evolution of gaseous by-products. Evolution is complete at about 410°C (770°F). The solid residue remaining is charcoal, with about 70 percent carbon and small amounts of tars. To drive off or decompose the tars, the temperature must be raised above about 600°C (1112°F) (FAO, 1983).

Tars are sticky, difficult to handle, and can plug equipment. The presence of chlorine in the plastics from DPE suits may create additional complications with respect to the chemical composition of the gases—for example, corrosion and the possibility of dioxin and furan formation in the CST offgas treatment system (OTS).

The Bechtel Pueblo team plans to use superheated steam as a sweep gas in the CST for removing gases generated when decontaminating nonmetallic waste to 5X. Chemical reactions between the steam and the gases and hot solids are anticipated in the complete absence of oxygen. The Bechtel Pueblo team refers to the reactions as steam reforming. However, the reaction products of agent-contaminated dunnage with steam have never been measured and are not amenable to modeling. The committee is waiting for the results of the TRRP testing planned for the equipment. The key reactions are as follows:

(Reforming)

$$CH_4 + H_2O \rightarrow CO + 3H_2 \qquad \Delta H_{298} = 206 \text{ kJ}$$

(Water gas shift)

$$CO + H_2O \rightarrow CO_2 + H_2 \qquad \Delta H_{298} = -41 \text{ kJ}$$

The first reaction is highly endothermic and will cause the temperature to drop in the CST. The second is slightly exothermic. The reforming reaction is generally conducted at 700°C to 1000°C at 3 to 25 bar in the presence of a catalyst.

Side reactions that can result in carbon formation are as follows:

$$2CO \rightarrow C + CO_2$$
$$CH_4 \rightarrow C + 2\,H_2$$

The committee notes that the prior demonstration test of the CST was, in fact, not a test of steam reforming, because when air leaked into the system some exothermic oxidation reactions took place, and traces of dioxin were found in the offgas. The literature describes many pyrolysis and gasification systems for the conversion of coal, biomass, and municipal solid waste into fuel gas, bio-oil, and char. None is designed to maintain the feed materials at 1000°F for 15 minutes. All focus on the generation of clean-burning fuel for power production.

Successful design and operation of the CST and its associated OTS depends on the thoroughness of the TRRP testing planned for this equipment. Tests on a prior design during the ACWA engineering design

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[13] ACWA Design Committee meeting with Army and Bechtel National, Inc., participants, Irvine, Calif., February 11–13, 2004.

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study phase of the program failed to yield completely satisfactory results. Furthermore, the TRRP tests as planned are not likely to test all actual operating conditions, making it highly probable that unexpected problems in operation and maintenance of these systems will occur. Finally, the CST OTS configuration as designed is an entirely new application of old technologies in which the technologies are being asked to meet very stringent performance goals.

The new CST design is expected to allow the solid feed material to reach 1000°F in the first chamber quickly, while the second chamber provides assurance of an adequate residence time. Agitator speeds will be set to give a residence time in each cylinder of about 15 minutes.

Discussions of the CST design at the May 19–21, 2004, design review meeting indicated that the composition of the material resulting from CST operation may include tarry materials as well as char and ash. The TRRP tests are essential to determine the characteristics of the solids as they pass through the CST and the impact of those characteristics on operational performance and ease of maintenance, especially when processing potentially contaminated materials. These tests must include all materials in the planned feed ratios, not just the three major waste streams, to ensure that the designers have anticipated all problems that may be encountered in operation and maintenance. All materials currently planned for processing in the CSTs during PCAPP operations are listed in Table 2-1 in Chapter 2.

Also, the TRRP testing should be used to demonstrate the ease of maintenance using the proposed auger shell withdrawal mechanisms. The auger shells in both chambers are being designed to be inserted into the chamber shells on rails to permit easy removal for maintenance. Potential jams in the material flow would be located inside the withdrawn auger shells.

Finding 3-18. The proposed two-chamber design for the continuous steam treater with auger shells may be more prone to jamming than the original concept, especially when all of the different feed materials listed in Table 2-1 in Chapter 2 of this report are processed. Moreover, it is unclear how any jammed material would be removed from the withdrawn auger shell. Further disassembly of the auger shell would be required. Furthermore, the condition of the material in the withdrawn auger shell that caused a jam may be very stiff and make extraction of the auger very difficult.

Recommendation 3-18. Technical risk reduction program testing of the design of the two-chamber continuous steam treater (CST) for the Pueblo Chemical Agent Destruction Pilot Plant should include the testing of all feed mixes at the design rates in order to characterize the composition of solids in the CST and the sweep gas flow characteristics through the CST.

Finding 3-19. The continuous steam treaters for the Pueblo Chemical Agent Destruction Pilot Plant will be required to treat a wide range of feed materials, including organic liquids.

Recommendation 3-19. The continuous steam treater (CST) testing should include all of the feed streams anticipated over the life of the Pueblo Chemical Agent Destruction Pilot Plant so as to identify those waste streams that may require alternate means of treatment for acceptable levels of decontamination. Moreover, consideration should be given to other means of treating these wastes if some prove to be the cause of low reliability and high maintenance requirements for the CST.

Wood shredded to 3/8-inch particle size, shredded DPE suit material (metal parts removed), and granulated activated carbon (GAC) are the three major feeds in the CST. But there are other materials as well (see Table 2-1 in Chapter 2). Currently, none of the other materials listed in Table 2-1 are included in the TRRP CST testing. Also, the PCAPP design criteria assume that the wood from the pallets and boxes is oak; however, the wood feed for the TRRP tests will be 10 percent plywood, with the remainder as oak. Copper naphthenate and copper arsenate solutions have been known to be used as wood preservatives in plywood. Copper is known to catalyze dioxin formation, and copper and arsenic may be poisonous to the catalytic oxidation catalyst.

Finding 3-20. The inclusion of plywood in the feed to the continuous steam treater (CST) may result in a feed stream containing constituents detrimental to the catalytic oxidation unit of the CST offgas treatment system.

Recommendation 3-20. Sampling of the pallet and wood box composition at Pueblo Chemical Depot should be performed to verify the presence or absence of preservatives that may contain heavy metals. If

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such constituents are found, additional testing may be required.

Another issue for the CST concerns the material of construction. High-temperature reducing gaseous environments can be more damaging than oxidizing environments. In addition, the prior experience with the earlier CST design indicated extensive corrosion (NRC, 2002c). The CST will have a reducing environment that has a significant potential for carburization. Similar conditions are typically found in syngas generation, chemical reactors, furnaces, steam generators, and downstream reformer components. Under these conditions, an alloy can suffer rapid metal corrosion through a process known as metal dusting (Lai and Patriarca, 1987). This metal dusting tends to occur in a carbonaceous atmosphere (high ratios of carbon monoxide to carbon dioxide and low ratios of steam to hydrogen). When such environments are present in the process stream within the critical temperature range of 400°C to 750°C, metal dusting can be severe (Baker et al., 2004). New nickel-base alloys (Alloy 671 or 693) (Baker et al., undated) have been recently developed for increased resistance to metal dusting. These alloys appear to be more resistant to dusting-type attack than are Alloys C276 and 625.

Finding 3-21. Significant corrosion occurred on an earlier prototype continuous steam treater unit used during the Assembled Chemical Weapons Assessment engineering design study testing (observed during the site visit to the Parsons Fabrication Facility in Pasco, Washington), indicating there could be significant material degradation issues.

Recommendation 3-21. Since metal dusting already appears to have been encountered with austenitic stainless steels used in the prototype continuous steam treater (CST), more dusting-corrosion-resistant alloys should be considered for the current CST design.

Superheated steam in the primary chamber of the CST will flow countercurrent to the solid-feed material flow. Cocurrent steam and dunnage feed material flow is not planned to be tested, although cocurrent flow was originally planned since entrainment of unprocessed fines in the offgas was experienced with countercurrent flow during earlier ACWA testing. (According to the test plan for the CST, the test system will be built so that it can also provide cocurrent flow between the steam and dunnage if so desired.) The CST offgas stream (steam, steam reaction gases, purge nitrogen and, possibly, a small amount of entrained particulates) will exit the primary auger shell near the feed end. The offgas then flows to the OTS. If the pyrolysis reactions occurring in the second (lower) auger shell are greater than expected, gas flow problems in the primary auger shell and potential seal leakage may result.

Finding 3-22. It is not possible to fully understand or characterize the full range of continuous steam treater (CST) offgas contaminants from all feeds if just the three major feed streams are tested, as proposed in the current technical risk reduction program test plan for the CST (U.S. Army, 2003a).

Recommendation 3-22. The test plans for the continuous steam treater (CST) at the Pueblo Chemical Agent Destruction Pilot Plant should provide for characterizing the CST offgas feed to the offgas treatment system (OTS) as well as the gas stream composition at critical locations in the OTS.

OFFGAS TREATMENT SYSTEMS

All process offgas streams flow through an offgas treatment system prior to release to the atmosphere through a stack. Equipment for each of the OTSs is summarized in Table 3-3. As shown by the listing of components in the table, the OTS designs vary from the most complex for the CSTs and MPTs to simple catalytic oxidation (CATOX) units for odor removal in the brine recovery system (BRS) OTS. Also, as indicated in Table 3-3, the munitions washout system/agent neutralization reactor (MWS/ANR) OTS design was not defined in the initial design, but it will be provided at the completion of the intermediate design.

In addition to the process OTSs, the ventilation air from all process areas that may be contaminated with agent is discharged to the HVAC activated carbon filter farm and then released to the atmosphere through a stack. Agent monitors are provided at various points in all systems to monitor system performance. Since the CST OTS is the most complex of the OTSs and will be subjected to TRRP testing, it is reviewed here in more detail. The committee notes that experience with the CST OTS testing will be used in the design of the metal parts treater OTS as well as other OTSs.

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TABLE 3-3 Equipment Summary for Offgas Treatment Systems at Pueblo Chemical Agent Destruction Pilot Plant

	OTS					
OTS Equipment	CST	MPT	ERH/ENR	MWS/ANR[a]	ICB	BRS
Trains	3 (1 per CST)	3 (1 per MPT)	2 (1 per ERH)	To be determined	6 (1 per 4 ICBs)	1
Induction heater	1/train (1200°F discharge)					
Cyclones	2 in series/train	2 in series/train				
Thermal oxidizer	1/train					
CATOX feed temperature control	1/train	1/train	1/train			
CATOX	1/train (1050°F discharge)	1/train (1150°F discharge)	1/train (750°F discharge)			1 (400°F discharge)
Quench scrubber	1	1	1			
Particulate filter	1	1	1			
Heater	1	1	1		1/train	
Carbon filter prefilter					1/train	
HEPA filter					2/train	
Blower (induced draft)	1	1	1		1/train	1
Carbon filter	1	1	1		1/train	

NOTES: A blank space indicates the absence of a component. Acronyms are spelled out in the report's "List of Acronyms."
[a]The OTS for the MWS/ANR had not been designed when this report was prepared.
SOURCE: Adapted from U.S. Army, 2004b.

Offgas Treatment System of the Continuous Steam Treater

An effluent heater heats the offgas stream leaving the CST primary trough to 1200°F. The effluent heater is an inductive heating unit, so it allows materials of construction to be used that can withstand the presence of chloride gases generated from DPE suit material decomposition. Resistive-type heating elements were found to be unsuitable in earlier ACWA testing because of chloride corrosion. An oxygen sensor, located upstream of the effluent heater in the OTS system, is used to monitor oxygen levels and to ensure that these levels are maintained below 3 percent to prevent fires or explosion.

From the effluent heater, the process gases are directed to a two-stage cyclone to remove most of the particulate matter from the offgas stream. The first cyclone removes more than 99 percent of particulates that are 100 microns and larger, while the second cyclone removes more than 99 percent of particulates that are 10 microns and larger. Each cyclone discharges collected particulates into a small drum. The gas stream flowing from the downstream cyclone is expected to contain less than 1 percent of particulates that are 10 microns or larger. Since it cannot be guaranteed that the collected particulates have undergone decontamination to a condition suitable for release to a commercial disposal facility, they will be collected and fed back to the CST or the MPT.

Offgas leaving the cyclones is then mixed with heated ambient air and fed to the bulk oxidizer (a catalytic oxidizer). A flame arrester is provided as a safeguard prior to the entry of gases into the bulk oxidizer. A differential pressure indicator is provided across the flame arrester to provide indication of imminent plugging conditions. The heated ambient air is added to the oxidizer inlet gas stream to ensure that the feed to the

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bulk oxidizer has a hydrogen concentration below its lower explosive limit (LEL) and a gas temperature of about 800°F to prevent the formation of dioxins and furans. The LEL sensor location is after the air addition point but before the bulk oxidizer.

In the bulk oxidizer, hydrogen is converted to water; methane and hydrocarbons to water and carbon dioxide; carbon monoxide to carbon dioxide; and chlorinated organics to hydrogen chloride, carbon dioxide, water, and products of incomplete combustion. This oxidizer is expected to remove at least 99 percent of both hydrogen and carbon monoxide and at least 90 percent of methane from the stream. The minimum oxygen concentration in the discharge gas will be 12 percent by volume. A water spray is provided to maintain the bulk oxidizer exit gas temperature at 800°F as the gas flows to the finishing CATOX unit.

A Military Air Purification CATOX unit is used as a finishing unit to complete oxidation of residual volatile organic compounds (VOCs) and semi-VOCs in the bulk oxidizer effluent. The discharge oxygen concentration of the finishing CATOX unit is maintained at a minimum of 12 percent to ensure complete oxidation. Oxygen content will be monitored with an electrolytic diffusion cell monitor capable of a 12 percent range. The finishing CATOX unit discharge temperature is maintained below 1050°F by injecting a water mist into the unit's inlet. According to the prototype CST test plan, if the finishing CATOX unit discharge temperature exceeds 1100°F, the CST feed will be stopped and the CST heaters will be shut down (U.S. Army, 2003d). Presumably, these steps are required to prevent damage to the catalyst and failure to properly treat material in the CST and its offgas. Other measures (operating conditions and procedures) also may be provided in the final design to protect against excessive temperature in the finishing CATOX unit discharge stream.

After the gas stream exits the finishing CATOX unit, it passes through a venturi scrubber to rapidly cool the gases and minimize the formation of dioxins and furans. The venturi scrubber also removes hydrochloric acid. In the venturi section, the hot process gases are cooled and condensed using a spray of cooled condensate. The cooled gases then go to a scrubber, where a spray of water further cools and scrubs the gases. After start-up, the spray water will be generated by condensation of the water in the incoming gas stream. The liquid condensate generated in the scrubber tower is collected in a tank and then cooled to the required spray temperature. Condensate pH will be monitored and adjusted using caustic to maintain the pH in the 7 to 10 range. Excess condensate is pumped to the agent hydrolysate tanks for subsequent treatment in the ICB units.

Process gas exiting the scrubber tower is directed to the filter, air heater, and carbon filter system. The first filter removes the solid particles greater than 0.5 micron. An electrical heater reduces the relative humidity to ensure better performance of the downstream carbon filter. The carbon filter has inlet and outlet dampers. After the carbon filter, the gas stream is exhausted through an induced draft blower into an exhaust duct and to the plant HVAC carbon filter farm.

The carbon filter unit contains six elements. From inlet to outlet, they are a pre-filter, a high-efficiency particulate air (HEPA) filter, three carbon filters, and a final HEPA filter. Each filter element is equipped with a differential pressure gauge to monitor its corresponding pressure drop. According to the TRRP test plan for the CST, this filter unit is for testing purposes only. The production unit may use carbon filters that are different in configuration from those used in the prototype system (U.S. Army, 2003d). In addition, the production unit may use the building's HVAC, or it may have its own filter system.

Finding 3-23. The number of offgas treatment systems required for operation of the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) is large and the process elements numerous. Most of the process elements have commercial equivalents, but the operating requirements for PCAPP, especially efficiency and reliability, may not be readily achieved.

Recommendation 3-23. Since only the continuous steam treater offgas treatment system (OTS) will be tested prior to plant systemization, there may be significant restriction of plant operation if the OTSs of the Pueblo Chemical Agent Destruction Pilot Plant prove to have lower-than-expected reliability. The Bechtel Pueblo team should develop limiting conditions of operation and operating workarounds that allow continued operation with some OTSs down or operating at reduced efficiency.

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4

Permitting Considerations and Public Participation

One reason for the successful implementation of the program to destroy chemical agent and munitions at Pueblo Chemical Depot (PCD) has been the constructive interaction with interested stakeholders in the Pueblo, Colorado, area and in the larger public nationwide. As described in an earlier National Research Council report (NRC, 1999a), both the Army and residents of the Pueblo area have invested substantial time and resources in dialogue and consensus building concerning the evaluation and selection of nonincineration alternatives for destroying the chemical munitions stored at the PCD and elsewhere.

Over several years, in preparation of an Environmental Impact Statement (for which a Record of Decision was issued in August 2002), the Army worked with the local community, the State of Colorado, and a group of regional and national stakeholders to agree on the location of the facility at PCD and the choice of technology (U.S. Army, 2002b). This was called the Assembled Chemical Weapons Assessment (ACWA) Dialogue, and it has been dubbed the "new style of doing business." This approach contrasts with the more traditional "public outreach" efforts that emphasize first selecting a technology and then informing or educating the public, rather than involving the public in any significant way during the program design and implementation.

The ACWA Dialogue, which includes citizens from nine states and regulators from federal, state, and tribal governments, as well as Army personnel, wrote the request for proposal (RFP) for identifying and selecting alternative technologies to incineration. The ACWA Dialogue then reviewed the proposals and also specified three sets of criteria for assessing the acceptability of alternatives. The ACWA Dialogue worked with Citizens Advisory Commissions (CACs) and other groups to develop an opinion about the public acceptability of these technologies (U.S. Army, 2001).

Finding 4-1. The Assembled Chemical Weapons Assessment Dialogue has been widely viewed as successful because it produced consensus on the choice of technology to be developed and implemented at the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) facility. The maintenance of the communication and dialogue process through the life cycle of the plant is very likely to continue to prove beneficial to the safe and rapid completion of PCAPP operations.

Recommendation 4-1. The Army and its contractors should regularly review, with community and citizen groups, the ongoing effectiveness of the "new way of doing business" that has thus far characterized the effort to safely and effectively destroy the chemical agent and munitions at Pueblo Chemical Depot in Colorado. The committee believes that this formal review will maintain the vitality and effectiveness of the overall process, thereby facilitating the rapid and safe completion of Pueblo Chemical Agent Destruction Pilot Plant operations.

PERMITTING CONSIDERATIONS

In addition to aiding in the choice of a technology,

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the ACWA Dialogue facilitated public endorsement of an accelerated approach to Resource Conservation and Recovery Act (RCRA) permitting (Klomp, 2004). The Army and the Bechtel Pueblo team applied for a phased research, development, and demonstration (RD&D) RCRA permit. RD&D permits are intended for situations in which no promulgated standards for the waste treatment technology exist. The PCAPP facility falls under this category. An advantage of the RD&D permit is that the state may modify or waive permit application or issuance requirements to expedite the permit.

In Pueblo, the local involvement and ACWA Dialogue efforts may have already paid substantial dividends in the form of very rapid progress in obtaining the necessary state RCRA permit. The permit application was submitted in December 2003, amended in March 2004, and made available for public comment in April 2004. A Phase 1 permit was granted in July 2004 (CDPHE, 2004a).

The Colorado Department of Public Health and Environment (CDPHE) agreed to allow the Army to begin phased construction operations before the entire permit was issued for PCAPP. The Phase 1 permit enables limited preliminary construction activities such as the building of access roads and utility services needed by the facility. Phase 2 applies to the construction of nontreatment buildings and Phase 3 to construction of the treatment buildings. It is unusual for the state to issue a permit before the design of the treatment process is complete. However, the CDPHE has stated that this "phased approach" to permitting is allowed by state law (CDPHE, 2004b). The public appears to accept this approach.

The CDPHE has stated that the phased permitting process enhances the opportunity for public review and input (CDPHE, 2004c). Under the Environmental Protection Agency's (EPA's) Enhanced Rule for Public Participation in RCRA permitting, the applicant is required to hold a pre-application meeting and may be required to have materials available in a public repository. A public comment period after the draft permit is issued is also required. Thus, public comment periods are held at each phase of the permitting process, enabling comments to focus on specific segments of the facility design. The CDPHE held three public meetings in the Pueblo area to explain the permit application and process, and it held one public hearing in Pueblo to collect public comments.

One limitation of the RD&D permit is that the EPA specifies that it can only be issued for the period of 1 year and may be renewed for a maximum of 3 years. Also, it can only be used to demonstrate a new technology. Because PCAPP will exist much longer than 3 years, and since it is intended to treat waste, not merely to demonstrate a technology, a standard RCRA permit will be required at some point. If the public is not satisfied with the Army's or the Bechtel Pueblo team's performance at the time that the standard permit application is made, that process may become contentious.

The expectations of the community, set by experience with the ACWA Dialogue and the subsequent working groups that have been formed, are quite high for continued openness to input from and involvement by the public. The outstanding success of the program in rapidly moving through the Colorado state permitting process to date reflects, in part, the legacy and current success of the public involvement process.

Finding 4-2a. The phased approach to the permit—a research, development, and demonstration Resource Conservation and Recovery Act permit—for the Pueblo Chemical Agent Destruction Pilot Plant appears to be advantageous to public review and involvement in the permitting process.

The committee observes that the CDPHE was motivated to adopt a phased permitting approach by the stated local, state, and national interest in accelerating the destruction of the chemical weapons at PCD. Local community members anticipate a huge public investment in the region that will significantly affect the local and regional economy (Emery, 2004). Much of the public goodwill toward Pueblo Chemical Depot and the permitting is based on a perception of a net positive return in terms of economic development and hazard elimination.

Finding 4-2b. Any change in budget priorities that jeopardizes accelerated chemical weapons destruction at Pueblo Chemical Depot would undercut the commitment by the state to this effort and diminish the trust acquired with the local community and interested regional and national stakeholder groups, leaving in its wake a sense of betrayal (CDPHE, 2004b).

Finding 4-2c. Public trust in the Bechtel Pueblo team, contractor for the Pueblo Chemical Agent Destruction Pilot Plant, and the Army depends on their sustaining positive relationships and a track record of keeping commitments. Keeping this trust is important for success in the Resource Conservation and Recovery Act permitting process.

Recommendation 4-2. The Army and its contractors for the Pueblo Chemical Agent Destruction Pilot Plant must continue to maintain a program of dialogue and involvement that is open and responsive to public concerns so that significant concerns are identified early and addressed.

PUBLIC ACCEPTANCE AND INVOLVEMENT

The Colorado Chemical Demilitarization CAC has continued to be active following the initial approval of the neutralization-biodegradation technology for chemical weapons destruction at PCAPP, and in many respects the Army and the Bechtel Pueblo team have acted to implement the "new style of doing business" that has resulted since 1997 from the ACWA Dialogue process. A public forum sponsored by the CAC and the Assembled Chemical Weapons Assessment led to the creation of three working groups, each with a substantial membership (20 to 30 members).[1] These include a working group on acceleration options (now in standby mode, as initial efforts have been completed); a working group on public involvement (which is now spinning off a working group on "community sustainability"); and a working group on permitting issues. Participants in the working groups include volunteers, local government representatives, stakeholder groups, the Army, and others, who have committed considerable individual time and energy. It should be anticipated that active community members may become unable to continue participating in the working groups indefinitely for various reasons.

Finding 4-3. For the public involvement process in the Pueblo Chemical Agent Destruction Pilot Plant effort to remain effective despite changes in participants, membership in working groups must be continually renewed.

Recommendation 4-3. A working group membership renewal process should be carefully maintained by identifying new participants and familiarizing them with the ongoing Pueblo Chemical Agent Destruction Pilot Plant dialogue so that the public remains actively engaged in formal and independent review and oversight.

The CDPHE prepared a draft public participation plan for the chemical stockpile disposal program (CDPHE, 2004d). This plan outlines objectives to keep the local community informed and involved. It specifies objectives and requirements for public participation. The committee has not yet received Bechtel's final Strategic Communication Plan describing its overall community involvement and communication program. However, the state's plan demands a multidimensional involvement program. Besides past and present interaction with the ACWA Dialogue and the CAC, this program has included efforts to ensure that vulnerable and marginalized groups (such as minority businesses and migrant farmworkers) are informed and given opportunities to express their concerns about the program.

Finding 4-4. The Draft Public Participation Plan for the Chemical Weapons Stockpile Disposal Program, U.S. Army Pueblo Chemical Depot, issued by the Colorado Department of Public Health and Environment, appears to abide by the Environmental Protection Agency's Enhanced Public Participation Rule for the Resource Conservation and Recovery Act (Federal Register, 1995).

Recommendation 4-4. The Bechtel Pueblo team should produce a final public participation plan that is consistent with the Colorado Department of Public Health and Environment's Draft Public Participation Plan and the Environmental Protection Agency's Enhanced Public Participation Rule for the Resource Conservation and Recovery Act, and, in particular, ensure that the environmental justice considerations of involving all segments of the population are applied.

Having the Bechtel Pueblo team run the public involvement program has not received uniformly positive reviews. Some observers argue that it may have been a mistake for the Army to turn the public interface function over to the same contractor that is responsible for implementing the demilitarization program. While the current contractor seems to be performing the public involvement program admirably, potential conflicts of interest exist and may result in problems in the future. One potential problem is that of incentives: The

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[1] The activities and minutes of the CAC and its subgroups can be found online at <www.cdphe.state.co.us/hm/archive/pcd/pcdcac1002min.pdf>. Last accessed November 9, 2004.

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contractor has a large stake in ensuring that the public is quiescent, if not supportive of the program, and information that may increase public concerns may not be disclosed. On the other hand, the contractor has significant incentives to fully disclose information and gain community "buy-in" early, in order to reduce the time necessary to obtain the permits and to destroy the Pueblo chemical agent and munitions stockpile. Because the contract provides financial incentives for reducing the time required to obtain necessary permits and destroy agent and munitions, failure to conduct effective community involvement could penalize the contractor. Such failure would likely increase opposition to permitting and therefore delay the program.

The committee believes that if an independent contractor were given the responsibility for conducting the public involvement program, the contractor would be dependent on the Bechtel Pueblo team for information about incidents, changes in operations, and so on. Thus, such an independent contractor might simply be one more layer between the primary contractor for PCAPP and the public and might impede rather than enhance the flow of information.

The Colorado Department of Public Health and Environment's Draft Public Participation Plan reports on results of CDPHE interviews with local residents and remarks, "The issue of a lack of trust for the Army remains a stumbling block for the community" (CDPHE, 2004c, p. 15). This lack of trust may also pose difficulties for the state, for the Army, and for the Bechtel Pueblo team, especially if new controversies or incidents occur.

Also noted in the CDHPE interviews was a deficiency in making readily available adequate information about incidents. Specifically, interviewees expressed concern over inadequate information concerning leaking munitions found in 2003. The perception of inadequate disclosure of incidents is related to the potential conflict-of-interest issues raised above. Oversight by outside objective parties and constant monitoring were cited by many interviewees as important ingredients to regaining public confidence (CDPHE, 2004c).

Finding 4-5. Based on interviews by the Colorado Department of Public Health and Environment with local residents, activists, officials, and others involved in public participation activities relating to the Pueblo Chemical Agent Destruction Pilot Plant, it is clear that a good rapport was carefully constructed via the ACWA (Assembled Chemical Weapons Assessment) Dialogue and ongoing public participation at Pueblo Chemical Depot and surrounding communities. This interaction has produced consensus on what the proper course of action should be. There are many advantages to having broad local buy-in to the program, as now exists. However, in the absence of independent program oversight, a fragility results. Interviewees commented that independent oversight encourages credibility. When independent oversight is absent, incidents can have devastating effects on the credibility of the process.

Recommendation 4-5. The Army should closely monitor the implications of having the contractor for the Pueblo Chemical Agent Destruction Pilot Plant carry out the dual role of implementing the demilitarization program and the public involvement program. Continued diligence by the Army, the contractor, and community groups and citizens will be necessary to ensure that conflicts do not develop between these roles.

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5

General Findings and Recommendations

General Finding 1. On the basis of the initial design documentation for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP), along with the results from completed technical risk reduction program (TRRP) studies and tests, as well as presentations on the intermediate design, the committee believes that the PCAPP can effectively and safely destroy the chemical agent and the energetic materials in the chemical munitions at Pueblo Chemical Depot. This assessment must be qualified by the limitations in available information and time constraints under which the committee operated, as described in this report. The committee remains concerned with the ability of the continuous steam treater to process dunnage effectively. The basis for the committee's assessment can be summarized as follows:

- The hydrolysis of HD (distilled mustard agent) is a mature technology whose chemistry has been extensively studied. The chemical mechanisms and kinetics are well established. The chemistry of the hydrolysis of HT (mustard agent containing mustard-T) has not been as extensively studied to date, but the committee does not foresee any major problems with the hydrolysis of HT mustard.
- Although the hydrolysis of energetic materials through the use of hot caustic solutions is not as mature as mustard agent hydrolysis, testing during the earlier engineering design phase of the Assembled Chemical Weapons Assessment program indicates that the energetic materials at Pueblo Chemical Depot in Colorado can be effectively and safely destroyed by this process.
- The successful biotreatment of agent and energetics hydrolysates has been demonstrated both during the engineering design phase of the Assembled Chemical Weapons Assessment program and in the more recent TRRP activities to confirm that the microorganisms transform the hydrolysates to products that are environmentally acceptable.
- The newly designed systems for disassembling the projectiles and the mortars and for accessing the chemical agent in these munitions are up-to-date approaches that appear to be effective. Both use modern, commercially available robots to handle the munitions. The high-pressure water washout of the munitions bodies removes all of the solids as well as the liquid agent from the munitions bodies, thus reducing the chemical agent load on the metal parts treater (MPT). The projectile/mortar disassembly (PMD) machine has not been tested. However, a trade study has been conducted for the new design to replace the PMD machines used in the baseline (incineration) system.
- Although the MPT is still undergoing developmental testing, it should be capable of decontaminating metal parts to a 5X condition.
- The continuous steam treater (CST) for processing dunnage and wastes and the complexity of the CST offgas treatment system constitute an area of great concern to the committee.

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> The fabrication and testing of the CST will not be completed until late 2004, when the entire PCAPP design is supposed to be in the final stages. The processing of wood in an oxygen-free atmosphere will lead to charring and to the formation of tars. Only wood, activated carbon, and demilitarization protective ensemble suit materials are planned as feeds during TRRP testing; other wastes to be treated in the CST are not being tested.

General Recommendation 1. Alternative approaches for treating the dunnage at the Pueblo Chemical Agent Destruction Pilot Plant should be considered by the Army, with involvement by the public. One such alternative is to send all uncontaminated dunnage and wastes off-site for disposal. Another is to develop a low-temperature system for the treatment of contaminated dunnage to reduce the contamination to levels acceptable for public release in accordance with new Army standards.

General Finding 2. After reconfiguration of the 4.2-inch mortars and 105-mm projectiles, the propellants, fuzes, and igniters that are not contaminated with agent could be sent for off-site disposal to facilities already equipped to treat energetic materials from conventional munitions. This would greatly reduce the energy and process-chemicals requirements for energetics hydrolysis.

General Recommendation 2. The wastes listed in General Finding 2—reconfigured 4.2-inch mortar and 105-mm projectile propellants, fuzes, and igniters not contaminated with agent—should be sent off-site for disposal. The Army should seek guidance from both the permitting agencies and the public on possible approaches to off-site disposal of all uncontaminated wastes from the Pueblo Chemical Agent Destruction Pilot Plant.

General Finding 3. The unit operations in the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) design have never been operated as a total, integrated process. As a consequence, and notwithstanding the throughput analysis that has been performed, a prolonged period of systemization will be necessary to resolve integration issues as they arise, even for apparently straightforward unit operations. For example, the lack of resolution at the intermediate design stage on the means for transferring agent and energetics following munitions disassembly presents major challenges to completing the PCAPP design.

General Recommendation 3. Adequate time should be scheduled during the design of the Pueblo Chemical Agent Destruction Pilot Plant for the contractor team, the Bechtel Pueblo team, to address integration issues. Addressing these issues should include a major effort to define a safe, efficacious, and acceptable method for transferring agent and energetics to destruction processes following munitions disassembly. Whatever method is implemented should continue to keep the energetics and agent separated.

General Finding 4. Public participation and involvement in the design of the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) have been strong—starting with the Assembled Chemical Weapons Assessment Dialogue (called the ACWA Dialogue) and continuing through the Colorado Chemical Demilitarization Citizens Advisory Commission and the working groups, whose participants have included volunteers, local government representatives, stakeholder groups, the Army, and others. Public interest in the design of PCAPP remains high. Although there is substantial agreement on the choice of core technologies (hydrolysis and biotreatment), there is not necessarily agreement on all aspects of the plant design—for example, the continuous steam treater and the metal parts treater designs. Thus, there continue to be opportunities for public involvement in the design.

General Recommendation 4. The Army and its contractor should continue to inform and offer meaningful opportunities to involve the public and state and local government officials in relevant Pueblo Chemical Agent Destruction Pilot Plant design decisions and the technical risk assessment process. Also, the Army and its contractor should encourage public scrutiny and be cautious about taking community consent for granted.

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Appendixes

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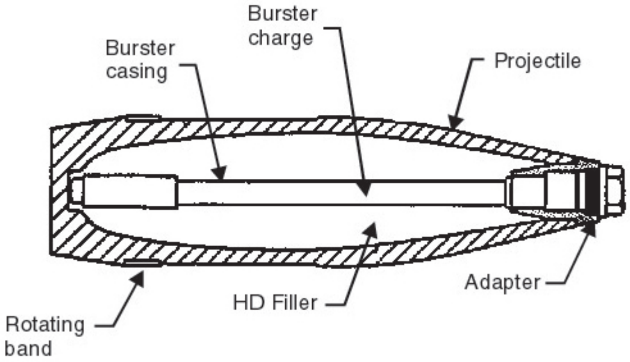
A

Diagrams of Munitions at Pueblo Chemical Depot

Figures A-1 through A-3 are drawings of the 105-mm projectile, 155-mm projectile, and 4.2-inch mortar projectile. Figure A-4 shows a boxed 105-mm projectile. Information is also included on the size, weight, energetics, and packaging of each projectile.

The stockpile inventory at Pueblo Chemical Depot consists entirely of munitions containing mustard agent. Most of the projectiles contain mustard agent HD (distilled bis(2-chloroethyl) sulfide). Some contain mustard agent HT, a 60:40 eutectic mixture of HD and bis[2-(2-chloroethylthio)ethyl] ether. All of the munitions may contain some degradation products and inorganic residues.



M60 Cartridge, 105-mm Howitzer

Length	31.1 in.	Booster	M22
Diameter	105 mm	Explosive	Tetrytol
Total weight	42.92 lb	Explosive weight	0.3 lb
Agent	HD	Propellant	M67
Agent weight	2.97 lb	Propellant weight	2.83 lb
Fuze	M557/M51A5	Primer	M28A2/M28B2
Burster	M5	Packaging	1 round/fiber container, 2 containers/wooden box

FIGURE A-1 A 105-mm howitzer projectile. Note: Some M60 105-mm cartridges have been reconfigured and therefore will not have propellant in the box with the projectile. For those that still have propellant, there will be M67 propelling charges containing M1 propellant in the box. SOURCE: Adapted from U.S. Army, 1977.

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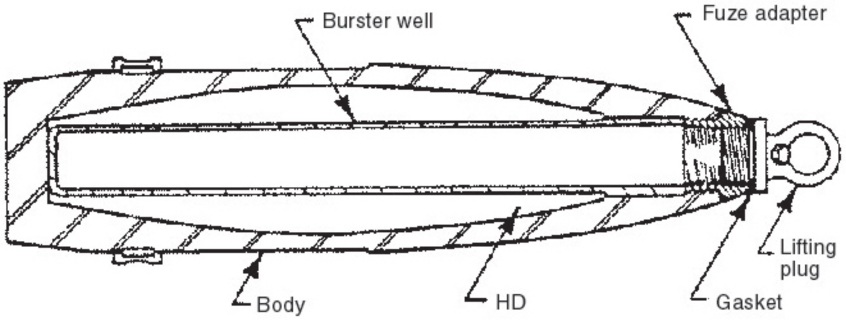
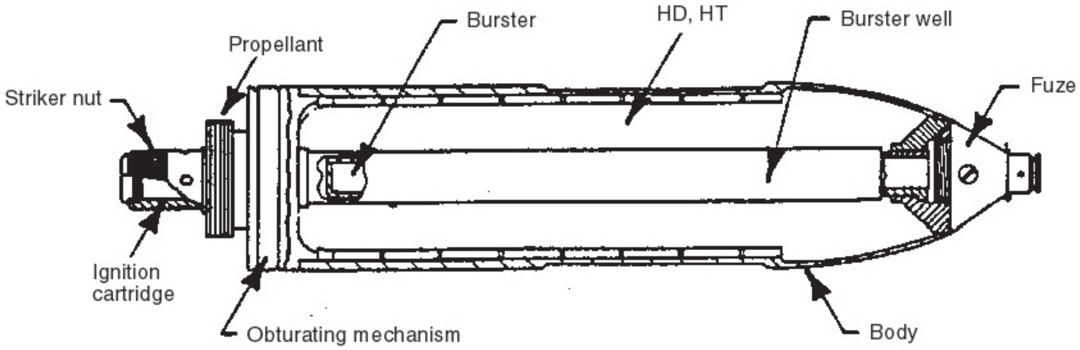
Interim Design Assessment for the Pueblo Chemical Agent Destruction Pilot Plant
http://www.nap.edu/catalog/11213.html



M110 Projectile, 155-mm Howitzer

Length	26.8 in.	Explosive	Tetrytol
Diameter	155 mm	Explosive weight	0.41 lb
Total weight	94.6 lb	Propellant	None
Agent	HD	Propellant weight	None
Agent weight	11.7 lb	Primer	None
Fuze	None	Packaging	8 rounds/wooden pallet
Burster	M6		

FIGURE A-2 A 155-mm howitzer projectile. Note: M110 projectiles have been stored separated from their propellant. SOURCE: Adapted from U.S. Army, 1977.



Cartridge, 4.2-inch Cartridge/Mortar

	M2/HT	M2Al/HD
Length	21.0 in.	21.0 in.
Diameter	4.2 in.	4.2 in.
Total weight	24.67 lb	24.67 lb
Agent	HT	HD
Agent weight	5.8 lb	6.0 lb
Fuze	M8	M8
Burster	M14	M14
Explosive	Tetryl	Tetryl
Explosive weight	0.14 lb	0.14 lb
Propelling charge	M6	M6
Propellant weight	0.6 lb	0.4 lb
Primer	M2	M2
Packaging	1 round/fiber container, 2 containers/wooden box	1 round/fiber container, 2 containers/wooden box

FIGURE A-3 A 4.2-inch mortar cartridge. Note: The M6 propelling charge comprises 25.5 increments of M8 sheet propellant arranged in the following order: one $^1/_2$ increment, four 5-increment bundles, and five single increments. 4.2-inch cartridges/mortars will be reconfigured as projectiles. Most 4.2-inch cartridges will also be defuzed. SOURCE: Adapted from U.S. Army, 1977.

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FIGURE A-4 Boxed 105-mm projectile showing the casing, the propellant bags, and other dunnage in the fiberboard tube. SOURCE: Personal communication from Yu-Chu Yang, Chief Scientist, Office of the Program Manager for Assembled Chemical Weapons Alternatives, Department of Defense, to Harrison Pannella, NRC staff, July 20, 2004.

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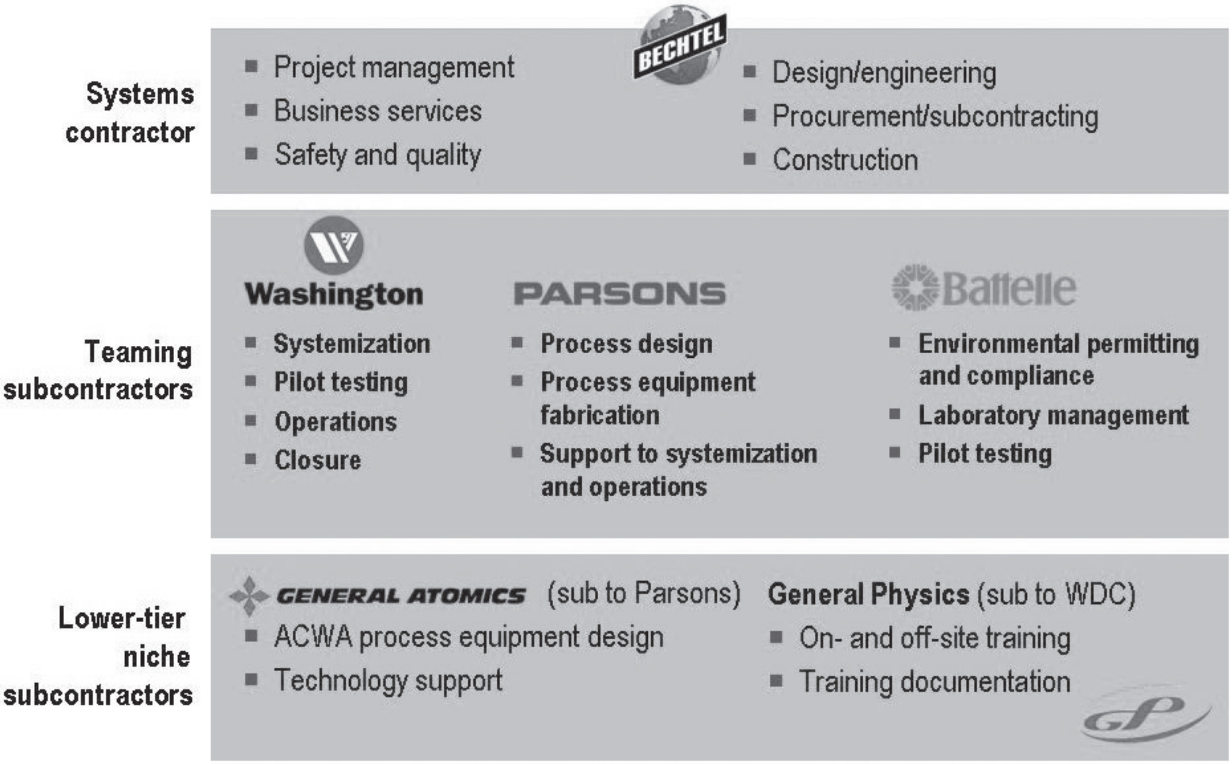
B

Bechtel Pueblo Team Division of Responsibilities



Systems contractor

BECHTEL
- Project management
- Business services
- Safety and quality
- Design/engineering
- Procurement/subcontracting
- Construction

Teaming subcontractors

Washington
- Systemization
- Pilot testing
- Operations
- Closure

PARSONS
- Process design
- Process equipment fabrication
- Support to systemization and operations

Battelle
- Environmental permitting and compliance
- Laboratory management
- Pilot testing

Lower-tier niche subcontractors

GENERAL ATOMICS (sub to Parsons)
- ACWA process equipment design
- Technology support

General Physics (sub to WDC)
- On- and off-site training
- Training documentation

FIGURE B-1 Bechtel Pueblo Team division of responsibilities. SOURCE: Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) Design Overview Briefing by Craig Myler, PCAPP Chief Scientist, to the ACWA Design Committee, Aberdeen Proving Ground, Md., November 6, 2003.

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C

Identified Risks from Initial Technical Risk Assessment

NOTE: U.S. Army. 2003. Design-Build Plan for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) Project, Rev. 0, June 16. Aberdeen Proving Ground, Md.: Program Manager, Assembled Chemical Weapons Alternatives, Appendix P.

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TABLE C-1 PCAPP Design-Build Plan, Appendix P

Risk Area/Risk		Probability of Occurrence	Weight	Consequence of Occurrence	Weight	Overall Risk Weight	Mitigation Measure	Overall Risk Weight
Material Handling Operations								
1	Inadequate delivery of munitions to Bechtel Pueblo Team impacts operations	Unlikely	2.0	Operations stop when munition buffer inventory depleted, with potential schedule impact	0.40	0.8	Design storage buffer capacity to accommodate delays; provide sufficient transport vans to PCD, and develop IPTs to coordinate program needs	0.2
2	Inability to deliver within the facility at night	Unlikely	2.0	Operations stop when munition buffer inventory (4 hours) is depleted, with moderate schedule impact	0.65	1.3	Design for munitions night transportation using adequate lighting and covered areas. Perform trade study to determine transportation alternatives with covered passageways, ensure safety analysis in limiting conditions operations (LCOs). Work with client to obtain permission to perform such night operations	0.3
3	Inability to maintain munitions dry/protected from weather poses safety risk	Unlikely	2.0	Wet or icy munitions increase probably of accident during movement of munitions, with minor schedule and cost impact	0.35	0.7	Coordinate with WDC and design for canopy over door and roadways to minimize potential	0.1
4	Munitions buffer storage capacity undersized	Unlikely	2.0	Operations stop when munition buffer inventory (48 hours) is depleted, impacting schedule	0.30	0.6	Design for extra storage capacity (48 hours) for MSB	0.1
5	Accidents during munitions movements	Remote	1.0	Personnel injured, investigation required, and termination of operations until root cause determined, with potential moderate schedule impact	0.60	0.6	Include scenarios in safety analysis, and include in training plans and LCOs	0.1
6	Forklift accidents (moving in reverse)	Unlikely	2.0	Personnel injured, investigation required, and termination of operations until root cause determined, with potential schedule impact	0.50	1	Address in SHA and consider results in design (more room to turn around)	0.2
7	Adverse weather impacts operations	Likely	3.0	Delivery of munitions terminated until weather improves, with potential schedule impact	0.30	0.9	Design contingency in schedule based on Pueblo meteorological data and include in availability value	0.2
Baseline Reconfiguration Operations								
8	Inability to meet process demands through manual operations	Unlikely	2.0	Average throughput rates not achieved, with potential for minimal schedule delay	0.30	0.6	Provide sufficient capacity for workers in UPA to meet design rates	0.1
9	Leakers/contaminated dunnage found in "C" category	Remote	1.0	Operations terminated pending investigation and modification/revision of SOPs	0.80	0.8	Provide adequate agent monitors in monitoring plan and include requirements in design relying on lessons learned (LL) from other chem demil programs	0.2
10	Safety related to lifting, manual operations	Unlikely	2.0	Worker injured, lost work time, some cost impact	0.40	0.8	Perform human factors engineering (HFE), training, and use of lifting devices in design	0.2
11	Environmental control - static electricity/HVAC poses explosive danger	Remote	1.0	Combination of dry air and static electricity spark an explosion, causing injury to personnel and equipment	0.80	0.8	Design to minimize static electricity in UPA and maintain humidity in HVAC design	0.2
12	Inadequate design considerations for explosives handling	Remote	1.0	Accident resulting in explosion with injury to personnel and/or damage to the facility with significant schedule impact	0.80	0.8	Not design issue, but include in safety plans and LCOs	0.2
Energetics Access Processes								
13	PMD/hydraulics throughput rates lower than average design rate	Likely	2.0	Plant average operational schedule not maintained, impacts other operations and moderate schedule delays	0.50	1	Design conservatively based on actual operational data, with 60% overall availability	0.2
14	Availability	Likely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal to moderate schedule delays	0.40	0.8	Design for 60% overall based on LL, model process via iGrafx, and adjust accordingly. Perform trade studies if warranted, to optimize process	0.2
15	Conveyor interface problems causes downtime	Unlikely	2.0	Increases maintenance and impacts throughput, causing minimal to moderate schedule delays	0.40	0.8	Develop and maintain ICDs, use 3D CAD model to minimize interface problems. Confirm with iGrafx model	0.2
16	Explosive considerations, (tetryol exudates) causes excess maintenance	Unlikely	2.0	Excessive build-up of explosives and increased maintenance requirements to remove, minimal impact to schedule	0.20	0.4	Housed in ECR, designed for explosives, but perform trade study to determine Tetryol Exudation problem	0.1

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Risk Area/Risk		Probability of Occurrence	Weight	Consequence of Occurrence	Weight	Overall Risk Weight	Mitigation Measure	Overall Risk Weight
Energetics Treatment Processes								
17	ERH/HDC throughput rates less than required and minimal full-scale data	Likely	3.0	Plant average operational schedule not maintained, impacts other operations and moderate schedule delays	0.50	1.5	Design for surge capacity and use a conservative rate (test data indicates higher achievable). Fabricate and perform extensive tests at fabrication shop prior to shipment to site	0.3
18	Availability less than assumed	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal to moderate schedule delays	0.40	0.8	Assume conservative rate, verify during exhaustive shop testing, and perform systems engineering using iGrafx to identify workaround solutions. Do trade study to determine buffer storage capacity needed	0.2
19	Interface problems with material handling equipment and single-point failure	Unlikely	2.0	Increases maintenance and impacts throughput, causing minimal schedule delays	0.30	0.6	Trade study to assess potential improvements in design to reduce potential for jamming at HDC interface and determine alternatives to minimize single-point failure points	0.1
20	Inadequate explosive considerations	Unlikely	2.0	Increased maintenance requirements to remedy, with potential for explosion resulting in minimal to moderate impact to schedule	0.40	0.8	Include in safety analysis and LCOs, and include safety requirements in design criteria/SDDs	0.2
21	Aluminum dissolution in caustic causing downstream problems with ICBs	Unlikely	2.0	Aluminum hydroxide reduces surface area of biomass and potential sloughing which results in poor performance, and moderate schedule impact	0.60	1.2	Trade study to determine impact on downstream equipment items. Consider adding pH adjustment and filter press upstream of the ICBs to remove precipitation, if warranted. Process used in industrial applications	0.3
22	Cotton fibers in propellants/bags impacting performance of ERH and reactors	Likely	2.5	Excess materials plug recirculation pumps, causing malfunction and requirement for maintenance, and moderate schedule impact	0.60	1.5	Trade study to consider separate reactor for propellants, with additional testing. Identify alternatives to adding bags to ERH	0.3
Agent Access Processes								
23	MWS throughput rates lower than expected	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal schedule delays	0.30	0.6	Perform simulant testing on prototype unit to confirm rates	0.1
24	Availability lower than expected	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal schedule delays	0.30	0.6	Obtain availability data from tests for input to throughput analysis and verify iGrafx model	0.1
25	Limited test data available for scale-up	Unlikely	2.0	Design not adequate for intended service, impacts cost through re-work and causes moderate schedule delay	0.50	1	Develop test plan with clear acceptance criteria with contingency plans for not meeting criteria, and then perform tests	0.2
26	Robotic design and operation does not work as required	Unlikely	2.0	Design not adequate for intended service, impacts cost through re-work and causes moderate schedule delay	0.50	1	Perform simulant testing on prototype unit to confirm rates	0.2
27	Manufacturing/modularization problems	Unlikely	2.0	Manufacturing process impacted with delay in fabrication and impact on construction and subsequent operations	0.30	0.6	Use additional test data in development of design and design models	0.1
Agent/Energetic Neutralization Processes								
28	Corrosion/materials of construction causes excess downtime	Unlikely	2.0	Reactors shut down for maintenance, causing minimal schedule impact	0.30	0.6	Use ABCDF LL, Titanium 7 or 2	0.1
29	Throughput rates lower than expected	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal schedule delays	0.30	0.6	Obtain data from ABCDF tests before PCAPP design complete, confirm in process model	0.1
30	Availability lower than assumed	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal schedule delays	0.30	0.6	Obtain data from ABCDF tests before PCAPP design complete, confirm in process model	0.1

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Risk Area/Risk		Probability of Occurrence	Weight	Consequence of Occurrence	Weight	Overall Risk Weight	Mitigation Measure	Overall Risk Weight
31	pH probe failure and over neutralization	Unlikely	2.0	Agent neutralization reactor over neutralized and overload downstream equipment, causing downtime for maintenance and repairs, with minimal schedule delays	0.30	0.6	Follow ABCDF LL and use CO_2 injection to maintain pH, and use dual pH meters with algorithm for accuracy	0.1
32	Cotton fibers in propellants/bags impacting performance of ERH and reactors	Likely	2.5	Excess materials plug recirculation pumps, causing malfunction and requirement for maintenance, and moderate schedule impact	0.60	1.5	Trade study to consider separate reactor for propellants, with additional testing. Identify alternatives to adding bags to ERH	0.3
33	HD/HT co-processing impacts reactor performance	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and moderate schedule delays	0.50	1	Perform Mettler testing to assess impacts on design. Input results into design. Clearly define test acceptance criteria with contingency plans for not meeting criteria	0.2
Metal Parts Treatment Processes								
34	Verification of heat transfer for Pueblo tray configuration to validate MPT throughput	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and moderate schedule delays	0.60	1.2	Perform additional testing using prototype munition trays in the ACWA test unit to obtain additional data to confirm the heat transfer model prior to scale-up. Design using model to full-scale unit, fabricate full-scale unit, perform tests using approved test plan with acceptance criteria and contingencies for failure	0.3
35	Throughput rates/availability lower than expected	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal to moderate schedule delays	0.40	0.8	Fabricate and test full-scale unit based on approved test plan for fabrication shop	0.2
36	Design does not allow flexibility for closure operations	Unlikely	2.0	Closure operations become more intensive and delays closure schedule, causing minimal to moderate schedule delays	0.40	0.8	Develop closure requirement document to define closure specifications, and include in MPT design	0.2
37	Explosive gas build-up/purging potential for explosion	Unlikely	2.0	Explosion occurs, requires downtime, repairs, and minimal to moderate impacts to cost and schedule	0.45	0.9	Perform hazards analysis and include monitoring equipment with purge capability in design	0.2
Biotreatment of Hydrolysate Processes								
38	Throughput rates/availability lower than expected	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal schedule delays	0.40	0.8	Spare capacity and surge tank capacity is included in design	0.2
39	HD/HT co-processing interferes with performance	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal schedule delays	0.30	0.6	Data available from CAMDS testing, and bench testing of ICB by Honeywell	0.1
40	Odor not adequately controlled	Unlikely	2.0	Potential regulatory violation, resulting in fines and potential shutdown, results in minimal cost and schedule impacts	0.30	0.6	Design CatOx use for odor control	0.1
41	High water consumption and recycling scaling	Unlikely	2.0	Results in more unscheduled maintenance, with minimal impact to schedule	0.30	0.6	Trade study to determine maximum water recovery and possible use of other make-up water sources such as sanitary sewer	0.1
42	Variability of energetics/agent hydrol. impacts performance	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal schedule delays	0.30	0.6	Design for feed surge tank to allow for more consistent feed to ICBs	0.1
Treatment of Secondary Wastes Processes								
43	CST throughput rates less than expected	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal to moderate schedule delays	0.40	0.8	Pilot testing demonstrated good performance. Perform shop testing to confirm. Model process using iGrafx and incorporate results into design	0.2
44	System not optimized including carrier media impacts performance	Unlikely	2.0	Plant average operational schedule not maintained, impacts other operations and minimal to moderate schedule delays	0.40	0.8	Perform trade study to optimize system and determine optimal carrier media using ACWA test unit	0.2

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Risk Area/Risk		Probability of Occurrence	Weight	Consequence of Occurrence	Weight	Overall Risk Weight	Mitigation Measure	Overall Risk Weight
45	Excess dioxin/furan generation causes violation of permit	Unlikely	2.0	Potential regulatory violation, resulting in fines and potential shutdown, results in minimal cost and schedule impacts	0.30	0.6	Perform trade studies to enhance dioxin/furan through testing at CAMDS	0.1
Facility Support Systems								
46	Inadequate design factors used in design	Unlikely	2.0	Requires extra maintenance, rework with minimal increased costs, and minimal schedule impacts	0.30	0.6	Use LL from other chem demil facilities for acceptable design factors, and include in design criteria/SDD documents	0.1
47	HVAC undersized	Unlikely	2.0	Requires extra maintenance, rework with minimal increased costs, and minimal schedule impacts	0.30	0.6	Use LL from other chem demil facilities for acceptable design factors, and include in design criteria/SDD documents	0.1
48	New facility consumption growth beyond design considerations	Unlikely	2.0	Requires extra maintenance, rework with minimal increased costs, and minimal schedule impacts	0.30	0.6	Use LL from chem demil for acceptable design factors to account for such situations (this has always been a concern)	0.1
Water Supply								
49	Reliability of entire water supply system	Likely	3.0	Requires facility to shut down, pending supply with moderate schedule impact	0.50	1.5	Perform trade studies to enhance recovery and possible alternate sources (sanitary sewer, pink water, new wells). Determine overall system reliability and availability for water supply; perform well testing and upgrade pumping system, if found inadequate to meet demands (CDRL A006)	0.3
50	Water quality poor and varies	Unlikely	2.0	Minimal impact as water is treated in the water treatment plant before being used	0.20	0.4	Perform well testing and use results in water treatment system design	0.1
51	Water consumption rates more than design	Unlikely	2.0	Potential to shut down plant if maximum allowable rates exceeded, resulting in facility shutdown with minimal schedule impact	0.30	0.6	Provide redundancy for upset condition situations and model, using iGrafx and other models	0.1
Power								
52	Excess outages impact operations	Likely	3.0	Potential to interrupt operations with minimal schedule impact	0.30	0.9	Design sufficient backup capability to minimize outages based on LL	0.2
53	Increased demand due to additional loads coming online after construction complete	Unlikely	2.0	Potential to increase costs for additional equipment, and minimal schedule impact	0.30	0.6	Consider sufficient design factors based on LL	0.1
Process Integration/Feed Characteristics								
54	Integration of material handling units with process equipment	Likely	3.0	Potential to require more maintenance, increase operating time, and cause moderate increase in schedule	0.80	2.4	Design in adequate buffer capacity. Develop and maintain ICDs early in program, use 3D CAD models to assess impacts, and perform systems engineering, using iGrafx model early in program to mitigate rework. 3D model to include repair/access, maintainability, construction tolerances, turnover, etc.	0.5
55	Unknown agent and energetic characteristics impacting performance	Likely	3.0	Potential to require more maintenance, increase operating time, and cause moderate increase in schedule	0.70	2.1	Use a broad design range for feed characteristics based on LL from other chem demil programs	0.4
Permitting/Regulatory Compliance								
56	Delays with obtaining the CD, which is a new permitting requirement	Unlikely	2.0	Delays start of construction and all subsequent operations with significant schedule impact	0.80	1.6	Prepare an RD&D permitting strategy using multiphases. Involve regulators in all phases of program and get their buy-in to the design. Form IPTs to support and resolve issues	0.3
57	Excess notices of deficiency (NODs) obtained during the permitting process	Unlikely	2.0	Delays permitting process and subsequent operations	0.30	0.6	Involve regulators in all phases of program and get their buy-in to the design. Form IPTs to support and resolve issues	0.1
58	Key regulatory personnel changes during the permitting process	Unlikely	2.0	Potential to delay permitting process with minimal impact to overall schedule	0.20	0.4	Situation beyond project manager's control and cannot resolve during design; however, it is important to make sure regulators involved in all phases of program	0.1
Public Acceptance								
59	Limited public involvement early in the program has potential for delays	Remote	1.0	Public unhappy with design and/or constructed facility, causing political pressure and minimal to moderate schedule delays	0.60	0.6	Involve public in all phases of program, encourage participation in reviews, and make them owners of the program	0.1

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Risk Area/Risk		Probability of Occurrence	Weight	Consequence of Occurrence	Weight	Overall Risk Weight	Mitigation Measure	Overall Risk Weight
60	Negative perception of the process selection has potential to delay/stop the program	Remote	1.0	Potential to impact schedule, but citizens' advisory commission (CAC) involvement should mitigate any negative impacts	0.60	0.6	Involve public in all phases of program, encourage participation in reviews, and make them owners of the program	0.1
61	Total process rejection by the public would cause rework and cause delays	Remote	1.0	Potential to impact schedule, but CAC involvement should mitigate any negative impacts	0.60	0.6	Involve public in all phases of program, encourage participation in reviews, and make them owners of the program	0.1
62	Lack of public involvement can result in mistrust	Remote	1.0	Potential to impact schedule, but CAC involvement should mitigate any negative impacts	0.60	0.6	Involve public in all phases of program, encourage participation in reviews, and make them owners of the program	0.1
Constructability								
63	Inadequate or constrained space	Unlikely	2.0	Minimal impacts to construction schedule and subsequent cost	0.30	0.6	Bring experienced construction engineers on board from day 1 to participate and input LL into design; rely on 3D model to assess construction sequences	0.1
64	Inability to install or difficulty with installation of equipment in the facility	Likely	3.0	Minimal impacts to construction schedule and subsequent cost	0.30	0.9	Bring experienced construction engineers on board from day 1 to participate and input LL into design; rely on 3D model to assess construction sequences	0.2
65	Delay in delivery of equipment or construction materials	Unlikely	2.0	Minimal impacts to construction schedule and subsequent cost	0.30	0.6	Not really a design requirement, but by bringing construction personnel on board early will aid in defining long-lead equipment and facilitate planning	0.1
66	Interface problems	Likely	3.0	Minimal impacts to construction schedule and subsequent cost	0.30	0.9	Bring experienced construction engineers onboard from day 1 to participate and input LL into design; rely on 3D model to assess construction sequences	0.2
Delays in Systemization								
67	Delays in construction	Unlikely	2.0	Minimal to moderate impacts to operational schedule and subsequent cost	0.40	0.8	Involve systemization and construction personnel in design from day 1 to facilitate planning and execution of work	0.2
68	Excess systemization time due to control problems	Unlikely	2.0	Minimal to moderate impacts to operational schedule and subsequent cost	0.40	0.8	Perform extensive shop tests of fully integrated process equipment to minimize problems at the site. Changes can be made at the fab. shop prior to shipment	0.2
69	Inability to perform integrated tests	Unlikely	2.0	Minimal to moderate impacts to operational schedule and subsequent cost	0.40	0.8	Perform extensive shop tests of fully integrated process equipment to minimize problems at the site. Maximize integrated tests at fab. shop and perform modeling to confirm design assumption. Changes can be made at the fab. shop prior to shipment	0.2
Delays in Operations								
70	Limited space for maintenance	Unlikely	2.0	Minimal impacts to operational schedule and subsequent cost	0.30	0.6	Bring experienced operations personnel on-board from day 1 to participate and input LL into design. Ensure that all factors such as sensor locations, space requirements, etc., are identified in design	0.1
71	Agent cross-contamination and more timely maintenance requirements	Unlikely	2.0	Requires extra maintenance, increased costs, and moderate schedule impacts	0.50	1.0	Ensure optimal layout, HVAC design, and egress from potentially contaminated areas in design. Coordinate design with operations experts early in design phase. Address in SHA	0.2
Delays in Closure								
72	Closure criteria not adequately defined	Likely	3.0	Minimal to moderate impacts to closure costs and schedule due to extra time and equipment requirements	0.45	1.35	Add experienced JACADS closure expert to DB team to participate and input LL into design, develop closure criteria early and maintain the "design to close" approach throughout the entire program. Add closure to design reviews and add closure data to EPC design tool for closure package	0.3
73	Excess agent contaminated areas and equipment	Unlikely	2.0	Minimal to moderate impacts to closure costs and schedule due to extra time and equipment requirements	0.40	0.8	Add experienced JACADS closure expert to DB team to participate and input LL into design, develop closure criteria early and maintain the "design to close" approach throughout the entire program. Add closure to design reviews and add closure data to EPC design tool for closure package	0.2
74	Overly complex construction areas	Unlikely	2.0	Minimal to moderate impacts to closure costs and schedule due to extra time and equipment requirements	0.45	0.9	Add experienced JACADS closure expert to DB team to participate and input LL into design, develop closure criteria early and maintain the "design to close" approach throughout the entire program. Add closure to design reviews and add closure data to EPC design tool for closure package	0.2

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Risk Area/Risk		Probability of Occurrence	Weight	Consequence of Occurrence	Weight	Overall Risk Weight	Mitigation Measure	Overall Risk Weight
Cost Risks								
75	Inadequate configuration management control and design rework	Unlikely	2.0	Impact to design schedule and subsequent minimal to moderate impacts to schedule and cost	0.40	0.8	Execute comprehensive configuration management plan from day 1; define basis of design and criteria; execute design per approved criteria. Implement comprehensive QA/QC program, and only approve changes that are found to be a safety or environmental concern	0.2
76	Design changes after baselining impacting the construction schedule	Unlikely	2.0	Impact to design schedule and subsequent moderate impacts to schedule and cost	0.50	1.0	Execute comprehensive configuration management plan from day 1; define basis of design and criteria; execute design per approved criteria. Implement comprehensive QA/QC program, and only approve changes that are found to be a safety or environmental concern	0.2
Safety Risks								
77	Potential for agent release and exposure to personnel (on- and off-site)	Remote	1.0	Agent release to the atmosphere is unacceptable and would result in major schedule impact and subsequent cost increase	1.00	1.0	Provide adequate agent monitors in monitoring plan and include requirements in design, relying on LL from other chem demil programs	0.2
78	Energetic accidents and potential for explosions during transportation	Remote	1.0	Personnel injured, investigation required, and termination of operations until root cause determined, with potential schedule impact	0.70	0.7	Include scenarios in safety analysis, and include in training plans and LCOs	0.1
79	Working around hot and toxic chemicals in certain process areas	Remote	1.0	Accident resulting in injury to personnel and/or damage to the facility, resulting in minimal to moderate costs and schedule impact	0.60	0.6	Ensure design meets codes, and assess alternative processes in trade study. Perform safety analysis and ensure findings included in design	0.1
80	Manual handling of munitions in the UPA	Unlikely	2.0	Worker injured, lost work time, some cost impact	0.40	0.8	Perform HFE, training, and use of lifting devices in design	0.2
81	Adequately designed space to allow safe egress and ingress	Unlikely	2.0	Worker injured, lost work time, some cost impact	0.40	0.8	Perform HFE, and confirm with 3D model to ensure egress and ingress routes adequately designed	0.2
82	Manual reconfiguration of munitions in the TOX area glovebox resulting in leaks or explosion	Remote	1.0	Worker injured, lost work time, investigation with schedule and some cost impacts	0.40	0.4	Perform HFE, and confirm with 3D model to ensure adequate glovebox design with sufficient HVAC to contain agent release. Design to specify limits to torquing used to remove energetics	0.1
83	Explosive atmospheres in MPT and ERH	Unlikely	2.0	Explosion occurs, requires downtime, repairs, and minimal to moderate impacts to cost and schedule	0.45	0.9	Perform hazards analysis and include monitoring equipment with purge capability in design	0.2
Environmental Risks								
84	Potential for agent release to the atmosphere	Remote	1.0	Agent release to the atmosphere is unacceptable and would result in major schedule impact and subsequent cost increase	1.00	1.0	Provide adequate agent monitors in monitoring plan and include requirements in design relying on LL from other chem demil programs	0.2
85	Potential for odor release from the bioreactors	Likely	3.0	Possible violation of permits with subsequent fine, and minimal schedule impact	0.30	0.9	Involve environmental experts from day 1; develop and implement comprehensive monitoring plan requirements in design; develop training manuals early in program	0.2
86	Excess volatile organic compound emissions	Unlikely	2.0	Possible violation of permits with subsequent fine, and minimal schedule impact	0.40	0.8	Use CatOx to treat exhaust from ICBs; involve environmental experts from day 1; develop and implement comprehensive monitoring plan requirements in design	0.2
87	Potential for waste water release	Unlikely	2.0	Possible violation of permits with subsequent fine, and minimal schedule impact	0.50	1.0	Involve environmental experts from day 1; develop and implement comprehensive monitoring plan requirements in design; allow design factors to mitigate potential for risk	0.2
88	Release of materials to general public without adequately meeting 5X criteria	Remote	1.0	Unlikely scenario as materials processed in MPT to ensure temperatures met	0.20	0.2	Verify design calculations with sufficient design allowance to account for upset conditions. Implement comprehensive monitoring plan to ensure compliance	0.0
89	Exceeding the allowable daily process water limit of 218,000 gpd	Remote	1.0	Situation would result in stoppage of operations, with minimal to moderate schedule and cost impact	0.50	0.5	Risk not likely as system designed for recycle and maximum waster consumption well below allowable. Perform exhaustive water M&EBs and identify areas where conservation and recovery can be made	0.1
90	Heavy metals in solid wastes	Likely	3.0	Situation expected as the solid wastes to be processed in permitted landfill facility	0.10	0.3	Risk not likely as system designed to dispose of wastes in permitted facility. Perform trade studies to determine areas and processes to minimize heavy metal generation	0.1

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D

Committee Meetings and Site Visits

Site Visit 1, October 23, 2003
Richmond, Kentucky

Objectives

Participate in Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) and Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) process reviews (IPRs). Receive briefings on the status of all activities preparatory to the completion of designs and initiation of construction for the two facilities, including information on public involvement, environmental permitting, design-build, business management, and scheduling.

NRC Participants

Committee Chair: Robert Beaudet. NRC staff members: Bruce Braun, Donald Siebenaler

Meeting 1, November 5–6, 2003
Aberdeen Proving Ground, Maryland

Objectives

Introduce committee, sponsor, and NRC staff; review history of the ACWA program; receive briefings on current plant designs at Blue Grass Army Depot and Pueblo Chemical Depot; determine times and locations for future meetings.

NRC Participants

Committee members: Robert Beaudet (Chair), Charles Barton, Joan Berkowitz, Lawrence Eiselstein, Harold Forsen, Willard Gekler, Clair Gill, John Merson, Kenneth Smith

ACWA Program Participants

William Pehlivanian, Joseph Novad, Yu-Chu Yang, Katherine DeWeese

Bechtel Parsons Participants

Michael Lewis, Chris Midget, Chris Haynes, Craig Myler

Office of the Secretary of Defense Participant

Brian Gladstone

Meeting 2, February 11–13, 2004
Irvine, California

Objectives

Receive comprehensive briefings and hold discussions on the ACWA program, including schedule revisions and PCAPP design, technical risk reduction program, and trade studies.

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NRC Participants

Committee members: Robert Beaudet (Chair), Charles Barton, Joan Berkowitz, David Daniel, Ruth Doherty, Lawrence Eiselstein, Harold Forsen, Willard Gekler, Clair Gill, Hank Jenkins-Smith, John Merson, Chandra Roy, Kenneth Smith, Michael Stenstrom, Thomas Webler

ACWA Program Participants

Joseph Novad, Yu-Chu Yang

Contractor Participant

Craig Myler (Bechtel)

Site Visit 2, March 19, 2004
Battelle Memorial Institute
Columbus, Ohio

Objectives

Obtain briefings on and observe 4-liter biotreatment test unit.

NRC Participant

Committee member: Ruth Doherty

ACWA Program Participants

Joseph Novad, Gary Anderson

Contractor Participants

Russell Smith (Battelle), Craig Myler (Bechtel), James Earley (FOCIS Associates)

Site Visit 3, April 6, 2004
General Atomics
San Diego, California

Objectives

View prototype energetics rotary hydrolyzer and receive briefings on energetic hydrolysis.

NRC Participants

Committee members: Ruth Doherty, Harold Forsen, John Merson

Contractor Participants

Gary Lee (General Atomics), Ronald Gallego (General Atomics), Louie Wong (General Atomics), Thomas Ritter (Parsons), Frederick Hamer (FOCIS Associates)

Meeting 3, April 13–15, 2004
Aberdeen Proving Ground, Maryland

Objectives

Receive comprehensive briefings and hold discussions on the ACWA program, including schedule revisions and PCAPP design, technical risk reduction program, and trade studies; receive responses from the Army to committee queries.

NRC Participants

Committee members: Robert Beaudet (Chair), Charles Barton, Joan Berkowitz, Adrienne Cooper, Ruth Doherty, Lawrence Eiselstein, Harold Forsen, Willard Gekler, Clair Gill, Chandra Roy, Michael Stenstrom, Thomas Webler

ACWA Program Participants

Joseph Novad, Yu-Chu Yang

Contractor Participants

Craig Myler (Bechtel), Chris Haynes (Bechtel)

Site Visit 4, May 7, 2004
Parsons Fabrication Facility
Pasco, Washington

Objectives

Receive briefings on PCAPP equipment development; view prototype munitions washout system and metal parts treater.

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NRC Participants

Committee members: Lawrence Eiselstein, Harold Forsen, Clair Gill. NRC staff member: Harrison Pannella

Meeting 4, May 19–21, 2004
Bechtel
San Francisco, California

Objectives

Receive comprehensive briefings and hold discussions on the ACWA program, including schedule revisions and PCAPP intermediate design, technical risk reduction program, and chemical weapons information; receive responses from the Army to committee queries.

NRC Participants

Committee members: Robert Beaudet (Chair), Charles Barton, Joan Berkowitz, Adrienne Cooper, Ruth Doherty, Lawrence Eiselstein, Harold Forsen, Willard Gekler, Clair Gill, Hank Jenkins-Smith, John Merson, Kenneth Smith, Michael Stenstrom

Meeting 5, July 12–14, 2004
The National Academies
Washington, D.C.

Objectives

Review and fill gaps in the first full message draft of the PCAPP Design Interim Report; achieve consensus on the PCAPP Design Interim Report.

NRC Participants

Committee members: Robert Beaudet (Chair), Charles Barton, Joan Berkowitz, Adrienne Cooper, Ruth Doherty, Lawrence Eiselstein, Harold Forsen, Willard Gekler, Clair Gill, John Merson, Chandra Roy, Kenneth Smith, Michael Stenstrom, Thomas Webler

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E

Biographical Sketches of Committee Members

Robert A. Beaudet, *Chair*, received his Ph.D. in physical chemistry from Harvard University in 1962. From 1961 to 1962, he was a U.S. Army Chemical Corps officer and served at the Jet Propulsion Laboratory as a research scientist. He joined the faculty of the University of Southern California in 1962 as an assistant professor and was chair of the Chemistry Department from 1974 to 1979. Dr. Beaudet has served on Department of Defense committees that have addressed both offensive and defensive considerations surrounding chemical warfare agents. He was chair of an Army Science Board committee that addressed chemical detection and trace gas analysis. He also was chair of an Air Force technical conference on chemical warfare decontamination and protection. He has served on several National Research Council (NRC) studies on chemical and biological sensor technologies and energetic materials and technologies. Most of his career has been devoted to research in molecular structure and molecular spectroscopy. Dr. Beaudet is the author or coauthor of more than 100 technical reports and papers in these areas.

Charles Barton received his Ph.D. in toxicology from the University of Louisiana. Dr. Barton is currently the Iowa state toxicologist and director of the Center for Environmental and Regulatory Toxicology at the Iowa Department of Public Health. In addition to being a certified toxicologist, he is certified in conducting public health assessments, health education activities, and risk assessments; in emergency response to terrorism and emergency response incident command; and in hazardous waste operations and emergency response. In his position as the state toxicologist, Dr. Barton serves as the statewide public health resource providing health consultations and advice to other environmental and health-related agencies, as well as to health care providers and to business and industry representatives. He currently directs, or has directed, a host of Iowa Department of Public Health programs, including the PCB Program, Radon Program, Water Treatment System Registration Program, Hazardous Substances Emergency Surveillance System, Hazardous Waste Site Health Assessment Program, Risk Assessment for Superfund Program, State of Iowa Toxicology Program, and many others.

Joan B. Berkowitz, who graduated from the University of Illinois with a Ph.D. in physical chemistry, is currently managing director of Farkas Berkowitz and Company. Dr. Berkowitz has extensive experience in the area of environmental and hazardous waste management, a knowledge of available technologies for the cleanup of contaminated soils and groundwater, and a background in physical and electrochemistry. She has contributed to several studies by the Environmental Protection Agency, been a consultant on remediation techniques, and assessed various destruction technologies. Dr. Berkowitz has written numerous publications on hazardous waste treatment and environmental subjects.

Adrienne T. Cooper is currently an assistant professor in the Department of Civil and Environmental En-

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gineering at Temple University. Dr. Cooper has a Ph.D. in environmental engineering from the University of Florida and a B.S. degree in chemical engineering from the University of Tennessee. During her early college years, she gained experience as an engineering aide working with engineers on environmental systems design, nuclear design, and preparing design criteria for solid, liquid, and gaseous radioactive waste systems for nuclear power plants. Following graduation, she became a process development engineer for E.I. DuPont de Nemours & Company, taking new products from the laboratory to the plant. In this capacity, Dr. Cooper developed a finishing process for a ceramic powder for electronics use. While in graduate school, she served as an adjunct instructor and became an environmental engineer for the hazardous materials program for the Alachua County Environmental Protection Department in Gainesville, Florida. In the summer of 1995, she was a research fellow in the National Science Foundation summer research institute in Ibaraki, Japan, where she evaluated the efficacy of immobilized titania for the photocatalytic removal of organics from water. Dr. Cooper has authored numerous publications and made presentations in her field. She is a member of several organizations, including the American Society of Mechanical Engineers, International Society of African Scientists, and National Society of Black Engineers.

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