Review and Assessment of Developmental Issues Concerning the Metal Parts Treater Design for the Blue Grass Chemical Agent Destruction Pilot Plant

Committee to Review and Assess Developmental Issues Concerning the Metal Parts Treater Design for the Blue Grass Chemical Agent Destruction Pilot Plant, National Research Council

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REVIEW AND ASSESSMENT OF DEVELOPMENTAL ISSUES CONCERNING THE METAL PARTS TREATER DESIGN FOR THE BLUE GRASS CHEMICAL AGENT DESTRUCTION PILOT PLANT

Committee to Review and Assess Developmental Issues Concerning the Metal Parts Treater Design for the Blue Grass Chemical Agent Destruction Pilot Plant

Board on Army Science and Technology

Division on Engineering and Physical Sciences

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Preface

The Committee to Review and Assess Developmental Issues Concerning the Metal Parts Treater Design for the Blue Grass Chemical Agent Destruction Pilot Plant (Appendix A) was appointed by the National Research Council in response to the following request from the Program Manager for Assembled Chemical Weapons Alternatives:

Statement of Task

- Review the design and thermal modeling of the metal parts treater (MPT) for BGCAPP;
- Review testing results that have become available in the course of Technical Risk Reduction Program activity 5c for the metal parts treater;
- Develop means to address the longer-than-expected heat-up times of munitions casings in the MPT in view of considerations of the effect this has on the throughput capabilities for overall BGCAPP operations;
- Review the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) Munitions Treatment Unit (MTU) design and test data, compare the MPT and MTU and make any recommendations regarding the MTU's application to BGCAPP;
- Produce a report with findings and recommendations concerning first-of-a-kind developmental issues and possible options concerning the MPT design for BGCAPP.

The committee is the latest in a series of committees assembled to provide scientific and technical advice to the Army as it seeks alternatives to the existing baseline incineration programs being used at five of the remaining eight chemical weapons stockpile locations.

The committee met three times (see Appendix B for the meeting agendas). At the first meeting, the committee visited the Parsons facility in Kennewick, Washington, to be briefed on the full Assembled Chemical Weapons Alternatives (ACWA) designs, the specifications for the metal parts treater (MPT), and the MPT Technical Risk Reduction Program (TRRP). The committee members also inspected the TRRP MPT used in testing. On September 20, 2007, representatives of the committee visited the Abbott Furnace Company in St. Marys, Pennsylvania, to receive presentations from the munitions treatment unit (MTU) manufacturer and to inspect the MTU being constructed and tested for the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP). The second full meeting was held on October 16-18, 2007, at the National Academies' Beckman Conference Center in Irvine, California. The first half-day was devoted to discussions with the Program Manager for Assembled Chemical Weapons Alternatives and the Bechtel Parsons Blue Grass Team to clarify any remaining questions, and the remainder of the 3-day meeting was devoted to discussions and to writing the report. At the last meeting, on November 6-8, 2007, also at the Beckman Conference Center, the committee focused on refining the report for peer review.

This was a very challenging study, in part because of the short time frame allowed the committee and in part because the delivery of sufficiently detailed written information necessary to inform the committee was delayed owing to security vetting. Such vetting, which appears to be an artifact of the September 11, 2001 attacks, continues to have a negative effect on the ability of committees to provide the type of technically detailed advice that is expected of them. The January 2008 date originally requested for delivery of the report required the committee to complete its data gathering before its third meeting, which took place November 6-8, 2007. Unfortunately, the Bechtel Parsons Blue Grass Team's final report, *Technical Risk Reduction Program Metal Parts Treater Final Study Report,* Revision B, containing 763 pages of information and describing the testing of the MPT, was not made available to the committee until November 2, 2007, owing to an extensive operational security review. Thus, although the committee did spend considerable time during its final meeting examining this information, it based the majority of its deliberations on the oral presentations of test results and discussions with the Program Manager for Assembled Chemical Weapons Alternatives and contractor representatives.

As the chair of this committee, I commend the diligent work and the contributions to the preparation of this report by the writing team leaders, Bill Gekler, John Howell, Joan Berkowitz, and Richard Ayen. Their efforts are particularly appreciated.

The entire committee, in turn, is grateful to the Program Manager for Assembled Chemical Weapons Alternatives Kevin Flamm and his staff, particularly Joseph Novad and Darren Dalton, for their considerable efforts to provide the needed information. The committee understands the challenges that these hard-working professionals encountered in assembling and gaining operational security clearances for the information and test results requested.

The committee also greatly appreciates the support and assistance of National Research Council staff members Bruce Braun, Margaret Novack, Nia Johnson, and Jim Myska, who ably assisted the committee in its fact-finding activities and in the production of the report.

The members of the Board on Army Science and Technology (BAST), listed on page v, were not asked to endorse the committee's conclusions or recommendations, nor did they review the final draft of this report before its release, although board members with appropriate expertise may be nominated to serve as formal members of study committees or as report reviewers. The BAST was established in 1982 by the National Research Council at the request of the U.S. Army. It brings broad military, industrial, and academic scientific, engineering, and management expertise to bear on Army technical challenges and other issues of importance to senior Army leaders. The BAST also discusses potential studies of interest; develops and frames study tasks; ensures proper project planning; suggests potential committee members and reviewers for reports produced by fully independent, ad hoc study committees; and convenes meetings to examine strategic issues.

Robert A. Beaudet, *Chair*
Committee to Review and Assess
Developmental Issues Concerning
the Metal Parts Treater Design for
the Blue Grass Chemical Agent
Destruction Pilot Plant

Acknowledgment of Reviewers

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 National Research Council's (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:

Martin Gollin, Carmagen Engineering Inc.,
Gary S. Groenewold, Idaho National Laboratory,
Elizabeth A. Holm, Sandia National Laboratories,
Peter B. Lederman, New Jersey Institute of Technology (retired),
James F. Mathis, NAE, Exxon Corporation (retired),
George J. Quarderer, Dow Chemical Company (retired),
W. Leigh Short, Principal and Vice President of Woodward-Clyde (retired), and
Michael K. Stenstrom, University of California, Los Angeles.

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 Harold Forsen, NAE. Appointed by the National Research Council, he 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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Abbreviations and Acronyms

ACWA	Assembled Chemical Weapons Alternatives
BGAD	Blue Grass Army Depot
BGCAPP	Blue Grass Chemical Agent Destruction Pilot Plant
BOX	bulk oxidizer (flameless thermal oxidizer)
BPBGT	Bechtel Parsons Blue Grass Team
CATOX	catalytic oxidizer
CFD	computational fluid dynamics
DOD	Department of Defense
EBH	energetics batch hydrolyzer
ENS	energetics neutralization system
GB	nerve agent (sarin)
H	Levinstein mustard agent
HD	distilled mustard agent
HT	distilled mustard mixed with bis(2-chloroethylthioethyl) ether
HVAC	heating, ventilation, and air conditioning
LSS	Lab Safety Supply
MDB	munitions demilitarization building
MPT	metal parts treater
MTU	munitions treatment unit
MWS	munitions washout system
NAE	National Academy of Engineering
NRC	National Research Council
OTM	off-gas treatment for the MPT
OTS	off-gas treatment system
PCAPP	Pueblo Chemical Agent Destruction Pilot Plant
PCD	Pueblo Chemical Depot
PMACWA	Program Manager for Assembled Chemical Weapons Alternatives
PMD	projectile mortar disassembly
PTFE	polytetrafluoroethylene
PVC	polyvinylchloride
SCWO	supercritical water oxidation
SDU	supplemental decontamination unit
TRRP	Technical Risk Reduction Program
VOC	volatile organic compound
VSL	vapor screening level
VX	nerve agent
WCL	waste control limit
WIC	waste incineration container

Summary

The United States is in the process of destroying its chemical weapons stockpile. In 1996, Congress mandated that the weapons at two sites, Blue Grass Army Depot in Kentucky and Pueblo Chemical Depot in Colorado, would not be destroyed by incineration and that the Department of Defense should demonstrate and select alternative methods. In 1999, Congress also passed Public Law 105-261, which required that the Under Secretary of Defense certify "in writing to Congress" that the alternative technology would "be as safe and cost effective for disposing of assembled chemical munitions as is incineration of such munitions. . . ."

The Assembled Chemical Weapons Alternatives (ACWA) program was established in response to these mandates. Because the selected alternatives at each site would be new applications of existing technologies, the Army designated the facilities used to implement the alternatives as pilot plants—the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) and the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP).

The Program Manager for Assembled Chemical Weapons Alternatives is overseeing the efforts of systems contractors to develop and test equipment to be used in the designs for constructing the two disposal pilot plants. Among the first-of-a-kind equipment under development for the BGCAPP are two metal parts treaters (MPTs), which would be used primarily for the treatment of washed-out metal munitions cases from which the agent has been drained. The MPTs could also be used to treat secondary waste generated during the destruction operations and waste materials generated during facility closure operations. During recent testing, results have shown the heat-up times of trays of munition casings to be longer than expected. Another issue that has developed involves problems in sealing the MPT as the temperature inside is increased. The Program Manager for Assembled Chemical Weapons Alternatives requested that the National Research Council (NRC) form a committee to review ongoing testing to investigate and determine causes for the longer-than-expected heat-up times and other issues concerning the MPT design. The full statement of task for the Committee to Review and Assess Developmental Issues Concerning the Metal Parts Treater Design for the Blue Grass Chemical Agent Destruction Pilot Plant is given in the Preface.

Contracts to design, build, operate, and close both pilot plants were awarded to Bechtel International, teamed with Parsons Engineering. For PCAPP, Parsons is a subcontractor to Bechtel. For BGCAPP, Bechtel and Parsons formed a joint venture called the Bechtel Parsons Blue Grass Team (BPBGT) and are teamed as prime contractors. These contractors tailored the specific design of the respective facilities to the content of each site's stockpile.[1]

THE METAL PARTS TREATER AND THE MUNITIONS TREATMENT UNIT

Originally the MPT was planned for use at both BGCAPP and PCAPP to decontaminate metal parts. The current PCAPP design now calls for a munitions treatment unit (MTU) to decontaminate projectile and mortar casings. The MPT uses radiant and convection heating in an enclosed metal cylinder to raise metal parts to 1000°F for a duration of 15 minutes in order to decontaminate these materials. Steam is used as a carrier or sweep gas to remove vapors and particulates released during heating. The intention is also to use the MPT to treat contaminated secondary waste before its off-site disposal.

The two MPTs being developed for the BGCAPP are

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[1] The stockpile at the Blue Grass Army Depot includes two nerve agents and a blister agent in various types of munitions. The agents are nerve agent sarin (GB) ($C_4H_{10}FO_2P$), nerve agent VX ($C_{11}H_{26}NO_2PS$), and Levinstein mustard agent (H) ($C_4H_8Cl_2S$). The nerve agents are in M55 rockets and 8-inch or 155-mm projectiles. The mustard agent H is in 155-mm projectiles. The stockpile at the Pueblo Chemical Depot consists of 105-mm boxed cartridges, palletized 155-mm projectiles, and 4.2-inch mortars, all of which are filled with one of two forms of mustard agent: distilled mustard agent (HD) or mustard agent HT.

designated as first-of-a-kind equipment because they are unique, are being designed for this particular application, and have never been used in an actual process. A small-scale test unit called the Technical Risk Reduction Program (TRRP) MPT was fabricated to demonstrate the operation of the MPT concept for the decontamination of metal parts and waste. In this report, the phrase "first-of-a-kind" or "full-scale MPT" is used to describe the full-scale equipment, and the term "TRRP MPT" is used to describe the three-quarter-scale version.

The PCAPP design calls for an MTU to decontaminate the projectile and mortar casings. The MTU, an adaptation of a metal annealing oven, is a continuous-belt muffle-type oven with material-handling equipment at the feed and discharge ends. Modifications include new feed and exit sections and a muffle large enough in cross section (10 in. high by 30 in. wide) to accommodate 155-mm projectile bodies riding on the metal conveyor. The muffle section is also long enough to ensure that all parts of the munitions reach 1000°F for at least 15 minutes at the operating speed of the metal conveyor.

The committee was not charged with evaluating the MTU in detail. What this report presents is a technical description and evaluation of the MPT (Chapters 2-4) plus an evaluation of the technical feasibility of replacing the MPT with an MTU and supplemental decontamination units and autoclaves such as those being designed and tested for PCAPP (Chapter 5).

ASSESSMENT OF METAL PARTS TREATER TESTING ACTIVITIES

The MPT concept has been subjected to testing in TRRPs, with most of the pertinent testing conducted under the Bechtel TRRP 05c test plan (BPBGT, 2007d). This testing has used the three-quarter-scale TRRP MPT.

The testing objectives as given in the TRRP 05c test plan were as follows (BPBGT, 2007d):

- Demonstrate reliable mechanical performance of all parts and functions of the MPT design, including seals, doors, bearings, and projectile jamming.
- Demonstrate BGCAPP-specific design improvements such as: projectile orientation, steam-injection orientation, gas take-off orientation, and tray design to improve heat-up.
- Calibrate the computational fluid dynamics (CFD) model of the test unit on VX 155-mm projectiles to serve as a basis for first-of-a-kind (FOAK) full-scale unit modeling. Inherent in this objective is the necessary demonstration that the MPT can heat all parts of materials fed to it to 1000°F for at least 15 minutes at a rate that meets expected feed rates during operation.
- Demonstrate treatment of simulated energetics batch hydrolyzer (EBH) rocket warhead debris.
- Demonstrate limited secondary-waste treatment options to gather data for further effort with the CFD model.
- Perform test runs and cycles of components to make observations of critical design parameters that apply to the FOAK unit under design—particularly those that affect the risk of scale-up to the full-scale unit. These include, but are not limited to projectile paint debris generation and accumulation, thermal expansion stresses and deformation points, interferences, Gaussian field measurements and localized heating effects, and wall temperature distribution.

The TRRP MPT testing used an off-gas treatment system that included a catalytic oxidizer unit rather than a bulk oxidizer unit (more accurately called a flameless thermal oxidizer) and did not include the venturi scrubber. Thus, the flow of off-gas from the MPT enclosures was demonstrated, but not the off-gas treatment system configuration or equipment that will be provided for the full-scale MPT. The off-gas treatment system bulk oxidizer unit is also considered to be a first-of-a-kind system.

TRRP MPT testing was performed using surrogates of all munitions metal parts and waste feed streams anticipated for the two BGCAPP full-scale MPTs. All feed streams were tested. However, the BPBGT terminated the waste stream testing before the completion of all planned tests because it was believed that sufficient data to design the full-scale MPT had been obtained. All feed streams were tested to the extent allowed by existing permits at the Parsons fabrication facility. The permitting limitation prevented testing of the energetics batch hydrolyzer waste with energetics remnants and halogenated materials.

During testing, the TRRP MPT unit experienced recurring operating problems, such as mechanical failures and munitions bodies taking longer than expected to reach the necessary high temperatures as estimated by computer modeling.

The committee grouped the MPT test results into three areas for review and evaluation: (1) mechanical issues and (2) secondary and closure waste treatment issues, which are assessed in this section, and (3) results of thermal testing, modeling, and predicted throughput of the MPT, which are assessed further below.

Mechanical Issues

New Door Closure Mechanism and Seals

Difficulties with getting an acceptably tight closure on the air lock and main chamber doors for the TRRP MPT have resulted in a change in the design of the door closure mechanism and seals for the full-scale MPT. Instead of the J-type sliding closure mechanism used on the TRRP MPT, the door for the full-scale MPT will be moved against the closure face by using a two-direction cam design recommended by a commercial oven contractor. In addition, the seal material design has been altered to give the equivalent of two gaskets between the door and closure face.

Bearings for the Conveyor Rollers

The Graphalloy® bearings for the conveyor rollers in the main chamber experienced galling and other wear failures attributed to oxidation/corrosion at the main chamber operating temperature. Three different bearing materials were evaluated: "improved" Graphalloy®, Stellite, and Deva (Deva-Mogul sintered metal). All materials experienced wear, and the BPBGT concluded that the "improved" Graphalloy® bearings were acceptable, although they exhibited some pitting. During full-scale MPT testing, the BPBGT intends to reconsider Stellite bearings that are interchangeable with the Graphalloy® bearings. The BPBGT has also developed maintenance protocols that shorten replacement times for bearings as much as possible.

Heating Zones

The full-scale MPT will use two heating zones in the main chamber. Each will be capable of about 450 kW of induction heating. The TRRP MPT used one 600-kW induction heater. The use of two-zone heating in the full-scale MPT main chamber should improve heating rates and control of heating. It is unclear whether maintenance on one MPT will be possible while the other is in operation. If not, the availability of the MPTs would be reduced, since both would have to be shut down if either required in-room maintenance. TRRP testing and CFD modeling showed that certain areas of some projectiles were heating more slowly than the rest of the projectiles. This slower heating required longer heat-up times to achieve a uniform 1000°F for 15 minutes for all projectiles. After its review of the chamber design, the BPBGT concluded that the slow heating resulted from "shadowing" of parts of the projectiles during the radiant heating process. The shadowing is being addressed by redesign of the projectile trays, the superheated steam inlet header, and the off-gas outlet header.

Secondary and Closure Waste Treatment Issues

Waste to be treated in the MPT includes the washed munitions bodies from the munitions washout system, solid residues from the energetics batch hydrolyzer, and secondary and closure waste. Agent-contaminated waste will be treated by chemical decontamination. When chemical decontamination cannot be used, waste (e.g., agent-contaminated pallets) will be treated in the MPT before off-site disposal. Secondary waste that is not agent-contaminated is not expected to be processed through the MPT.

In general, secondary waste can be shipped off-site safely if it meets one of two criteria: (1) if analysis shows levels less than the applicable waste control limits (WCLs)[2] or (2) if the waste has been subjected to thermal treatment at 1000°F for 15 minutes. The second criterion, formerly called treatment to 5X, was a requirement for off-site shipment until June 2004 when the criteria on WCL were introduced. The BPBGT plans to heat all secondary waste to 1000°F for at least 15 minutes in the MPT. At that temperature, in the very low oxygen activity environment of the MPT, many secondary waste materials will pyrolyze, leading to the formation of chars and tars. By lowering the temperature to ~500° F for 1 to 2 hours, six nines (99.9999 percent) agent destruction and removal efficiency should be achievable, and char and tar formation should be greatly reduced.

RESULTS OF THERMAL TESTING, MODELING, AND PREDICTED METAL PARTS TREATER THROUGHPUT

TRRP testing of secondary waste treatment in the MPT was conducted at the Parsons fabrication facility in Kennewick, Washington, in May 2007. The test results were generally favorable. However, the range of waste types treated was narrow, and the total amount of waste treated was small. Thus, the committee recommends that the BPBGT perform more comprehensive testing during systemization, using waste representative of that encountered during closure as well as various types of secondary waste from operations and maintenance. Heat-up times for projectiles located in the trays passing through the TRRP MPT were measured and predicted to demonstrate that the metal parts at all locations in the tray could be heated to 1000°F for at least 15 minutes within a total time duration that supported the design production rate. The experimental data and the modeling focused on the temperature-time profiles for projectiles at specified locations in the tray. The key elements of this effort were as follows:

- Thermocouple measurements of the surface temperature were made on a limited number of projectiles at specific locations in the tray as they passed through the MPT and were heated.
- Predictions of the temperature distribution in the projectiles were made by using a CFD thermal modeling program that was compared with a previous model used in initial PCAPP MPT testing. However, all model results must be validated with experimental data, as discussed elsewhere in this report.

Experimental Temperature Measurements

Type K thermocouples encased in stainless steel sheaths were mounted to the top and bottom of three projectile cas-

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[2] WCLs and the analytical methods required to demonstrate that they have been achieved vary by state. In general, the WCL is defined as 20 parts per billion (ppb) for GB and VX and 200 ppb for HD, as determined by EPA'S toxicity characteristic leachate procedure (TCLP) applied to the residuals from the metal parts treater. The WCL may also, or additionally, be based on agent concentration in the air space above the containerized waste treatment residuals. Minimum required levels are typically 1 STEL (short-term exposure limit)—0.0001 mg/m^3 for GB, 0.00001 mg/m^3 for VX, and 0.003 mg/m^3 for HD.

ings in order to allow the monitoring of temperature-time profiles in the prototype TRRP MPT. Selection of the locations on the casings was aided by use of the CFD thermal model to identify potential cool spots.

Temperature Prediction by Computational Fluid Dynamics Thermal Modeling

The BPBGT used a mathematical model for comparison with the TRRP experimental measurements and to predict the performance of the full-scale MPT for BGCAPP. The BPBGT model gives spatial and temporal temperature behavior of the parts being processed in the MPT. The purpose of the modeling was to show that the MPT design was adequate for treating munitions at 1000°F for 15 minutes while meeting operational and schedule requirements and that the design could guide the scale-up and the testing of the full-size unit. Comparison with the experimental measurements was used to validate and modify the model. The improved model appears to be fairly rigorous. The code is based on a nonlinear solver that (1) is accurate to second order in space and time; (2) globally and locally conserves mass, momentum, and energy; and (3) allows a choice of finite-element shape function. The model handles multimode heat transfer, including graybody radiation with view factor computation.

COMPARISON OF THE METAL PARTS TREATER AND MUNITIONS TREATMENT UNIT FOR BGCAPP

The committee reviewed the applicability of the MTU as an alternate method for decontaminating munitions bodies and secondary waste at BGCAPP. As noted above, the MTU is currently planned for installation at PCAPP for the thermal decontamination of 155-mm and 105-mm projectiles and 4.2-in. mortars that have been drained of mustard agent and passed through a high-pressure wash. Table S-1 compares various operating requirements and features of the MPT and the MTU and identifies changes that would be required for the MTU to be used at BGCAPP. The same table appears in Chapter 5, which gives additional supporting and clarifying information.

GENERAL FINDINGS AND RECOMMENDATIONS

Finding. The full-scale MPT as currently designed for BGCAPP can decontaminate projectile bodies and secondary and closure waste, and it will be able to achieve its target throughput rates provided that the BPBGT is able to resolve the following issues:

- Successful implementation of new designs for door closure and seals, for roller bearings on conveyors, and for the superheated steam header;
- Effective thermal treatment of secondary waste without excessive fouling of the duct work leading to the bulk oxidizer;
- Successful integration of the MPT with its flameless thermal oxidizer (i.e., the bulk oxidizer) and cyclone; and
- Complete destruction of energetic materials in the waste stream of the energetics batch hydrolyzer without adversely affecting the MPT.

Finding. The current range of heat-up times of munitions in the MPT should not affect the overall schedule of BGCAPP operations.

- Heat-up times in the TRRP tests are close to target and appear to be capable of being improved by raising the wall temperature of the full-scale MPT.
- CFD modeling predicts correct trends in temperature-time profiles and locations of cold spots and should be useful in guiding the design and testing of the full-scale MPT.
- The processing rate of projectile bodies in the MPT is not on the critical path of the process throughput. The design calls for two MPTs. The second is intended to be used for secondary waste, but it could also be used for treating munitions bodies in an emergency.

Finding. The MTU could be substituted for the MPT at BGCAPP; however, it would be necessary to do the following:

- Use supplemental decontamination units and autoclaves to treat secondary waste,
- Find another means of treating the detonators in the M417 rocket fuzes,
- Modify the MTU design to accommodate 8-in. projectiles,
- Modify the footprint of the building to accommodate the units, and
- Modify the existing permits.

Finding. For BGCAPP, the TRRP testing did not address a method to thermally treat the fuzes and a limited number of igniters from contaminated propellant that are not decomposed in the energetics batch hydrolyzers.

Recommendation 6-1. The BPBGT needs to develop a method to collect and pop the igniters and fuzes that will not adversely affect the operation of the MPT.

Recommendation 6-2. To reduce the technical risks in treating secondary waste in the MPT, the BPBGT should continue to strive to send secondary waste off-site whenever possible and minimize the use of halogenated materials.

Recommendation 6-3. To reduce the load on the off-gas treatment system, the BPBGT should consider obtaining permits that allow the use of the Airborne Exposure Limit Guidelines to operate the MPT at lower temperatures for the thermal treatment of secondary waste whenever possible.

Finding. TRRP testing demonstrated the validity of using an MPT for thermal decontamination. It also identified many changes and design improvements that will be necessary to achieve an acceptable throughput rate and control maintenance and operating costs. Further testing with varied secondary waste materials including halogenated waste is still required. These changes and improvements may require several iterations before satisfactory results are achieved.

Recommendation 6-4. A test plan should be prepared for all design changes identified for the MPT but not verified in the TRRP tests. This test plan should be conducted at the fabrication facility and should include time for the repeated trials needed to arrive at acceptable performance for the overall full-scale MPT. A similar test plan should be prepared for testing the integrated full-scale off-gas treatment system for the MPT at BGCAPP. This test plan should include the testing of a full range of secondary, energetics batch hydrolyzer, and closure waste at the full-scale MPT design rates.

TABLE S-1 Comparison of the Metal Parts Treater and the Munitions Treatment Unit

Characteristic	MPT at BGCAPP	MTU at PCAPP	Changes for MTU Use at BGCAPP
Status of testing	Prototype (~3/4 scale) demonstrated on surrogate munitions and waste streams. Two full-size MPTs will be built and tested at the manufacturer's facility.	Full-scale unit completed acceptance tests at the manufacturer's facility with surrogate munitions.	Full testing would be required, using the energetic dregs and agent or appropriate surrogate material. Only small design changes from the PCAPP MTU are required. Using the MTU would save extensive testing of the MPT with secondary waste. Treatment of secondary waste in the SDU[a] and autoclaves has already been performed at the other sites.
Feed streams			
4.2-inch mortars and base plates	None	97,106 (HD)	Applies only to PCAPP, no mortar rounds at BGCAPP.
105-mm projectiles	None	383,418 (HD)	Not applicable to BGCAPP.
155-mm projectiles	15,492 (H) 12,816 (VX)	299,534 (HD)	A new permit will be needed to use the MTU at BGCAPP.
8-inch projectiles	3,977 (GB)	None	Muffle height must be increased for use at BGCAPP. The MTU currently has internal height of 9.75 in. and width of 30 in.
M55 rockets; undissolved fragments, including undissolved squibs and fuzes from hydrolysis of rocket warhead and rocket motor segments in EBHs[b]	51,716 (GB) 17,757 (VX) Method for treating squibs and fuzes in the MPT is to be tested.	None	Squibs and fuzes must be thermally decomposed (must be popped). Some fragments are combustible and may require inert gas and special baskets if treated in the MTU or, alternatively, they may be treated in the SDU or autoclave if WCL[c] guidelines for off-site disposal are used.
Secondary waste	Thermal treatment in MPT using special carrying trays.	Treatment in SDU or autoclaves.	SDU and autoclave use based on approach used at ABCDF.[d] Use at BGCAPP may require special permitting and higher temperatures for GB- and VX-contaminated waste. Only limited testing on various waste types has been performed in the MPT.
Closure waste	Thermal treatment in MPT.	Treatment in second SDU.	See comments for secondary waste.
Agents destroyed			
Mustard	Yes	Yes	

continues

TABLE S-1 Continued

Characteristic	MPT at BGCAPP	MTU at PCAPP	Changes for MTU Use at BGCAPP
GB and VX	Yes	None	SDU and autoclave would be required with the MTU for GB- and VX-contaminated waste streams. This method of decontamination may require higher treatment temperatures to achieve acceptable treatment times to meet WCL guidelines for off-site disposal.
Number of units	2 MPTs with one for projectile processing and one for waste streams and as a backup spare.	2 MTUs with only one ordinarily required to meet PCAPP processing rates.	BGCAPP might require only 1 MTU because the number of projectiles is an order of magnitude less than at PCAPP; MTU availability expected to be higher than that of the MPT.
MDB[e] footprint	~70 ft long × 40 ft wide × 20 ft high Total direct footprint for 2 MPTs plus 50 percent of MPT/washout support room plus MPT cooling room is 4,640 square feet.	~100 ft long × 30 ft wide × 20 ft high Total direct footprint for 2 MTUs is 5,100 square feet plus 216 square feet for collection bin enclosures.	MTU would require changes in BGCAPP MDB layout to accommodate longer processing length and SDU and autoclave units and to provide for collection bins for receiving treated metal parts from MTU discharge chute.
Post-treatment agent clearance	In exit air lock before leaving level A area.	In treated munition collection bin in Level D area.	MTU use at BGCAPP would require permit change for use of current MTU discharge configuration.
Atmosphere in unit	Nitrogen in air locks and superheated steam in main chamber.	Air flowing from both ends of muffle to off-gas duct exit from muffle system.	Change in Kentucky permit would be required for use of MTU and SDU or autoclave.
Off-gas treatment system	Flame arrestor, cyclone, bulk oxidizer, venturi scrubber, and reheater.	Flame arrestor, filter media, bulk oxidizer, venturi scrubber, and reheater.	Same components, with different gas flow rates and sizes.
Method of heating	2 induction coils at 450 kW each plus 75 kW resistance heating for steam superheater.	Resistance heaters at 600 kW	None
Method of operation	Batch	Continuous	Would have to change from a batch stream to a continuous stream.
Char and tar buildup from secondary waste treatment	Expected, but the design allows for addressing tar and char buildup.	Secondary waste not processed in MTU.	Secondary waste not processed in MTU.
Method of control of atmosphere in main treatment unit	Doors and seals on air locks attached to main chamber.	Curtains on munitions cold feed end and cooling section exit of muffle.	Curtains on munitions cold feed end and cooling section exit of muffle.
Overall availability (percent of time the system will be operating)	83 percent estimated using spare MPT.	91 percent estimated for single MTU; no estimate given with spare MTU.	Both estimates based on using both treatment units.
Munitions throughput rates			
4.2-inch mortars	None for BGCAPP	~60/hr	
105-mm projectiles	None for BGCAPP	~60/hr	
155-mm projectiles	~40/hr	~40/hr	~40/hr
8-inch projectiles	~15/hr	None	MTU should be capable of modification to achieve BGCAPP 8-inch projectile processing rates.

[a] SDU, supplemental decontamination unit.
[b] EBH, energetics batch hydrolyzer.
[c] WCL, waste control limit.
[d] ABCDF, Aberdeen Chemical Agent Disposal Facility.
[e] MDB, munitions demilitarization building.

SOURCE: Adapted from BPBGT, 2007c.

1

Introduction

BACKGROUND

The United States has been actively destroying its chemical weapons stockpile since 1990. Originally, there were nine locations where the stockpile was stored. Johnston Atoll has completed the destruction of all its chemical weapons using the incineration process described below and has been closed since 2002. At four other sites—in the order of their coming online: Tooele, Utah; Anniston, Alabama; Pine Bluff, Arkansas; and Umatilla, Oregon—the agent and munitions are also being destroyed using incineration for the chemical agents and energetic materials. The metal parts are then decontaminated by being passed through a metal parts furnace where they are heated to 1000°F for more than 15 minutes before being released to the public sector. The large amounts of secondary waste that are generated during operations are treated onsite and sent to a commercial treatment, storage, and disposal facility.

Two sites, Aberdeen Proving Ground, Maryland, and Newport, Indiana, had only bulk chemical agents, and these were stored in 1-ton containers. Mustard agent (HD), the only chemical agent at Aberdeen Proving Ground, was destroyed by hydrolysis with hot water. Destruction operations at Aberdeen were completed in 2006, and the facility is now closed. At Newport, Indiana, nerve agent VX is being destroyed by hydrolysis with caustic solution.[1] The Newport hydrolysates, which are the products of the hydrolysis, are being sent to a commercial wastewater treatment facility to be reduced to environmentally acceptable materials. This action also serves to meet certain Chemical Warfare Convention treaty requirements. At both sites, the ton-containers were either decontaminated with steam or passed through a metal parts furnace.

In 1996, Congress mandated that the weapons at the two remaining sites, Blue Grass Army Depot (BGAD) in Kentucky and Pueblo Chemical Depot (PCD) in Colorado, would not be destroyed by incineration and that the Department of Defense (DOD) should demonstrate and select alternative methods (Public Law 104-208). In 1999, Congress also passed Public Law 105-261, which required that the Under Secretary "certify in writing to Congress" that the alternative technology would "be as safe and cost effective for disposing of assembled chemical munitions as is incineration of such munitions. . . ." The DOD initiated the Assembled Chemical Weapons Alternatives (ACWA) Program in response to the congressional mandate.[2] Because the selected alternatives at each site would be new applications of the technologies, the Army designated the facilities used to implement the alternatives as pilot plants. Thus, for BGAD the plant was designated the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP), and for PCD the plant was designated the Pueblo Chemical Agent Destruction Pilot Plant (PCAPP).

The stockpile at PCD consists of only mustard agent, the majority contained in about 800,000 artillery shells. The stockpile at BGAD includes three chemical agents: sarin (GB), mustard Levinstein agent (H), and the nerve agent VX. The highest-risk munitions are 80,000 M55 rockets containing either sarin or VX. These rockets contain approximately 8 pounds (3.6 kg) of agent and 20 pounds (9.1 kg) of a double base propellant composed of about 20 percent nitroglycerine and 80 percent nitrocellulose. The inventories at BGAD are shown in Table 1-1, and at PCD in Table 1-2.

After an extensive selection process, the Army chose hydrolysis with caustic solution (NaOH) as the primary means of destroying the chemical agents and the energetic materials at BGAD. Because the hydrolysates are still hazardous materials, they must be treated further by a second process before they can be released to the environment. Secondary treatment of the hydrolysate is also a stipulation of the Chemical Weapons Convention.[3] At PCAPP, the Army selected bioremediation to

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[1] This process is often called *neutralization*.

[2] In 1996 the DOD program was called the Assembled Chemical Weapons Assessment (ACWA) Program.

[3] The Chemical Weapons Convention was ratified by the U.S. Senate on April 24, 1997.

TABLE 1-1 Inventory of the Chemical Weapons in the Blue Grass Army Depot Stockpile

Item	Fill	Quantity	Agent per Munition (lb)	Total Agent (tons, rounded)	Energetics	Energetics Weight per Munition (lb)	Total Energetics Weight (tons, rounded)
155-mm projectile, M110	H	15,492	11.7	91	Tetrytol	0.41	3
8-inch projectile, M426	GB	3,977	14.4	29	None		
115-mm rocket, M55	GB	51,716	10.7	277	Composition B M28 propellant	3.2 19.1	74 449
115-mm rocket warhead, M56	GB	24	10.7	0.13	Composition B	3.2	0.035
155-mm projectile, M121/A1	VX	12,816	6	38	None		
115-mm rocket, M55	VX	17,733	10.1	89	Composition B M28 propellant	3.2 19.1	26 154
115-mm rocket warhead, M56	VX	6	10.1	0.03	Composition B	3.2	0.0086

SOURCE: Data adapted from the Munition Items Disposition Action System (MIDAS), provided to the Program Manager for Assembled Chemical Weapons Assessment by the MIDAS team, July 1997.

treat the hydrolysates from the mustard agent and the energetic materials. At BGCAPP, the Army selected supercritical water oxidation (SCWO) to treat the hydrolysate.

Contracts to design, build, operate, and close both facilities were awarded to Bechtel International teamed with Parsons Engineering. For PCAPP, Parsons is a subcontractor to Bechtel. For BGCAPP, Bechtel and Parsons formed a joint venture and are teamed as prime contractors. This team is frequently referred to as the Bechtel Parsons Blue Grass Team (BPBGT). The contractors tailored the specific design of each of the two facilities to the respective content of each site's stockpile. The original processes are described in two reports from the National Research Council (NRC) (NRC, 2005a,b), but these processes have since been modified and downsized because off-site disposal is now being used to dispose of noncontaminated waste. A simplified process flow diagram showing the feed streams for BGCAPP is provided in Figure 1-1.

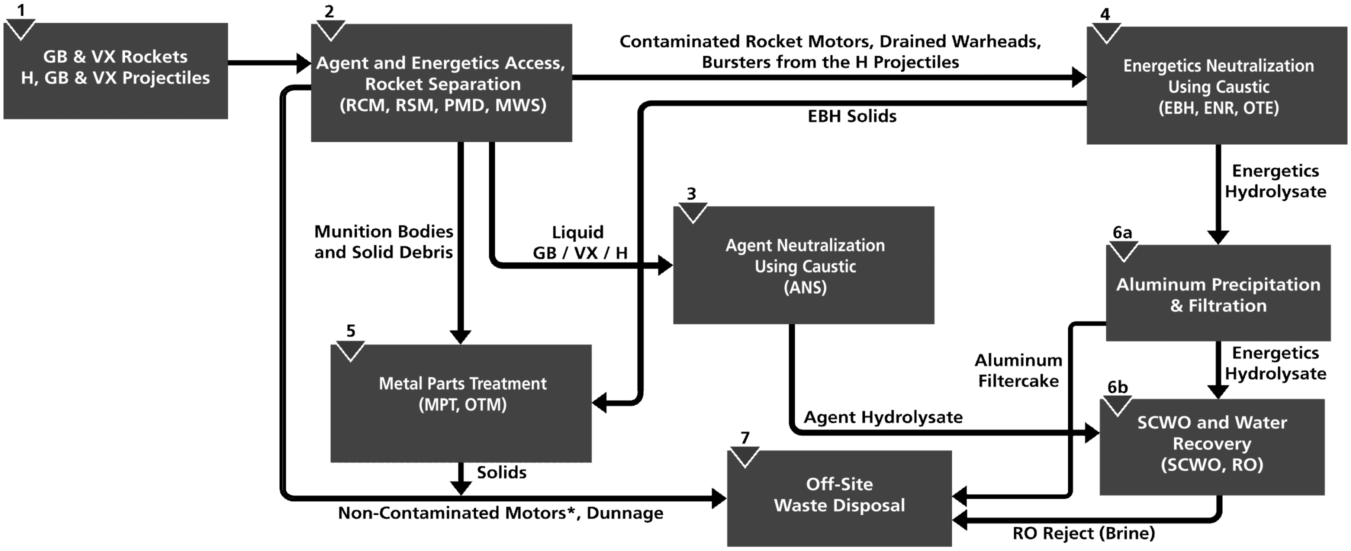
THE BGCAPP DESIGN AND THE METAL PARTS TREATER

The stockpile at BGAD consists only of rockets and projectiles. All munitions are stored on pallets in igloos, which

TABLE 1-2 Pueblo Chemical Depot Chemical Weapons Stockpile of HD- or HT-filled Munitions

Munition Type	Model No.	Chemical Fill	Energetics	Configuration	Number
105-mm cartridge	M60	1.4 kg HD	Burster: 0.12 kg tetrytol Fuze: M51A5 Propellant: M1	Unreconfigured: semi-fixed, complete projectile: includes fuze, burster. Propellant loaded in cartridge. Cartridges packed two per wooden box.	28,376
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.	355,043
155-mm projectile	M110	5.3 kg HD	0.19 kg tetrytol	Includes lifting plug and burster but no fuze. On pallets.	266,492
155-mm projectile	M104	5.3 kg HD	0.19 kg tetrytol	Includes lifting plug and burster but no fuze. On pallets.	33,062
4.2-inch mortar	M2A1	2.7 kg HD	0.064 kg tetrytol Propellant: M6	Includes propellant and ignition cartridge in a box.	76,722
4.2-inch mortar	M2	2.6 kg HT	0.064 kg tetrytol Propellant: M8	Includes propellant and ignition cartridge in a box.	20,384

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



RCM	Rocket Cutter Machine
RSM	Rocket Shear Machine
PMD	Projectile Mortar Disassembly
MWS	Munitions Washout System
EBH	Energetics Batch Hydrolyzer
ENR	Energetics Neutralization Reactor
ANS	Agent Neutralization System

MPT	Metal Parts Treater
OTM	Offgas Treatment System for MPT
OTE	Offgas Treatment System for EBH
SCWO	Supercritical Water Oxidation
RO	Reverse Osmosis
*	Non-contaminated rocket motor disposition still under review

FIGURE 1-1 Process flow diagram for the Blue Grass Chemical Agent Destruction Pilot Plant. SOURCE: Joseph Novad, Technical Director, Assembled Chemical Weapons Alternatives Program, "Assembled Chemical Weapons Alternatives Overview, ACWA Program," briefing to the committee, September 5, 2007.

are monitored to indicate any leakers. The leakers will be treated in a separate campaign. The BPBGT estimates that there will not be more than 200 leaking rockets, all containing GB. The munitions that do not leak will be handled and disassembled on two separate lines, one for rockets and one for projectiles.

After being unpacked from the pallets, the rockets are conveyed to the rocket-cutting machine in an explosives containment room. The rockets are cut while they are still in their firing tubes. The cut is indexed so that the rocket motor, including the M67 igniter (squib), is separated from the warhead, which still contains the agent. The rocket motors and firing tube segments will be sent off-site for processing. The rocket warhead is punched, drained of agent, and washed with a high-pressure water jet in the munitions washout system (MWS). After washing, the aluminum rocket bodies are sheared into segments. The warhead pieces (and any contaminated rocket motors treated during the leaker campaign) are conveyed to the energetics batch hydrolyzers (EBHs), where the aluminum casings dissolve in the caustic solution. The warhead pieces include the M417 fuzes. One portion of the fuze, the stab detonator, has two copper cylinders that are sealed with lacquer that does not dissolve in the caustic solution. Thus these detonators remain energetically active. The energetic hydrolysate containing aluminum in the form of sodium aluminate is sent to the aluminum filtration unit and then to the SCWO system for further treatment before being sent off-site for disposal.

After being unpacked from the pallets, the projectiles are conveyed to the projectile mortar disassembly (PMD) machine and the MWS. A robot then picks up a shell and places it at the first PMD machine station. The burster is removed from the burster tube. The projectile is moved to the next station, where the burster tube is dislocated and deformed. This is accomplished by punching into the casing so that access to the agent can be gained. The casing still containing the agent is moved to the MWS, where it is placed nose down to drain the agent. The interior is washed with a high-pressure water jet to remove any agent heels or crystals. The agent is sent to the agent neutralization system where it is hydrolyzed with caustic solution (sodium hydroxide). The projectile casings, burster tubes, fuze pieces including the unexploded detonator, and other miscellaneous metal parts are sent to the MPT for decontamination prior to release to the public-sector facilities for recycling.

In the MPT, the metal parts are heated to 1000°F for at least 15 minutes. This procedure is an Army-approved method for decontaminating any material before its release to the public sector. The MPT is also intended to treat contaminated secondary waste prior to off-site disposal. The MPT and its off-gas treatment system (OTM) are described in detail in Chapter 2.

The facility contractor is designing, constructing, and testing the MPT as a first-of-a-kind item at the Parsons facility in Kennewick, Washington. A three-quarter-scale version of the MPT, called the TRRP MPT in this report, is being used in the testing at the Parsons facility.

During testing, the TRRP MPT unit experienced recurring operating problems, such as mechanical failures and munitions bodies taking longer than expected to reach the necessary high temperatures as estimated by computer modeling. The program manager for ACWA asked the NRC to initiate a study to evaluate the current design and testing results and to advise on the adequacy of the design and the need for any future testing. The NRC formed the Committee to Review and Assess Developmental Issues Concerning the Metal Parts Treater Design for the Blue Grass Chemical Agent Destruction Pilot Plant to perform this evaluation. The committee's statement of task is given in the Preface of this report.

THE PCAPP DESIGN AND THE MUNITIONS TREATMENT UNIT

Originally the MPT was planned for use at both BGCAPP and PCAPP to decontaminate metal parts. The current PCAPP design now calls for a munitions treatment unit (MTU) to decontaminate projectile and mortar casings. The MTU is being designed by Abbott Furnace Company, St. Marys, Pennsylvania, a commercial firm that has extensive experience in the construction of high-temperature muffle furnaces for metal annealing and processing. The BGCAPP design still calls for two MPTs.

The committee was tasked with considering the MTU without actually evaluating it. The MTU is being used in the PCAPP design to treat all the projectile bodies. At PCAPP, neutralization followed by bioremediation will be used to destroy the munitions. The munitions will be transported to the explosives containment room, where they are unpacked. The propellant will be removed from the boxed 105-mm projectile cartridges and the boxed 4.2-inch mortar rounds. The 155-mm projectiles will be removed from their pallets. All munitions will be passed through the projectile/mortar disassembly machines. The lifting lugs, fuzes, and bursters are separated from the projectile bodies. These bodies still contain chemical agent sealed in the projectile body by the burster well. Noncontaminated energetics[4] will be sent off-site to an existing permitted disposal facility. At each major step in the disassembly process, the rounds will be monitored for agent vapor leaks. Any leakers (contaminated rounds) or munitions that cannot be opened safely (rejects) are placed into overpacks and sent to a unit that will use explosive destruction technology to destroy them without disassembly.

Rounds that do not require treatment in the explosive destruction unit mentioned above will be transported to the agent-processing building, where they enter the MWS. For projectiles, the burster well that seals in the chemical agent will be rammed into the body to gain access to the agent. For mortars, the base plate is cut off. In either case the agent is then drained out and a high-pressure water jet cleans any remaining solids from the body. The empty metal bodies are sent to the MTU, where they are heated to over 1000°F for 15 minutes.

The chemical agent is piped to the agent neutralization system, where it is treated with hot water to neutralize the agent. Caustic is added to raise the pH to 10-12. Biotreatment is selected for treating the agent hydrolysate at PCAPP.

SCOPE AND ORGANIZATION OF THE STUDY

The committee reviewed the design, testing, and thermal modeling of the MPT for BGCAPP. The committee was also briefed on the MTU to enable a comparison of the two units, to determine if any features of the MTU might be applicable at BGCAPP, and to discover whether an MTU could be applicable in the BGCAPP design. Discussions between the committee and the sponsor indicated that the committee was not charged with evaluating the MTU in detail, nor was it asked to consider the relative costs or schedules of the two systems or any issues related to permitting and public involvement.

This report presents a technical evaluation of the MPT and an evaluation of the technical feasibility of replacing the MPT with an MTU and supplemental decontamination units and autoclaves such as those being designed and tested for PCAPP.[5] The committee's task was limited to these two evaluations and precluded any decision to substitute the MTU for the MPT: such a decision can be made only after considering cost, permitting feasibility, and modifications to the design and the building, as well as the technology.

In Chapter 2, the MPT, its off-gas treatment system, and feed streams are described in detail and reviewed. Chapter 3 reviews testing results that have become available in the course of the MPT TRRP 05c tests. Chapter 4 addresses the modeling results and the longer-than-expected heat-up times of munitions casings in the MPT and the effect on the overall throughput rates. Chapter 5 reviews the applicability of the PCAPP MTU at BGCAPP. Finally, Chapter 6 presents the committee's general conclusions and recommendations.

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[4] Noncontaminated energetics are energetics taken from munitions that have had no detectable leak of agent and were not found to be leakers upon accessing the energetics. All energetics from munitions that are leakers are considered to be contaminated.

[5] The supplemental decontamination unit (SDU) and autoclave are both necessary with an MTU to destroy secondary waste.

2

Metal Parts Treater System

OVERVIEW

The Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) design will treat the metal parts and other waste in one of two metal parts treater (MPT) systems. Each of the two MPT systems consists of an MPT and its dedicated off-gas treatment system (OTM),[1] comprising a flameless thermal oxidizer and a cyclone. A venturi scrubber system cleans the gases coming from the cyclones. The MPT systems will be used to decontaminate the following:

- Washed projectile bodies and associated nose plugs from 8-in. GB (sarin) and 155-mm VX (nerve agent) and H (Levinstein mustard gas) projectiles,
- Solid materials (including undissolved fuze parts) remaining after rocket warhead processing in the BGCAPP energetics batch hydrolyzers (EBHs), and
- Agent-contaminated secondary and closure waste.

Decontamination will be accomplished by heating all of the materials to 1000°F for at least 15 minutes. For projectiles, the bodies and nose plugs are cleared for unrestricted release into the public domain. Solid materials from the EBHs and secondary and closure waste can then be released to an appropriate disposal site. Superheated steam at 1200°F serves as a sweep gas to remove gases and particulates generated by the heating of the metal parts and other materials in the MPT.

The MPTs are designated as first-of-a-kind equipment because they are unique, are being designed for this particular application, and have never been used in an actual process. A smaller-scale test unit[2] called the Technical Risk Reduction Program (TRRP) MPT was fabricated to demonstrate the operation of the MPT concept for the decontamination of metal parts and waste. Major equipment in each first-of-a-kind full-scale MPT system consists of an MPT, a first-of-a-kind bulk oxidizer (BOX) (more accurately called a flameless thermal oxidizer) and cyclone, and an electrically heated steam superheater, as shown in the simplified flow diagram in Figure 2-1.

The first-of-a-kind BOX and cyclone on each MPT are considered part of the dedicated off-gas treatment system. Major process equipment in the remainder of the OTM consists of a single venturi scrubber system and off-gas blower, as shown in Figure 2-2.

One MPT is expected to be sufficient for processing all projectile bodies. The second MPT will serve as a spare or backup and also will be used for the processing of EBH residues, secondary waste, and closure waste.

METAL PARTS TREATER

System Description

Each full-scale MPT consists of four sections: an inlet air lock, a main chamber, an outlet air lock, and a cooling chamber. Figure 2-3 shows the arrangement of the major elements of the MPT. The air locks, main chamber, and cooling chamber are provided with separate roller conveyor systems for moving racks containing washed projectiles or trays containing EBH solid waste and secondary and closure waste through the MPT. The air locks and the cooling chamber are equipped with doors that are moved up and down in structural frames using a screw drive. The main chamber inlet and outlet doors serve as the chamber interface with the inlet and outlet air locks.

Inlet and outlet air locks have mechanisms that are used to move trays and projectile racks in and out of each of the four MPT sections. Only the main chamber is heated. The inlet and outlet air locks and cooling chamber are not heated but will vary in temperature from ambient to higher

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[1] The Bechtel Parsons Blue Grass Team uses the acronym "OTM" to designate the off-gas treatment system attached to the MPT, and reserves the acronym "OTS" for other off-gas treatment systems in the design.

[2] The smaller-scale unit has a 4 ft 8 in. diameter compared with a 6 ft 6 in. diameter for the full-scale MPT.

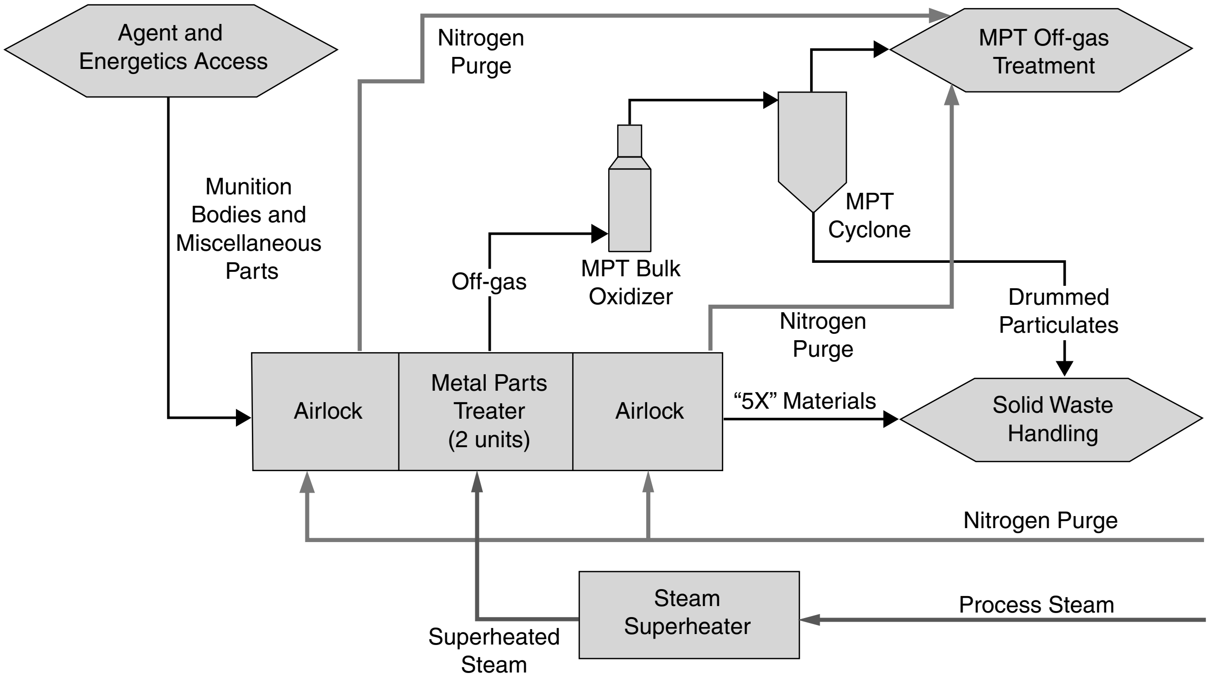

FIGURE 2-1 Simplified flow diagram of the metal parts treater system. SOURCE: Samuel Hariri, Process Design Lead, Bechtel Parsons Blue Grass Team, "Overview of the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) Process," presentation to the committee, September 5, 2007.

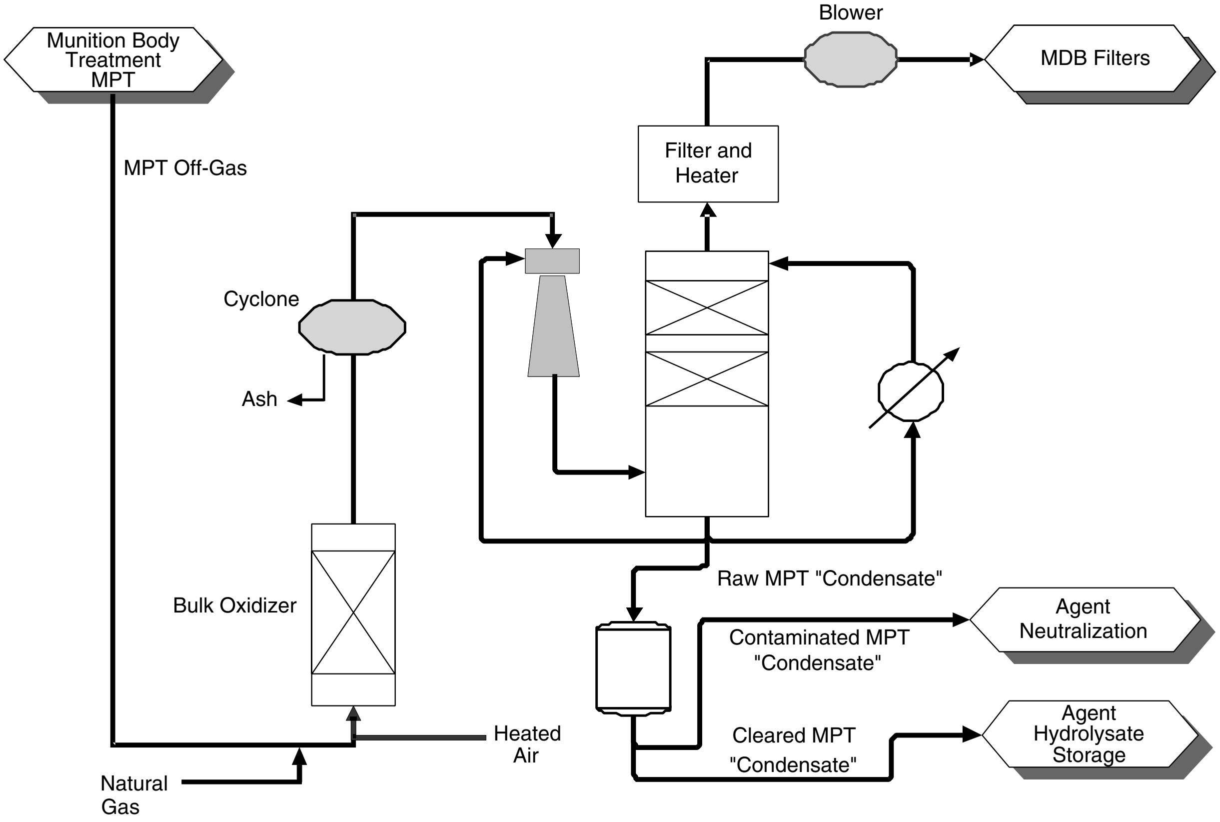

FIGURE 2-2 Current design of the off-gas treatment system for the metal parts treater. SOURCE: Samuel Hariri, Process Design Lead, Bechtel Parsons Blue Grass Team, "Overview of the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) Process," presentation to the committee, September 5, 2007.

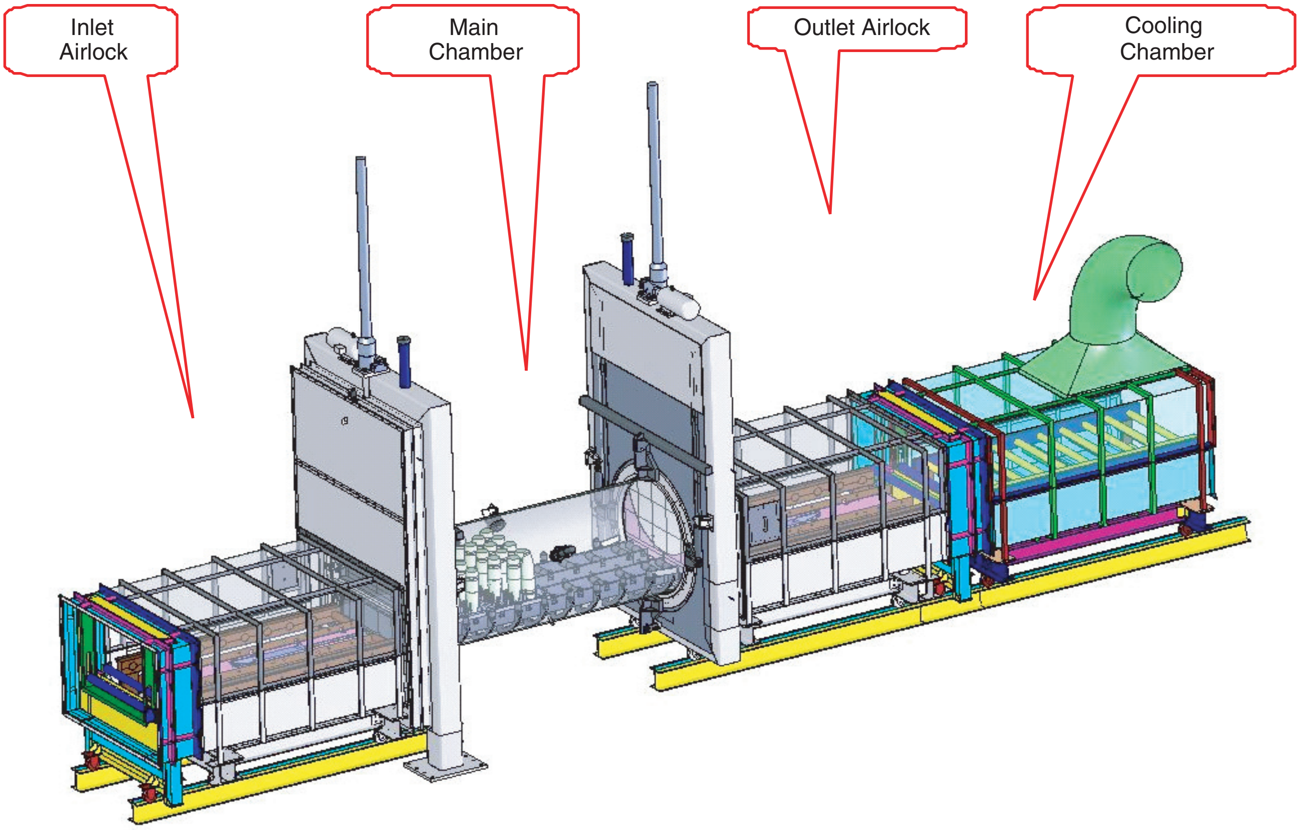

FIGURE 2-3 First-of-a-kind full-scale metal parts treater system. SOURCE: BPBGT, 2007b.

temperatures when air lock doors are opened and when heated trays are present. The air locks are provided with a nitrogen purge gas supply. Exhaust gas from the air locks flows to the MPT BOX unit. The main chamber is heated by two 300-kW water-cooled induction coils wrapped on the outside of the main chamber wall. Each coil heats one of the two zones in the main chamber. Gases generated by the heating of the projectiles or waste in the main chamber are swept from the chamber using low-pressure, superheated 1000 °F–1200°F steam generated by the electrically heated MPT steam superheater. The steam and gases flow out of the main chamber through a header in the top of the chamber to the BOX unit along with purge gases from the inlet and outlet air locks. Ducting for all gases flowing to the BOX is insulated and trace heated to prevent a condensation of tars. In the BOX, the combustible gases generated in the MPT are oxidized and then flow through a cyclone before being discharged to the downstream equipment of the OTM. Additional MPT system details are provided in the following discussion of MPT system operation.

System Operation

All agent-contaminated solid materials are fed to the MPTs in trays specifically designed to support the rapid and uniform heating of the materials. Because of the varying off-gas generation rates, the feeding of secondary waste, EBH residue, and projectiles into the MPT are controlled by software that, at any one time, allows the MPT main chamber to process only the same type of material in Zones 1 and 2. A *zone* is defined as a position within the main chamber where a tray is heated for a set period of time. Interlocks are provided to prevent the mixing of feed materials in the main chamber.

Before a tray is transferred into the MPT inlet air lock, the vent valve from the inlet air lock is closed, the air lock nitrogen purge valve remains open, and the main chamber in-gate remains closed. The MPT main chamber pressure is also lowered before the main chamber inlet gate, or in-gate, is opened. These actions minimize the intrusion of main chamber gases into the air lock. Gas flow generally is from the inlet air lock to the main chamber.

The inlet air lock in-gate is then opened and a tray is transferred into the inlet air lock; then the inlet air lock in-gate is closed. The air lock is continuously purged with nitrogen to reduce its atmosphere to below 3 percent oxygen. The estimated time to purge the inlet air lock is approximately 20 minutes. Because some air in-leakage from door seals is expected, the nitrogen purge is continuous. The inlet air lock is maintained at a negative atmospheric pressure of –0.25 in. water column with respect to the ambient room pressure during purging. At the same time, the pressure in the main chamber is maintained at –0.5 in. water column with respect to the MPT room by controlling the off-gas treatment system pressure. Thus, gas flow will be from the air lock to the main chamber.

After completing the purge, the air lock conveyor advances the tray to a latching position. A push-pull mechanism engages the tray at the latching position, the main chamber inlet gate is opened, and the tray is pushed onto the MPT main chamber roller conveyor. The main chamber in-gate is closed after the tray is moved into the main chamber. Then, the inlet air lock is purged with nitrogen gas to remove any gases that may have flowed from the main chamber to the inlet air lock when the in-gate was open. Purge gases from the air locks and main chamber flow to the MPT system BOX.

A loaded tray of projectiles or secondary waste is first heated in Zone 1 of the main chamber. In Zone 1, most combustible material (including agent and paint on projectiles) is vaporized and pyrolyzed. Some oxidation is expected owing to the oxygen in the air in-leakage during tray transfers and during operations. In the main chamber, vaporization and pyrolysis continue at a rate that minimizes major peaks in the amount of oxidizable material going to the BOX. The BOX is sized to treat up to 252 pounds per hour (lb/h) of products from pyrolysis and partial oxidation resulting from the air in-leakage. After approximately 1 hour in Zone 1, the tray is advanced to Zone 2. The tray will not be advanced to Zone 2 until the oxygen content in the chamber indicates that no further reaction is occurring. The preceding cycle is repeated when each new tray is loaded.

At the end of the required time in Zone 1, the main chamber in-gate is opened and a new tray in the inlet air lock is inserted into the main chamber by using the inlet air lock mechanism to push the tray in. This in turn pushes the other tray from Zone 1 into Zone 2. During normal operation, there will be trays in both Zones 1 and 2. Trays are heated in Zone 2 for 40 to 60 minutes. At the end of this time period, the oxygen in the outlet air lock atmosphere is reduced below 3 percent by being purged with nitrogen, and the main chamber pressure is reduced to below the outlet air lock pressure to minimize intrusion of the main chamber gases into the outlet air lock. Then the main chamber outlet door is opened, and a mechanism in the outlet air lock, which works with the powered roller conveyor in the outlet air lock, pulls the tray into the outlet air lock and the main chamber outlet door is closed.

Low-pressure superheated steam at a design flow rate of 250 lb/h between 1000°F and 1200°F is used as the sweep gas to remove the gases and vapors generated in the main chamber and for maintaining low oxygen concentrations in the main chamber. The superheated steam is fed into the bottom of the main chamber through a header designed to provide a uniform distribution of steam in the chamber.

Projectiles are normally processed on one MPT line, while waste containers are normally processed on the other MPT line. During the processing of secondary waste, the temperature of each zone in the main chamber can be controlled independently to minimize a rapid volatilization of the waste that would overload the associated BOX and the rest of the OTM. During secondary-waste processing, if the volatile organic compound (VOC) monitor in the outlet air lock indicates that VOCs are still being emitted, the tray must be backed into the main chamber's Zone 2. Therefore, Zone 2 remains empty until the tray in the MPT outlet air lock/conveyor is cleared.

Prototype Testing of the Metal Parts Treater Technology

The Bechtel Parsons Blue Grass Team (BPBGT) has conducted prototype testing of the MPT technology at the Parsons fabrication facility in Kennewick, Washington. The prototype, referred to as the TRRP MPT, is a three-quarter-scale version of the full-scale MPTs planned for BGCAPP. Figure 2-4 shows the arrangement of major elements of the TRRP MPT. The prototype testing demonstrated that the MPT can heat projectile bodies and secondary and closure waste to a temperature of 1000°F for 15 minutes. However, the testing was performed on surrogate materials.

The prototype testing, discussed in Chapter 3, identified design changes or improvements that will be incorporated into the full-scale MPT. It also provided data to test the validity of the computational fluid dynamics (CFD) model of heat transfer in the main chamber. The CFD model, discussed in Chapter 4, will be used to guide the final design of the full-scale MPT.

Besides scale-up from three-quarter to full-scale size, the other modifications from the prototype TRRP design that will be implemented in the full-scale design include the following:

1. *New designs for gate closure mechanisms and seals on the main chamber and air locks*. The closure mechanism in the TRRP unit abraded the seal material and caused excessive air in-leakage. The planned design is a cam type of closure mechanism in which downward vertical motion to the bottom of the gate seat is followed by lateral movement against the chamber or air lock face. This design is derived from other commercial applications, but it has not been tested under operating conditions. It is noted that the main chamber doors will be larger and heavier than in the prototype. The doors will have approximately a 6-ft-diameter opening and will weigh approximately 2 tons.
2. *Improved bearings for conveyor rollers in the main chamber and outlet air lock*. Bearing failures occurred during testing. A more robust bearing design has been identified for the full-scale design, as discussed in Chapter 3. It will include the capability for rapid change-out of bearings to accommodate the failure rate in actual operation.
3. *Improved superheated steam inlet header design to eliminate the shadowing of projectiles from radiant heat.*

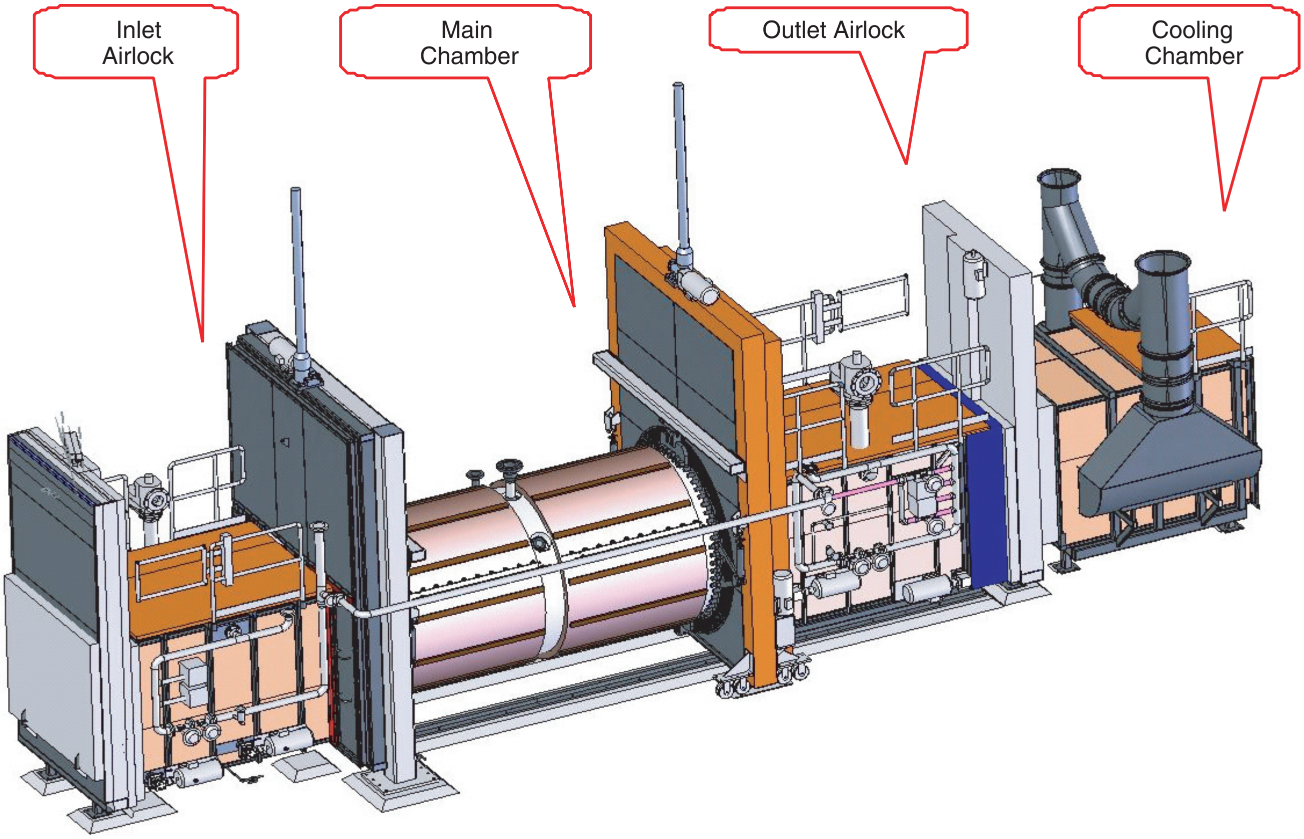

FIGURE 2-4 Technical Risk Reduction Program metal parts treater system (without staging conveyors, air lock doors, and cooling chamber). SOURCE: BPBGT, 2007b.

Computerized thermal modeling of heating in the main chamber and instrumentation of prototype test projectiles revealed places on the projectiles that were heating more slowly than other places. The BPBGT believes that the radiative shadowing by the prototype steam header was the primary cause of the slower heating by shadowing the radiant heat transfer from the main chamber walls. Because the prototype projectile trays also may have created some shadowing, the design of the trays for the full-scale MPT will be reviewed to minimize or prevent this effect. Both effects may have contributed to longer heat-up times than those predicted by the thermal modeling of the prototype tests. *Heat-up time* is defined as the time to achieve the 1000°F for 15 minutes criterion.

4. *Improved induction coil installation, including the shielding of parts of surrounding structures from stray current heating and providing improvements to prevent arcing.* Currently it is unclear if the induction heating coils will prevent maintenance from taking place on one MPT if the other MPT is still in operation. If this is true, some impact on processing availability may result, although it is not expected that simultaneous operation of both MPTs will be needed for much of the processing time.

5. *Improved design of secondary waste trays*. The design improvements included increasing tray capacity—for example, layering with space between the layers—and increasing the ease of removing treated waste. These test results were from a limited test period that involved limited amounts of surrogate materials, but they indicate that the tray designs for secondary waste are adequate. It is noted that the surrogate materials did not contain halogenated materials because of restrictions in the TRRP MPT operating permit. The BPBGT noted that there was little char and tar in the off-gas ducting from the main chamber. However, the short test period provided little chance for a buildup of char and tar deposits. Also, the presence of air in-leakage may have reduced tar and char production by partially oxidizing these materials. The BPBGT design team is providing clean-out access points, added insulation, and trace heating of off-gas ducting to the BOX unit to minimize the chance of depositing tars and chars during actual operation. The testing of EBH solid waste treatment was also demonstrated. However, because of permit limitations on TRRP MPT operations, the EBH surrogate waste materials did not include energetics, which will be present in the actual EBH waste. Therefore, possible popping of energetics and containment of resulting debris were not demonstrated.

Finding. It is unclear if the induction heating coils, or other issues, will prevent maintenance on one MPT if the other metal parts treater is operating.

Recommendation 2-1. The two MPTs should be positioned and isolated so that one MPT can be operated while the second undergoes maintenance.

These test results and proposed changes to the full-scale MPT were identified in the BPBGT presentation to the committee on September 6-7, 2007, and in the TRRP draft of the test report (BPBGT, 2007c).[3] While the prototype testing established a "proof of concept," it also pointed to significant design changes that would improve the operability of the MPT concept as noted above. These design changes are being implemented in the full-scale MPT design but will not have been successfully demonstrated until completion of acceptance testing at the Parsons fabrication facility.

Normal industrial practice would call for each full-scale MPT to undergo, at a minimum, electrical and control system testing and mechanical and thermal functional testing at the Parsons fabrication plant and then be disassembled, transported to BGCAPP, and reassembled to undergo systemization and final acceptance testing.

Finding. The full-scale MPTs, including their associated off-gas treatment system, will not be tested for complete operational performance until systemization. Testing of the prototype TRRP MPT cannot reliably predict these performance parameters for the full-scale MPTs and their off-gas treatment system.

Recommendation 2-2. The full-scale MPTs, with the associated off-gas treatment system, must undergo a complete set of acceptance tests which demonstrate that each unit will operate as planned and that the predicted thermal performance on both projectile and waste streams can be achieved.

Recommendation 2-3. The operating permit should be changed to allow MPT and off-gas treatment system testing with secondary waste, including halogenated waste, at rates expected during BGCAPP operation. This testing should be performed at the fabrication facility to provide quick turnaround on issues requiring changes in the full-scale MPT.

Recommendation 2-4. If permitting at the fabrication facility is not possible or if it would result in extraordinary schedule delays, the BPBGT should be provided time and resources to support acceptance testing of the MPT and associated off-gas treatment system at BGCAPP before the start of systemization.

Recommendation 2-5. The selection of metal and refractory materials exposed to the feed gas and off-gas for the BOX and other equipment in MPT off-gas treatment systems must be carefully assessed to ensure that they will provide reliable long-term operation, with adequate resistance to corrosion and other effects at operating conditions and under all anticipated transient conditions including shutdown and start-up.

OFF-GAS TREATMENT SYSTEM

System Description

The OTM consists of the first-of-a-kind BOX units and cyclones assigned to each MPT system and the venturi scrubber system that cleans the gases from the cyclones. The flow diagram in Figure 2-2 shows the complete OTM; Figure 2-5 shows the BOX unit that is connected to the MPT main chamber and air locks by ducting. The BPBGT has recognized the potential for char and tar deposition in the ducting and has provided design features including increased insulation of the off-gas ducting, trace heating of the ducting, and duct design to allow inspection and cleaning.

The gas discharges of the cyclones are combined in a common duct and then flow to the OTM venturi scrubber where the hot gases are quenched and then scrubbed in a packed column using a caustic solution. Each of the BOX-and-cyclone units is designed to receive and process vent gases from other process equipment as well as the MPT system. These vapors and gases come primarily from process vessel vapor spaces. Off-gas leaving the scrubber top passes through a demister, a cooler, and a reheater, and then to the OTM blower. The blower discharges into the munitions demilitarization building (MDB) heating, ventilation, and air conditioning (HVAC) ducting, connected to the BGCAPP carbon filters.

The first-of-a-kind BOX units, which are flameless thermal oxidizers, are designed to oxidize pyrolysis products, hydrocarbons, halogenated organics, carbon monoxide, and hydrogen. The resulting products of oxidation consist of hydrogen halides, chlorine, carbon dioxide, sulfur dioxide, phosphorus pentoxide, and water. Figure 2-5 shows the major elements of each BOX. The BOX is to be custom-designed by EPCON Industrial Systems, LP for the BGCAPP MPT systems and is a first-of-a-kind unit. It incorporates an air inlet with electrical air heater and process gas inlet chamber at the bottom where significant oxidation takes place. The gases at approximately 1900°F enter a 12-in.-deep structured ceramic matrix section where Epcon assumes that mixing takes place. The gases then enter a plenum section, which includes custom-designed natural gas lances. If sufficient heating value is not present in the process gases to heat the gases to 2000°F (or 2200°F for polychlorinated biphenyls), the natural gas lances introduce sufficient fuel to reach the required operating temperature. Above the natural gas lance section, the gases flow through a 6-in.-deep random ceramic

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[3] John Ursillo, Pasco Resident Engineer, Bechtel Parsons Blue Grass Team, "MPT Technical Risk Reduction Program (TRRP) Testing," presentation to the committee, September 5, 2007.

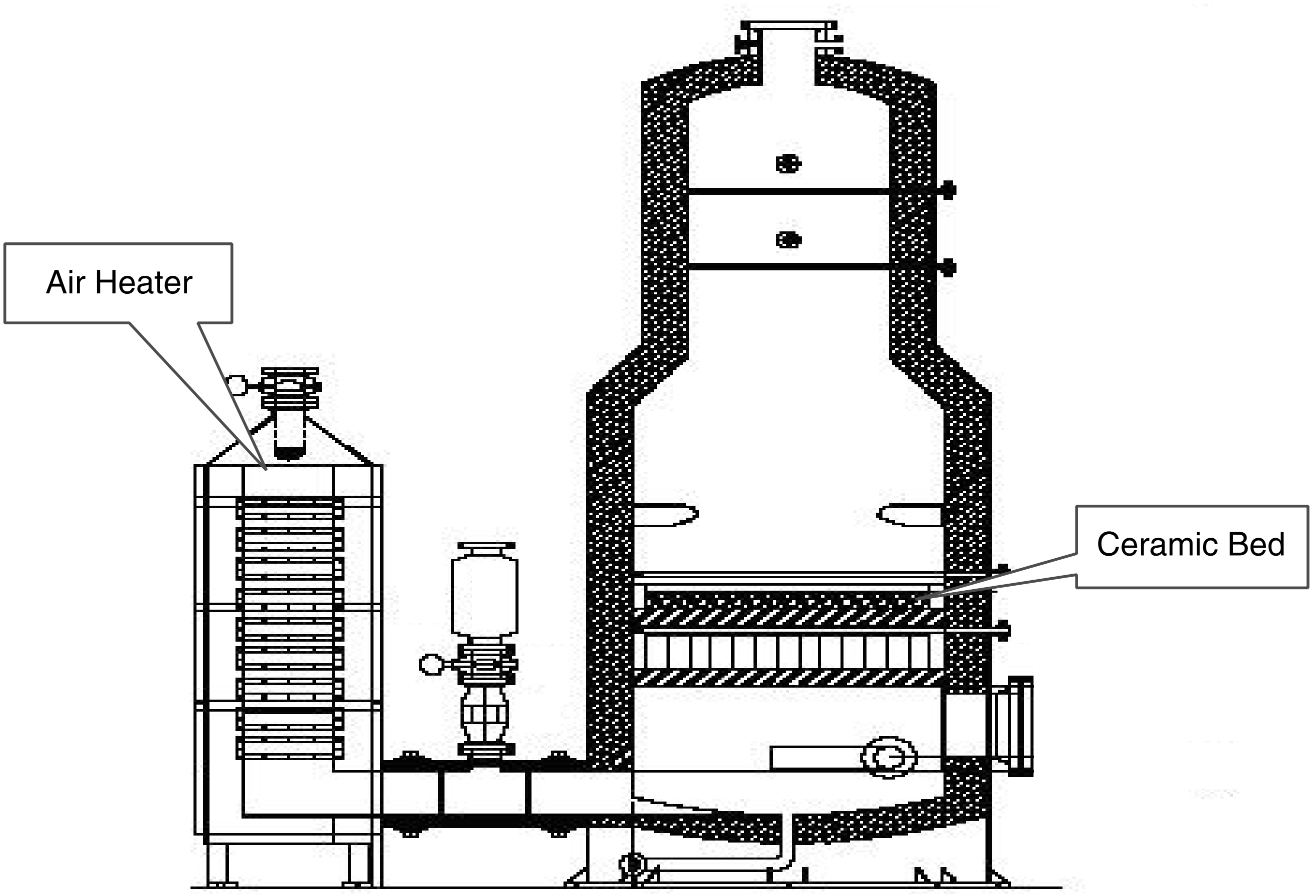

FIGURE 2-5 Bulk oxidizer in the off-gas treatment system for the metal parts treater.
SOURCE: Samuel Hariri, Process Design Lead, Bechtel Parsons Blue Grass Team, "Overview of the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) Process," presentation to the committee, September 5, 2007.

(saddles) section. The 2000°F or 2200°F gases then enter a residence chamber for 2 seconds, followed by an evaporative cooling section to cool the gases down to 1200°F prior to leaving the BOX.

Each BOX is followed by a cyclone unit for the removal of more than 90 percent of particulates smaller than 14 microns. These particulates may catalyze the formation of dioxins and furans and contaminate the downstream OTM equipment. These particulates would also increase the rate of sludge accumulation in the scrubber system. The collected cyclone particulates would be disposed of in an appropriate treatment, storage, and disposal facility.

Finding. The bulk oxidizer is considered first-of-a-kind equipment because it is custom-designed and its operation has not been demonstrated in any existing facilities. In addition, the ceramic structure matrix and the ceramic saddles selected for the bulk oxidizer typically are used at temperatures between 1600ºF and 1800ºF. There is little if any experience with EPCON Industrial Systems equipment when the structured matrix is operating at 1900ºF or when these saddles are operating in the 2000°F to 2200°F range.

Finding. It is difficult to predict the mixing of preheated air with the process gas to obtain uniform flow through the structured matrix and to predict the mixing of the 1900ºF gases with natural gas ahead of the saddles to minimize local hot spots and to ensure complete oxidation.

Recommendation 2-6. The natural gas lance section should be modeled by suitable three-dimensional computational fluid dynamics modeling and the design modified as required to ensure that good mixing takes place and that a uniform gas temperature profile is achieved before the gases reach the 6-in.-deep section of saddles.

Recommendation 2-7. Following the development of a three-dimensional model, a pilot test unit at least 6 ft^2 in cross section should be designed, built, and tested to demonstrate good mixing, uniform temperature profiles, and no deterioration of structured ceramic media at 1900ºF or ceramic saddles at 2200ºF prior to fabrication of the full-sized bulk oxidizer units. Performance of the air heating and natural gas system should also be demonstrated before the bulk oxidizer units are shipped to the BGCAPP.

System Operation

As previously discussed, the OTM consists of the two BOX-and-cyclone unit combinations, each one dedicated to an MPT, as well as the venturi scrubber system, which receives all process gases from the operating BOX-and-cyclone units, and a scrubber off-gas blower that discharges scrubbed and suitably dried off-gas to the MDB HVAC system. Vent gases from other tank and process vessel vapor spaces are combined with off-gas flowing to the BOX unit on an operating MPT. These vent gases flow from storage tank or process vessel vapor spaces in the agent neutralization system, agent collection system, spent decontamination solution, and energetics neutralization system (ENS). They include the following:

- Agent hydrolyzers,
- Spent decontamination holding/agent washout treatment tanks,
- An agent holding tank,
- An agent surge tank,
- Agent hydrolysate sampling tanks, and
- Energetics neutralization reactors.

These vent gases, which contain VOCs and water vapor, are combined in a single pipe or duct that is heated and insulated to prevent condensation before the gases enter the MPT ducting feeding a BOX unit. These gases are not sent to a BOX if the associated MPT is processing secondary waste. This restriction is intended to prevent the condensation of tars and chars in the MPT-to-BOX ducting. If neither BOX unit is available, that is, if both MPTs are shut down or only secondary waste is being processed, the vent gases flow directly to the venturi scrubber.

As process gases enter a BOX, the gases are combined with air heated by an electrical heater to 1500°F-1600°F. The combined gas stream then passes through the previously described ceramic media, and the process gases are oxidized. The ceramic media cross section is designed to provide a 2-second residence time, which is sufficient to decompose any residual agent or VOCs. Gas exits the ceramic media at 2000°F when the MPT processes projectiles. When processing gases are generated from contaminated wood and contaminated shipping and firing tubes in the MPT, the gases will leave the ceramic media at 2200°F. A minimum 2-second residence time is provided to ensure oxidation of any phencyclidines and polychlorinated biphenyls in the off-gas.

Normally, one of the BOX units is always onstream for processing vent gases from other process units. However, these vent gases may also be routed to the MDB HVAC. ENS off-gas may be diverted (under supervisory control) to the off-gas treatment system for the ENS. If both MPTs are required to process closure waste and the agent collection system, agent neutralization system, and ENS are down, the remaining vents from the spent-decontaminant tanks will be sent to the MDB HVAC.

As mentioned above, the MPT BOX uses natural gas as required during operation for supplemental heating to maintain an oxidized off-gas temperature of 2000°F or 2200°F. The amount of natural gas increases as the amount of oxidizable material in the process gas decreases. When vaporizing agent during the initial processing of projectiles or when processing secondary waste or closure waste, a water mist (using plant air) is provided in the lower oxidizing section in order to maintain its operating temperature at no higher than 1900°F. Fresh air to the BOX is preheated to 1550°F by an electrical air heater, which is part of the BOX unit. The fresh-air flow rate is regulated to achieve a 4.5 to 5.0 percent oxygen concentration, leaving the upper oxidizing section of the BOX during agent vaporization or during secondary waste processing. Flame arrestors are provided within the BOX package: two (one high-flow and one low-flow) in the process gas feed line to the BOX and one in the air line to prevent the possibility of flame propagation upstream. A process water mist (using plant air) is provided above the upper oxidizing section to cool the effluent stream to 1200°F before it enters the cyclone. A plant water line is provided as an emergency backup for the cooling section in the event that the process water supply fails.

Particulates are removed in the MPT cyclone. A motorized rotary valve is included at the cyclone solids discharge to allow periodic removal of solids. A BOX and its associated cyclone can be isolated from the venturi scrubber by closing isolation valves downstream of the cyclone.

After passing through the cyclones, the off-gas is sent to the venturi scrubber tower system common to both MPT systems. The venturi scrubber tower can process gases from either one or both cyclones. The venturi scrubber tower consists of two major components: a variable throat venturi quencher and a packed bed scrubber tower. The venturi scrubber tower will remove at least 99 percent of the hydrogen chloride, sulfur dioxide, and other acid gases (except carbon dioxide). The venturi scrubber is a typical gas-scrubbing system designed for acid gas streams.

The particulate removal efficiency of the venturi scrubber is 99 percent for particles that are 3.0 μ and larger and 90 percent for particles from 1.0 to 3.0 μ. The time to quench the gas to its wet bulb (adiabatic saturation) temperature in the venturi section is designed to not exceed 0.3 second based on instantaneous maximum flow rate into the venturi. The rapid quenching minimizes the formation of dioxins and furans. The venturi incorporates a variable throat to maintain a constant pressure differential and achieve high particulate collection efficiency over a wide range of inlet gas flow rates. The throat of the venturi can be automatically adjusted by moving a slide gate with a fast-response stepping motor. A recycled stream of quench brine from the scrubber bottoms quenches the gas in the venturi. A solution of 18 weight percent sodium hydroxide is added to the venturi quench brine to maintain the condensate stream at a pH of approximately 9.0 (8.0 to 9.5) to ensure that the acid gases in the vapor feed are neutralized and to reduce corrosion.

Separated liquid leaving the venturi drains by gravity to the scrubber bottom where a sump provides storage and surge capacity for the recirculation pump. Condensate from the scrubber section above the venturi inlet to the tower is added to the sump through the scrubber recirculation pump discharge line to make up for the flash evaporation that occurs in the venturi quencher. Process water can be added as additional makeup. Excess scrubber bottoms are sent to the energetics hydrolysate storage tanks or to the spent decontamination-solution storage tank.

The scrubber tower is based on commercial designs and includes a chimney tray, a packed bed, and a mist eliminator pad. The recirculated scrubber solution is cooled to maintain the scrubber exit gas temperature at 100°F or less. A crinkled Hastelloy C® (or equivalent) wire mesh mist eliminator pad is provided above the scrubber liquid distributors for the packed bed to remove large mist droplets in the gas leaving the scrubber tower. The gases exiting the scrubber are heated in an air reheater to 95°F to prevent condensed liquids from entering the blower and to reduce the relative humidity of the blower discharge as it is fed via the ducting to the MDB HVAC carbon filters.

The scrubber gas discharge blower provides an induced draft for proper operation of the OTM and in turn for removing gases from the MPT main chamber and air locks. The blower has a variable frequency drive to accommodate variable off-gas flows during MPT operations. Key components in the OTM, particularly the pumps and blower, will be provided with installed spares to give added assurance of high reliability.

Finding. Except for the first-of-a-kind bulk oxidizer units, the off-gas treatment for the MPT uses design concepts found in commercial, high-reliability, off-gas cleanup systems. The venturi scrubber design is a mature technology.

3

Assessment of Metal Parts Treater Testing Activities

The metal parts treater (MPT) concept has been subjected to testing by the Bechtel Parsons Blue Grass Team (BPBGT) in Technical Risk Reduction Programs (TRRPs) for the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP), with most of the pertinent testing conducted under TRRP 05c. (See Box 3-1.) This testing has used a three-quarter-scale version of the MPT, designated as the TRRP MPT.

The testing objectives as given in the Bechtel TRRP 05c test plan were as follows (BPBGT, 2007d):

- Demonstrate reliable mechanical performance of all parts and functions of the MPT design, including seals, doors, bearings, and projectile jamming.
- Demonstrate BGCAPP-specific design improvements such as: projectile orientation, steam-injection orientation, gas take-off orientation, and tray design to improve heat-up.
- Calibrate the computational fluid dynamics (CFD) model of the test unit on VX 155-mm projectiles to serve as a basis for first-of-a-kind (FOAK) full-scale unit modeling. Inherent in this objective is the necessary demonstration that the MPT can heat all parts of materials fed to it to 1000°F for at least 15 minutes at a rate that meets expected feed rates during operation.
- Demonstrate treatment of simulated energetics batch hydrolyzer (EBH) rocket warhead debris.
- Demonstrate limited secondary-waste treatment options to gather data for further effort with the CFD model.
- Perform test runs and cycles of components to make observations of critical design parameters that apply to the FOAK unit under design—particularly those that affect the risk of scale-up to the full-scale unit. These include, but are not limited to, projectile paint debris generation and accumulation, thermal expansion stresses and deformation points, interferences, Gaussian field measurements and localized heating effects, and wall temperature distribution.

The TRRP MPT testing used an off-gas treatment system that included a catalytic oxidizer (CATOX) unit rather than a bulk oxidizer (BOX) unit that will be used for the full-scale MPT and did not include the venturi scrubber. The CATOX unit had a processing rate of 30 pounds per hour (lb/h) of oxidizable gases. The BOX is being designed to process up to 252 lb/h of oxidizable gases. Thus the flow of off-gas from the MPT enclosures was demonstrated, but not the OTM configuration, the maximum gas flow rates, or equipment that will be provided for the full-scale MPT. The OTM BOX unit is also considered to be a first-of-a-kind system, as mentioned in Chapter 2.

TRRP MPT testing was performed using surrogates of all munitions metal parts and waste feed streams anticipated for the two BGCAPP full-scale MPTs except halogenated waste and energetics batch hydrolyzer (EBH) waste containing energetic materials. All feed streams were tested. However, the BPBGT terminated the waste stream testing before the completion of all planned tests because it was felt that sufficient data to design the full-scale MPT had been obtained.

This committee has chosen to group the TRRP MPT test results into three areas for review and evaluation. They are (1) mechanical issues, (2) secondary and closure waste issues, and (3) results of thermal testing and thermal modeling. A discussion of results obtained and required future testing for the first two issues follows, and issue 3 is discussed in Chapter 4.

MECHANICAL ISSUES

The following is a discussion of key mechanical issues identified in the TRRP MPT testing.

New Door Closure Mechanism and Seals

Difficulties with getting an acceptably tight closure on the air lock and main chamber doors for the TRRP MPT have resulted in a change in the design of the door closure mechanism and seals for the full-scale MPT. Instead of the

J-type sliding closure mechanism used on the TRRP MPT, the door for the full-scale MPT will be moved against the closure face by using a two-direction cam design recommended by a commercial oven contractor. To close a door, this design moves the door vertically downward with a mechanical screw drive to its bottom position, and the door is then moved horizontally against the closure face. In addition, the seal material design has been altered to give the equivalent of two gaskets between the door and closure face. A prototype of this new arrangement has been developed and tested, but not under the expected operating conditions. Changes were also made in the structural support for the door closure and main chamber to make it easier to get a good seal. It is noted that all of this testing was done with doors for a 4-ft.-8-in.-diameter chamber and that the full-scale MPT will use a 6-ft.-6 in.-diameter main chamber.

Finding. The larger size of the full-scale MPT doors will pose additional challenges in maintaining seal face alignment and minimizing air in-leakage during operation.

Finding. The new closure mechanisms for the four doors on the full-scale MPT have not been tested at operating conditions.

Recommendation 3-1. The new closure mechanisms for the full-scale MPT should be tested and cycled at operating conditions at the fabrication facility prior to systemization.

Bearings for the Conveyor Rollers

The Graphalloy® bearings for the conveyor rollers in the main chamber experienced galling and other wear failures during TRRP testing.[1] The bearing failures were attributed to oxidation/corrosion at the main chamber operating temperature. Three different bearing materials were evaluated: "improved" Graphalloy®, Stellite, and Deva (Deva-Mogul sintered metal). The Stellite and Deva bearings are more expensive than Graphalloy® bearings, and the Deva bearings are produced by a foreign manufacturer. The Stellite bearings exhibited surface galling and friction at temperature, causing the bearings to come loose from their mountings and interfere with the trays. All materials experienced wear. The BPBGT concluded that the "improved" Graphalloy® bearings were acceptable, although they exhibited some pitting. The BPBGT also developed a bearing-mounting design that allows for quick replacement of the bearings. The ton-container MPT used at the Newport Chemical Destruction Facility, Indiana, has experienced similar bearing failures, and a repair and replacement approach was adopted.[2] During full-scale MPT testing, the BPBGT intends to reconsider Stellite bearings that are interchangeable with the Graphalloy® bearings. The BPBGT believes that it has identified an acceptable path forward for resolving the problem of premature main chamber conveyor bearing failures. However, replacing the bearing mounts will require cooling the unit and reheating. Excessive temperature cycling could cause metal fatigue. The BPBGT has also developed maintenance protocols that shorten replacement times for bearings as much as possible.

Finding. The proposed conveyor bearing selection and replacement approach is appropriate, but actual demonstration of reliable performance has yet to be achieved. If bearing replacement is required more frequently than anticipated, it could reduce the MPT throughput rate.

Recommendation 3-2. The proposed approach for the replacement of conveyor bearings should be tested in conjunction with the testing of the full-scale MPT at operating temperature and design with tray loading at the fabrication facility.

Heating Zones

The full-scale MPT will use two heating zones in the main chamber. Each will be capable of 450 kW of induction heating. The TRRP MPT used one 600-kW induction heater. It is unclear whether maintenance on one MPT would be possible while the other was in operation. If not, when one MPT required in-room maintenance, it could not be repaired until the second MPT was shut down. It would reduce the availability of the MPTs if both had to be shut down when either required in-room maintenance.

Finding. It is unclear that heat and magnetic fields generated by one MPT would allow maintenance on the second unit while the first was in operation.

Recommendation 3-3. The BPBGT should consider providing suitable spacing and electromagnetic and thermal shielding to allow maintenance on one unit while the other is operating.

TRRP testing and computational fluid dynamics (CFD) modeling showed that certain areas of some projectiles being heated in the main chamber were heating more slowly than most parts of the projectiles. This slower heating required longer heat-up times to achieve the 1000°F for 15 minutes for all projectiles. After its review of the chamber design, the BPBGT concluded that the slow heating resulted from "shadowing" of parts of the projectiles during the radiant heating process.

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[1] John Ursillo, Pasco Resident Engineer, Bechtel Parsons Blue Grass Team, "MPT Technical Risk Reduction Program (TRRP) Testing," presentation to the committee, September 5, 2007.

[2] Question-and-answer session with BPBGT personnel and the committee, September 6, 2007.

BOX 3-1
The Technical Risk Reduction Program (TRRP) 05c Heat Transfer Test

The TRRP #05c Heat Transfer test will be performed in accordance with Appendix R of the BGCAPP Design-Build Plan, using the minimum equipment arrangement and testing material (at the Parsons Technology Development and Fabrication Complex) necessary to accomplish the objectives outlined within this Test Protocol and the corresponding Test Plan (to be developed as a follow-on to this protocol). As currently recognized, the overall test program objectives for resolution of the issues identified are described below.

1. Demonstrate design fixes to the PCAPP MPT Test Unit such as: seals, doors, bearings, projectile jamming, etc. as identified in the overall study protocol and the various reports and recommendations emanating from that effort.
2. Demonstrate BGCAPP-specific design improvements such as: effect of projectile orientation, steam injection orientation, gas take-off orientation, tray design to improve heatup. Calibrate the CFD Model of the test Unit on VX 155 mm projectiles to serve as a basis for FOAK full scale unit modeling.
3. Demonstrate treatment of simulated EBH rocket warhead debris.
4. Demonstrate limited Secondary Waste treatment options to gather data for further effort with the CFD Model.
5. Perform test runs and cycles of components to make observations of critical design parameters that apply to the FOAK unit under design—particularly those that affect the risk of scale-up to the full scale unit. These include, but are not limited to: projectile paint debris generation and accumulation, thermal expansion stresses and deformation points, interferences, Gaussian field measurements and localized heating effects, wall temperature distribution, etc.
6. Major Test Acceptance Criteria

The following test results are considered acceptable (Note: see test matrix acceptance criteria for specific values):

1. Objective 1:
a. Heat rate testing will be acceptable if 5X treatment is achieved as measured by temperature indicating for devices or paints (dosimeters, thermal indicating paints, thermocouples, optical pyrometer, etc.) values of at least 1000 degrees F for 15 minutes; with "coldest spot" thermal treatment duration times under 90 minutes this yields an overall tray duration of 105 minutes. This timing may be adjusted based on further CFD modeling underway for the new tray design and under-tray steam distribution header.
b. New door structure travels without binding, operates smoothly with cycle times of no more than 60 seconds to open and 60 seconds to close. Actuating mechanism is not unacceptably heated or mechanically stressed. Two-axis door operating motion remains trouble free and the door seats to the main chamber with no fit issues.

The shadowing is being addressed by redesign of the projectile trays, the superheated steam inlet header, and the off-gas outlet header. The choice of mounting projectiles nose up or nose down in the trays is still a concern for full-scale MPT projectile trays. The BPBGT intends to resolve this issue by further analysis using the full-scale CFD model results (see Chapter 4).

Finding. The proposed redesigns for the projectile trays and headers to reduce "shadowing" of parts of the projectiles are appropriate. (See Chapter 4 for further information and support.)

Recommendation 3-4. The proposed header and tray redesigns to reduce "shadowing" of parts of the projectiles should be tested at the full-scale MPT operating conditions at the fabrication facility.

SECONDARY AND CLOSURE WASTE TREATMENT

Pyrolysis testing of secondary waste simulants was carried out at Hazen Research Inc. (HRI, 2005). This was followed by MPT TRRP testing of secondary waste treatment at the Parsons facility in Kennewick, Washington, in 2007.

Waste to Be Treated in the MPT

A flow diagram of the BGCAPP waste treatment system is provided in Figure 1-1 in Chapter 1. Waste to be treated in the MPT includes the washed munitions bodies from the munitions washout system (MWS), solid residues from the EBH, and secondary and closure waste. Estimated secondary waste generation and MPT processing rates for BGCAPP are given in Table 3-1.

Table 3-1 shows the waste streams in generic form: metal waste, butyls, PVCs, sludge, wood, and so on. Specific

c. Main Chamber seal is tight and sufficiently contributes to maintaining the oxygen content in the MPT under 3 % after the appropriate purge cycle is completed. The seal remains in place and intact with no pulling loose, damage or visible misalignment. Face plate and flange heat warpage is minimal (i.e. does not affect the ability of the door seals to function. Helium leak testing devices will be in place to accomplish seal integrity tests.)
d. Conveyor bearings enable free rolling tray with full set of projectiles evenly with no visible binding or excessive wear or deformation (i.e., upon post-test disassembly, close inspection yields little or no evidence of galling, pitting, bearing material degradation, etc.).

2. Objective 2:
a. The Test Unit will perform as predicted by the CFD model within experimental accuracy.
b. Nose up (PCAPP TRRP mode) and nose down (BGCAPP mode) projectile-loaded tray heat up times, in particular the so-called “cold spots” on predicted munition locations will perform as predicted within experimental accuracy; i.e. the location and times of the hotter munitions and the colder munitions are consistent with the CFD model.
c. Projectiles will remain free in their tray locations and capable of ready removal after treatment.
d. Alternative steam injection and main chamber gas removal orientation designed to mimic the FOAK unit installation will conform to the CFD model’s predicted “cold spot” heatup improvement effects and not degrade system performance.

3. Objective 3:
a. Miscellaneous metal parts originating from the EBH treatment of rocket warheads will reach 1000 degrees F for a minimum of 15 minutes within an MPT main chamber thermal treatment duration under 90 minutes. Although this is not an EBH-pacing cycle time.

4. Objective 4:
a. The limited secondary waste testing will be considered successful if design data can be obtained from the tray types, surrogate wastes, and heating profiles (low and high) to support further testing with actual secondary waste materials during plant systemization. Design data will consist of information and observations on the efficacy of different tray configurations, debris/particulate generation, treated waste consistency, etc.
b. Data on heat transfer through various materials and loading configurations will be obtained to support CFD modeling.

5. Objective 5:
a. Success criteria for this objective is to gather enough information during the short testing time available to help reduce the risk that the FOAK unit will have either major design flaws or a reduced throughput when it is tested during the Factory Acceptance Testing at the end of its fabrication. The quantity and type of information that will satisfy this criteria is subjective.

SOURCE: BPBGT, 2007d.

waste streams that are expected to be treated using MPTs are the following:

- Solid residue from the EBHs, a stream that includes metal parts and elastomeric material, M2 squib booster assembly, segments of the shipping and firing tubes, and steel parts from the sheared rocket propellant sections of contaminated rockets. The M2 squibs are heat-sealed in polyethylene. These components are not decomposed in the EBH and must be “popped” within the MPT.[3]
- Nose closures from projectiles.
- Personal protective equipment and other plastic and rubber items.
- Agent-contaminated wood.
- Other secondary waste that may be generated during operation, including miscellaneous metal parts, contaminated metal straps from the enhanced on-site containers, metal-reinforced hoses, metal piping, valves, and tools generated during facility operation.
- Other secondary waste that may be generated during closure, including solid residues, building components, and appurtenances.

For several of the secondary waste categories above, agent-contaminated waste will be treated by chemical decontamination. When chemical decontamination does not prove successful (e.g., for agent-contaminated pallets), such waste will be treated in the MPT before off-site disposal. Secondary waste that is not agent-contaminated is not expected to be processed through the MPT (BPBG, 2004).

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[3] The rocket motor sections also include a squib in the M67 motor assembly. During normal operation these squibs are removed with the motor section and sent off-site. However, during the leaker campaign they will also be sent to the EBH and then to the MPT where they are destroyed.

TABLE 3-1 Solid Waste Generation and Processing Rate in the Metal Parts Treater

Type of Waste	Waste Creation During Operations (lb/week)	Required MPT Processing Rate (lb/week)[a]	Processing Time Needed (hours/week)
Metals[b]	698	2,598[c]	1.0
Butyls	104	25.5	4.1
PVCs[d]	762	100	7.6
Sludge	373	232	1.6
Wood	214	81	2.6
Total	2,151		

[a] As given in BPBG, 2006a.
[b] All metal waste can be processed in a single tray over a 1-hour period.
[c] Weight of GB projectile bodies within a tray and is given for comparison only.
[d] PVC, polyvinylchloride.

SOURCE: Adapted from Sam Hariri, Process Design Lead, Bechtel Parsons Blue Grass Team, "Thermal Modeling to Support OTM Design," presentation to the committee, September 5, 2007.

Pyrolysis Testing of Secondary Waste Simulants

A bench-scale test program was carried out at Hazen Research Inc. in 2005 using a muffle furnace. Four materials were subjected to pyrolysis: polytetrafluoroethylene (PTFE), butyl rubber, polyvinylchloride (PVC), and wood. These materials were obtained in the form of PTFE sample line tubing, butyl rubber boots with steel toes, PVC Lab Safety Supply (LSS) hose, and pallet wood. Butyl rubber boot material with no steel was also tested. Activated carbon was not tested because it is expected that this material will be treated off-site. One objective was to obtain information on gas generation during pyrolysis to confirm the design of the OTM. Another objective was to view the physical form of the solid residues from pyrolysis. The test materials were pyrolyzed under a nitrogen and steam atmosphere. Sample weight loss was recorded as a function of temperature as the temperature was increased to 1200°F. A summary of results is shown in Table 3-2.

The amount of gas generated during heating to 1200°F ranged from 0.413 g of gas per gram of starting sample material for PVC hose to 1.00 g of gas per gram of starting sample material for PTFE. This information is useful for confirming the design of the BOX and associated equipment. Visually, the wood sample and the PVC LSS hose had shrunk in size during treatment, but were intact. The butyl rubber boot material had crumbled. As would be expected from the gas generation results, the PTFE tubing had essentially disappeared.

TABLE 3-2 Summary of Results from Secondary Waste Testing Carried Out in 2005

	Material Tested at 1200°F			
Stream	PVC[a] Hose	Wood	PTFE[b]	Rubber
Feed, g	68.5	60.7	51.6	64.0
Residue, g	40.2	11.4	0.0	23.8
Weight change (loss to gas phase), g	28.3	49.3	51.6	40.2
Gas generated, g gas/g feed	0.413	0.842	1.00	0.628

[a] PVC, polyvinylchloride.
[b] PTFE, polytetrafluoroethylene.

SOURCE: Sam Hariri, Process Design Lead, Bechtel Parsons Blue Grass Team, "Thermal Modeling to Support OTM Design," presentation to the committee, September 5, 2007.

Technical Risk Reduction Program Testing of MPT Treatment of Secondary Waste

TRRP testing of secondary waste treatment in the MPT was conducted at the Parsons fabrication facility in Kennewick, Washington, May 15-31, 2007. Three issues were identified for evaluation in the testing:[4]

- *Solid waste processing characteristics and rates:* In coordination with the process and operations groups, establish the criteria and throughput processing rates for secondary waste and miscellaneous metal parts.
- *Real-time volatile organic compound (VOC) monitors:* Investigate and provide recommendations on the need for a real-time VOC or total organic carbon analyzer system for the MPT and OTM to mitigate OTM overload.
- *Duct plugging:* Investigate and provide recommendations on methods to mitigate the potential for downstream component plugging.

One issue that is still being addressed by the BPBGT is the thermal destruction of the fuze detonators in the EBH waste stream. According to the TRRP test plan, approximately 360 of these items are produced from each EBH discharge. It is currently planned to send this waste to the MPT; however, the method of controlling the energetic releases in the MPT has not been identified. If not addressed properly, these releases could result in greatly increased maintenance requirements and possible damage to the MPT. A separate study is underway to investigate the potential effect of energetics remaining in the EBH debris as fuze remnants (BPBGT, 2007b).

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[4] Samuel Hariri, Process Design Lead, Bechtel Parsons Blue Grass Team, "Thermal Modeling to Support OTM Design," presentation to the committee, September 5, 2007.

The simulated waste materials that were treated in the MPT were these:

- Actual butyl rubber toxic agent protective gear: M3 suits, aprons, boots, gloves;
- Surrogate demilitarization protective ensemble material (30 mil poly sheet) and poly drum liners;
- Ethylene propylene diene monomer chemical hose (non-PVC [LSS] air hose surrogate);
- Spill pillows saturated with ethylene glycol (hydraulic fluid stimulant);
- Simulated EBH rocket warhead debris (fuze mock-ups, cut-to-length steel tubes, poly tube);
- Scrap piping components (large dense valves and pipe); and
- Simulated equipment test hardware rocket shipping and firing tube sections and cut aluminum rocket bulkheads from the rocket-cutting machine TRRP.

Waste was fed on mini-waste incineration container (mini-WIC) trays, half the length but otherwise identical to the baseline-design WICs. WIC trays were "stacked" using fabricated tray inserts to test the concept of "double-decking."

The testing at Kennewick was limited to nonhalogenated materials and did not include EBH energetic materials because of permitting considerations. Waste feeds were limited to 20 lb of organic constituents per tray since the CATOX capacity was equivalent to the VOC loading from 30 lb/h of waste.

The results indicated the following:[5]

- Chamber oxygen content consistently fell from the initial value at tray insertion to less than detectable (<0.01 percent) within minutes after tray insertion. The process logic controller, which recorded O_2 levels to 0.0001 percent, indicated that the O_2 level continued to drop, stabilized, and eventually rose rapidly back above the 0.01 percent level. This duration was generally on the order of 60 minutes.[6]
- The BPBGT pyrolysis study concluded that VOC/total organic carbon monitors are not appropriate for determining the completion of pyrolysis when treating organic-containing materials such as secondary waste (BPBGT, 2007d).
- The off-gas treatment CATOX experienced temperature rises that exceeded the CATOX operating limits. The temperature spikes varied for different types of waste. This was not considered a concern by the committee because the full-scale BOX has a higher temperature rating.
- Sharp, but low-level, spikes of VOCs and carbon monoxide were measured in the outlet air lock. These spikes are believed to be contributors to the rises in CATOX noted in the preceding observation and are not considered a concern for the BOX unit. Also, since nitrogen purge is used in the outlet air lock, ignition of these materials did not occur.
- Wood and cotton cloth waste did not flame when the tray was removed. Most treated waste appeared reduced to nonorganic constituents and was readily removed from the WIC by vacuum or brush and pan.
- The mini-WICs showed very little thermal deformation.
- All dosimeters indicated that treatment at 1000°F for 15 minutes was met within the 120-minute standard residence time. Oxygen level response indicated that all organic material was gone after 75 minutes.
- Remaining issues of concern included steam flow into the air locks immediately on door opening, and smoking of some types of waste shortly after the tray was placed in the chamber.
- Estimated weekly secondary waste processing rates were developed using an ASPEN[7] model, projecting BGCAPP waste generation rates to estimate weekly process time anticipated in the MPT.
- Inspection of duct interiors during disassembly of the off-gas treatment system showed no buildup of tars or chars that would be indicative of full-scale operational cleanout or downtime issues. However, the amount and rate of surrogate material processed was much lower than will be experienced in the full-scale MPT.

Finding. The range of secondary waste materials tested was limited in comparison to the anticipated range of waste to be treated in the full-scale MPT. Furthermore, halogenated materials were excluded because the TRRP MPT permit could not be readily changed to allow such materials.

Recommendation 3-5a. The BPBGT should perform more-comprehensive testing prior to systemization, drawing from operator experience at prior operating plants. This testing should include waste materials and waste flow rates representative of those encountered during closure, as well as miscellaneous secondary waste from operations and maintenance and any possible residual energetics.

Recommendation 3-5b. The use of halogenated materials should be minimized in operations and maintenance activities wherever possible, and selection of materials should

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[5] Bechtel Parsons Blue Grass Team, "Secondary Waste Testing 15–31 May 2007," presentation to the committee, September 5, 2007.

[6] Bechtel Parsons Blue Grass Team, "Secondary Waste Testing 15–31 May 2007," presentation to the committee, September 5, 2007, slide 253.

[7] ASPEN is chemical engineering processing software. For more information, see http://www.aspentec.com/products/process-engineering.efm.

anticipate halogenated materials and the possible corrosive nature of steam. Also, testing prior to systemization should include halogenated feeds at the rate expected from plant design and operations.

Finding. Inadequate data were collected to serve as the basis for determining processing rates for secondary waste. Waste loading in trays during the TRRP testing may not be representative of loading configurations during operation (e.g., weight per tray, double-stacking, and so on).

Recommendation 3-6. Additional testing is needed to verify the complete destruction of secondary waste and to verify appropriate feed (e.g., tray and loading) configurations that render effective treatment of the variety of types of secondary waste.

Alternative Treatment and Disposition of Secondary Waste

In general, secondary waste can be shipped off-site safely if it meets one of two criteria: (1) if analysis shows levels less than the applicable waste control limits (WCLs)[8] or (2) if the waste has been subjected to thermal treatment at 1000°F for 15 minutes. The second criterion, formerly called treatment to 5X, was a requirement for off-site shipment until June 2004 when the WCL criteria were introduced.

The BPBGT plans to heat all secondary waste to 1000°F for at least 15 minutes in the MPT. The advantage of that approach is that documentation is straightforward and no further analysis need be done before shipment. The disadvantage is that many of the secondary waste materials form chars and tars at that temperature that can foul the trays and the OTM.

Permits under the Resource Conservation and Recovery Act of 1976 for baseline incineration facilities generally consider waste to be nonhazardous for chemical agents and suitable for off-site shipment if extractive analysis of the waste shows the concentration of agent to be less than the WCL (NRC, 2007). The analysis can be done using the toxicity characteristic leaching procedure, as described in the Environmental Protection Agency's publication SW-846, or by using a different methodology approved by the state regulatory agency (NRC, 2007).

In order to be able to use a WCL criterion, the BPBGT would need to get approval from the State of Kentucky on the acceptable WCL for each agent and the method of analysis to be used. If approval is obtained, each secondary waste batch suspected of being agent-free may be tested. If it meets the WCL, it can be shipped off-site with no further treatment. If it does not meet the criterion and is likely to char or tar at 1000°F, it can be treated at a lower temperature in the MPT and the end product can be analyzed to verify that it meets the WCL. By lowering the temperature to ~500° F for 1 to 2 hours, six nines (99.9999 percent) agent destruction and removal efficiency should be achievable, and char and tar formation should be greatly reduced.

Finding. In many cases, secondary waste can be shipped off-site for treatment and disposal in a safe manner.

Finding. For waste that cannot be shipped off-site, the MPT could be used at a lower temperature for treating secondary waste to reduce tar and char load.

Recommendation 3-7. To reduce the technical risks in treating secondary waste in the MPT, the BPBGT should continue to strive to send as much secondary waste off-site as possible, and should obtain the necessary permits to allow lower-temperature processing in the MPT.

Finding. TRRP MPT testing confirms that treatment of metal parts and secondary and closure waste can be performed at 1000°F for 15 minutes in a suitably sized MPT if enough time is allowed for the treatment and if the testing recommended in Recommendation 2-1 is completed.

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[8] WCLs and the analytical methods required to demonstrate that they have been achieved vary by state. In general, the WCL is defined as 20 parts per billion (ppb) for GB and VX and 200 ppb for HD, as determined by the Environmental Protection Agency's (EPA's) toxicity characteristic leachate procedure (TCLP) applied to the residuals from the metal parts treater. The WCL may also, or additionally, be based on agent concentration in the air space above the containerized waste treatment residuals. Minimum required levels are typically 1 STEL (short-term exposure limit)—0.0001 mg/m^3 for GB, 0.00001 mg/m^3 for VX, and 0.003 mg/m^3 for HD.

4

Thermal Testing, Modeling, and Predicted Throughput of the Metal Parts Treater

The objective for thermal testing and modeling of the metal parts treater (MPT) was to demonstrate that the metal parts at all locations in the tray could be heated to 1000˚F for at least 15 minutes within a total time duration that supported the design production rate. Heat-up times for projectiles located in the trays passing through the Technical Risk Reduction Program (TRRP) MPT were measured and predicted. The key elements of this effort were as follows:

- Thermocouple measurements of the surface temperature were made on a limited number of projectiles at specific locations in the tray as they passed through the MPT and were heated.
- Predictions of the temperature distribution in the projectiles were made by using a computational fluid dynamics (CFD) thermal modeling program that was compared with a previous model used in initial Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) MPT testing. However, all model results must be validated with experimental data as discussed elsewhere in this report.

The experimental data and the modeling focused on the temperature-time profiles for projectiles at specified locations in the tray. Figure 4-1 shows the projectile numbering system and the locations of the test thermocouples.

In this chapter, the reliability of both temperature measurements and model predictions is evaluated, as well as the ability of the model to estimate the heating rates for the projectiles in the full-scale unit. Conclusions on the ability of the full-scale MPT to meet throughput requirements are then presented.

EXPERIMENTAL TEMPERATURE MEASUREMENTS

Type K thermocouples encased in stainless steel sheaths were mounted to the top and bottom areas of three projectile casings in order to allow the monitoring of temperature-time profiles in the prototype TRRP MPT. The numeric designations of the projectile locations and the location of the thermocouples are shown in Figure 4-1. An example of the temperature-time profile for thermocouples numbers 4 and 6 located on projectile 14 and comparison with the CFD predictions are shown in Figure 4-2. Figure 4-2 is representative of the agreement between the model and experiment for final versions of the CFD code, although some earlier versions of the code had greater differences. The thermocouples were usually placed on projectiles 6 and 7, because the modeling indicated that these were the slowest to heat. Thermocouples were also placed on projectile 14 because this location was used in early testing at PCAPP.

Thermocouple measurements are subject to errors created by (1) heat transfer in the thermocouple wires and shielding, (2) the creation of junctions not in the intended location, and (3) calibration. In the experimental TRRP trials, thermally sensitive paint[1] and thermal dosimeters[2] were also used. Both the paint and the dosimeters confirmed that the peak temperature had indeed exceeded 1000°F, and the dosimeters confirmed that the criterion requiring 1000°F for 15 minutes was met (BPBGT, 2007d).

The shielded thermocouples were inserted into ¼-in.-diameter holes in the surface, and the leads were strapped on the surface by hose clamps (see Figure 4-3). The ther-

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[1] The thermally sensitive paints selected for use are Tempilaq °G temperature-indicating liquids manufactured by Tempil, Inc. They have individual colors that indicate their temperature specification. When the specified temperature is reached, they require about 10 minutes to change color, usually to black. Four temperature-level paints were used in the tests, paints that changed at 950°F, 1000°F, 1022°F, and 1050°F (according to the manufacturer, these are accurate to +/– 1 percent). One-inch-wide stripes were painted along the length of the projectiles tested.

[2] The thermal dosimeters use a crystalline solid inside a metal shell. The solid begins to melt at 1000°F. When melted completely (which takes a minimum of 15 minutes), the result is a glassy solid, indicating performance of the MPT within specifications. Tests were run on May 8, 2007, with five dosimeters; four indicated that the 1000°F/15 minute criterion was reached; the fifth failed because it could not be removed from the projectile.

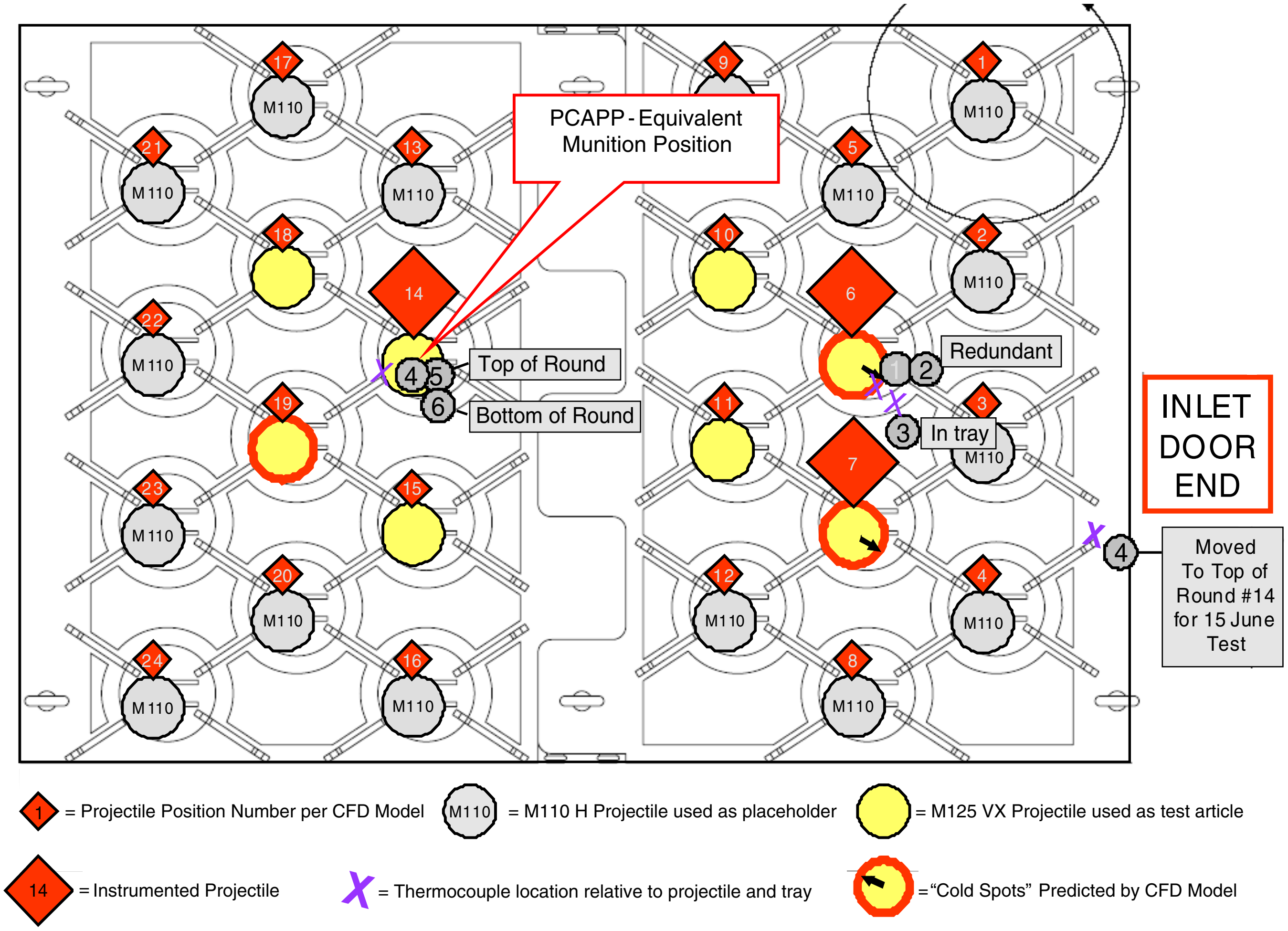

FIGURE 4-1 Location of thermocouples (X) and computational fluid dynamics model "cold spots" on test rounds and in tray for June 14 testing. SOURCE: BPBGT, 2007a.

mocouples are in direct contact with only the sheath, which is in contact with the projectile surface. The measurements were taken to be surface temperatures when compared with the CFD predictions. However, the sheath is also in contact with the outside environment and is subject to both direct convective and radiative heating. It is a matter of speculation whether or not the extra heat transported through the outside sheath to the thermocouple lead is significant, but it could lead to erroneous temperature measurements. The preferred method of measuring surface temperature is to feed the thermocouple wires through holes from the inside of the projectile to the surface. Then, the sheath and leads are not exposed to the outside environment.

Finding. Errors may exist in the experimental temperature measurements with thermocouples from heat transfer through the leads.

TEMPERATURE PREDICTION BY COMPUTATIONAL FLUID DYNAMICS THERMAL MODELING

The Bechtel Parsons Blue Grass Team (BPBGT) used a mathematical model for comparison with the TRRP experimental measurements and to predict the performance of the full-scale MPT for the Blue Grass Chemical Agent Destruction Pilot Plant. The BPBGT's model gives spatial and temporal temperature behavior of the parts being processed in the MPT. The purpose of the modeling was to show that the MPT design was adequate for treating munitions at 1000°F for 15 minutes while meeting operational and schedule requirements and that the design could guide the scale-up and the testing of the full-size unit.

Comparison with the experimental measurements was used to validate and modify the model. The improved model appears to be fairly rigorous; it uses a commercial CFD package, AcuSolve Version 1.7b (Acusim Inc.), which is a

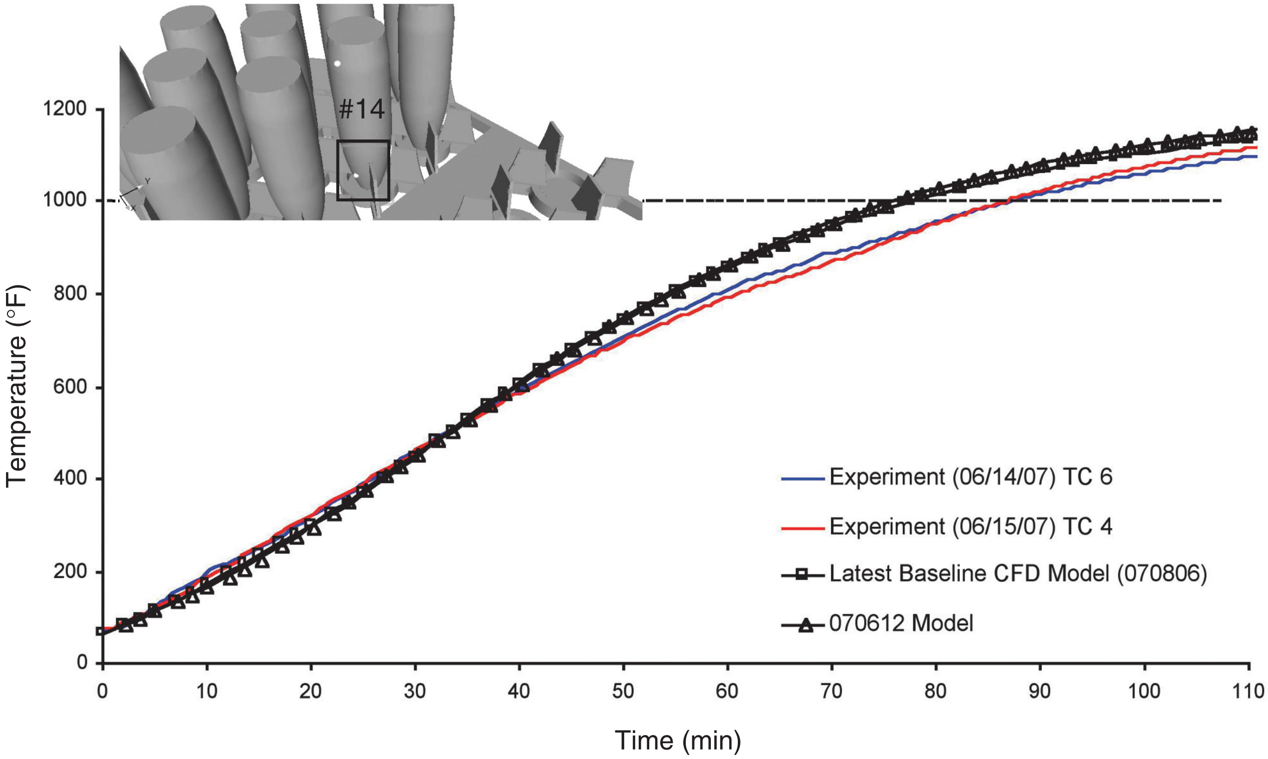

FIGURE 4-2 Comparison of computational fluid dynamics (CFD) model predictions with experimental results for thermocouples 4 and 6 on projectile 14 with CFD predictions. SOURCE: Jonathon Berkoe, Manager, Bechtel Advanced Simulation and Analysis Group, “Blue Grass MPT CFD Modeling Comparison to Pasco TRRP Experiment Measurements,” presentation to the committee, September 5, 2007.

general-purpose finite-element-based incompressible flow solver. The code is based on a nonlinear solver that (1) is accurate to second order in space and time; (2) globally and locally conserves mass, momentum, and energy; and (3) allows a choice of finite-element shape function. The model handles multimode heat transfer, including graybody radiation with view factor computation.

The model includes the coupled effects of (1) convective heat transfer rates between the injected steam and the projectiles, (2) conduction within the projectiles, and (3) radiative transfer rates between the inductively heated chamber surfaces and the projectiles, and between the projectiles themselves. These rates are used to predict the local projectile temperature-time profiles while the projectiles are in the chamber. The model is complex because the instantaneous heat transfer rate depends on the following:

- The temperature difference between the local steam and the projectile surface temperatures at any time;
- The radiative transfer rate, which depends on the difference between the fourth power of the absolute temperature of each element on the inductively heated surface and a projectile element;
- The emissivities of all the surfaces; and
- Reflected and emitted radiation from the adjacent projectiles and other structures inside the MPT chamber.

These effects must be summed over all surface elements at each time interval. A typical set of parameters used in the model for the TRRP MPT is given in Table 4-1, and typical boundary conditions are shown in Table 4-2. The model is highly nonlinear in temperature, and it includes first- and fourth-power temperature dependences and their effect on the heat-up rates.

The present CFD model uses constant values for the projectile emissivity and for the specific heat of the projectiles. Because of the variety of coatings used on the projectiles and the unknown change that occurs during coating pyrolysis, it is probably not possible to model the emissivity more accurately. However, measured values of temperature-dependent specific heat c_p were obtained by the BPBGT (Figure 4-4), but these were not used in the CFD model except to extract a representative constant value. The specific heat nearly doubles between room temperature and 700°C. The increasing values of c_p with temperature will tend to cause the heat-up rate to be slower at higher temperatures. This may contribute to the difference in behavior between the

FIGURE 4-3 Thermocouple installation on the projectile. SOURCE: BPBGT, 2007a.

TABLE 4-1 Metal Parts Treater Unit's Material Properties

Component Materials	
Tray, fins	ASTM[a]
Projectiles	Carbon steel
Insulation on MPT doors	CS 85
MPT conveyor, conveyor support, rollers	ASTM
MPT door frames	ASTM
Emissivities	
Projectiles	0.65
MPT coils and walls	0.9
Conveyor and conveyor support	0.65
Rollers	0.3
MPT doors (insulation)	0.4
Material Properties	
Steam	
Density	0.2673 kg/m³
Conductivity	0.0261 J/m-s-˚K
Specific heat	2014 J/kg
Expansivity	0.003472 1/˚K
Viscosity	0.00005 kg/m-s
ASTM	
Density	8000 kg/m³
Conductivity	16.3 J/m-s-˚K
Specific heat	500 J/kg
CS85	
Density	85 kg/m³
Conductivity	0.29 J/m-s-˚K
Specific heat	1260 J/kg
Carbon Steel	
Density	7850 kg/m³
Conductivity	51.9 J/m-s-˚K
Specific heat	485 J/kg

[a] American Society for Testing and Materials RA 330 Steel.

SOURCE: BPBG, 2006b.

experiments and the CFD model that is observed. (Figure 4-2 is a typical example.)

The committee originally had concerns that the modeling predictions were inaccurate because the model did not take into consideration the effects of the door openings and closings nor of the purge flows during these transients because the effect was found to be small. The TRRP report indicates that door-opening transients resulted in a "flat spot" of from 1 to 7 minutes in the measured temperature profiles. These were not significant over the 90-105 minute test period. The inlet and exit chamber purge flows of nitrogen are maintained during door openings and enter the MPT and exit through the MPT exhaust headers during door openings (BPBGT, 2007b). The CFD model was modified for prediction of full-scale performance by changing the physical properties and boundary conditions to conform with the full-scale design. The boundary conditions and properties for full-scale analysis are shown in Tables 4-3 and 4-4.

Finding. The CFD model developed by the BPBGT predicts the trends in temperature behavior over time and space and the location of cold spots within the system.

Finding. The specific heat of the projectile material varies by a factor of two over the temperature range of interest, which may affect the predicted temperature-time profiles.

Recommendation 4-1. For more accurate prediction of temperature heat-up, the dependence of specific heat on temperature should be included in further modeling.

COMPARISON OF TEMPERATURE MEASUREMENTS AND MODELING

Because the experimental data could also be inaccurate, comparisons between the CFD predictions and the data cannot differentiate between errors in the model and

TABLE 4-2 Computational Fluid Dynamics Model Boundary Conditions for the Technical Risk Reduction Program

Model Region		Condition
Steam Inlet		
Full model		150 lb/hr 1000°F
Four-munitions sub-model[a]		11.1 lb/hr 1000°F
Steam outlet		0 pressure
Induction-heated MPT wall temperature		
Constant		1350°F
Temperature gradient[b]	Distance (ft)	Temperature (°F)
	1.03	1233.5
	3.00	1329.5
	4.67	1310.5
	6.93	1326.5
	8.90	1362.0
	10.87	1174.5
Air leak[c]		2.72 ft^2/min 65°F

[a] Four-munitions sub-model only.
[b] Baseline with variable MPT wall temperature case only.
[c] Air leak model only.

SOURCE: BPBGT, 2007a.

the measured data. The BPBGT did not present any error analysis in either case. However, the temperature trends in time and distributions in space are in general agreement with the experimental measurements, although there are some differences in magnitude. The differences in the model and the measurements appear to be within the usual differences expected in such modeling.

Finding. The error bounds have not been reported on the experimental data for the TRRP test; therefore, it is not possible to assess the significance of differences between the experimental measurements and the CFD model predictions.

Recommendation 4-2. In the testing of the full-scale MPT unit, error analysis should be performed and reported on the temperature measurements from multiple runs.

Finding. The CFD model has been used to aid in the design of the full-scale MPT and should be adequate for predicting cold spots and thus guiding thermocouple placement for testing of the full-scale MPT.

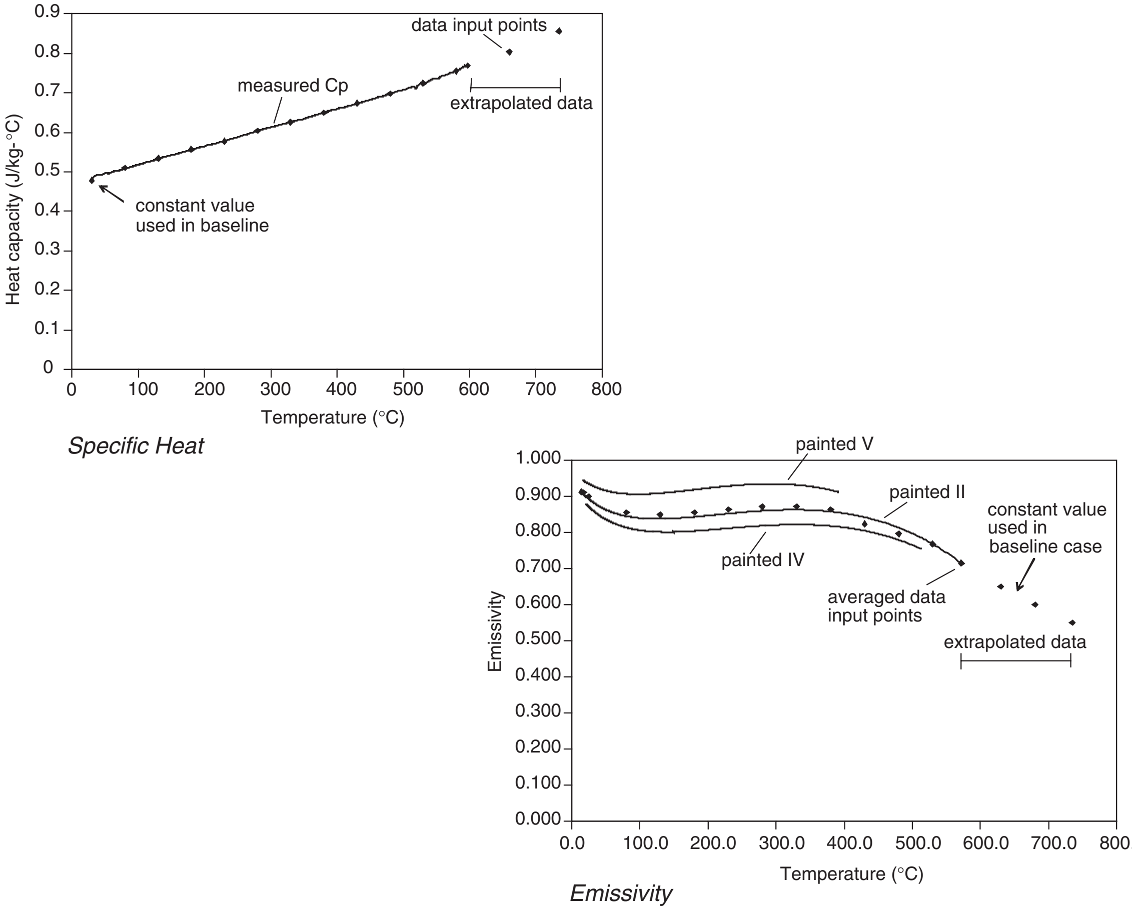

FIGURE 4-4 Variation of specific heat and emissivity with temperature.
SOURCE: Jonathon Berkoe, Manager, Bechtel Advanced Simulation and Analysis Group, "Blue Grass MPT CFD Modeling Comparison to Pasco TRRP Experiment Measurements," presentation to the committee, September 5, 2007.

TABLE 4-3 Computational Fluid Dynamics Model 070806 Boundary Conditions

Boundary Condition	Quantity
Steam temperature	1000˚F
Wall temperature	1250˚F in Zone 1 and 1350˚F in Zone 2
Steam flow rate	0.0189 kg/s
Rail temperature	Varies in axial direction
Inlet door temperature	140˚F
Initial temperature	
Cold munition	65˚F
Hot munition	1000˚F
Inside MPT	1000˚F

SOURCE: BPBGT, 2007a.

TABLE 4-4 Computational Fluid Dynamics Model 070806 Component Masses

Component	Mass (kg)
Munition	75.52
Tray	448.86
Rail and support	1080.20

SOURCE: BPBGT, 2007a.

Recommendation 4-3. The Army should depend on actual testing of the full-scale MPT, rather than solely on modeling.

ABILITY TO SCALE UP AND MEET THROUGHPUT REQUIREMENTS

Early tests of the three-quarter-scale TRRP MPT indicated that measured ramp-up heating rates to 1000ºF were slower than anticipated by modeling.[3] This raised concerns that the full-scale MPT might be unable to meet required MPT throughput rates. The pertinent design goal is that the MPT be "designed to support decontamination of one munition body every 1.5 minutes maximum" (BPBG, 2006c).

Assurance of meeting throughput rates has been addressed by the BPBGT. This conclusion is reached on the basis of the following:

1. Incorporation of the proposed modifications in the mechanical configuration of the three-quarter-scale MPT unit (e.g., better seals on the inlet and outlet doors and repositioning of the steam header) has improved the agreement between observed and predicted ramp-up rates in the three-quarter-scale TRRP MPT.[4,5,6]

2. Improvements in the CFD model have resulted in better agreement between observed and predicted rates in the three-quarter-scale MPT.[7] Predicted values of 108 minutes to reach 1000ºF now compare with experimental values of 105 to 114 minutes.

3. Ramp-up rates are chiefly affected by the temperature attained by the radiating internal surface of the MPT. The full-scale MPT is designed to have a controllable interior wall temperature of 1450ºF (1910ºR) or higher in comparison with the 1350ºF (1810ºR) available in the TRRP proof-of-concept unit. Because of the dependence of radiative transfer on the fourth power of the absolute temperature, this increase in wall temperature translates to an appreciable increase in heat transfer rate to the projectiles (or secondary waste containers) of $(1910/1810)^4 = 1.24$, or a potential 24 percent increase in heat transfer rate to the projectiles. This should allow proportionally faster ramp-up rates in the full-scale MPT unit. Because the most recent TRRP MPT ramp-up rates were close to design values, the full-scale MPT should be capable of meeting design requirements.[8]

4. The projected required full-scale MPT munitions processing rates are quite low. Peak operating rates are projected to be 15 8-in. GB projectiles per hour, 39 155-mm VX shells per hour, or 40 155-mm H projectiles per hour. These rates are based on charging one munitions tray at a time. The BPBGT has stated: "For the VX case, the tray can hold 40 rounds, but one out of 40 positions is left open to hold nose closures. The duration of processing each tray in the MPT main chamber is 2 hours" (BPBG, 2006c, p. 22).

The TRRP MPT testing was terminated before all planned testing was completed on waste streams because the BPBGT concluded that the available test results were adequate for designing the full-scale unit.

The BPBGT throughput analysis states:

> As stated earlier, there are two MPTs. The spare MPT, although processing secondary waste, is assumed to be read-

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[3] Bechtel Parsons Blue Grass Team, "Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP)," presentation to the committee, September 5, 2007.

[4] John Ursillo, Pasco Resident Engineer, Bechtel Parsons Blue Grass Team, "MPT Technical Risk Reduction Program (TRRP) Testing," presentation to the committee, September 5, 2007.

[5] Jonathan Berkoe, Manager, Bechtel Advanced Simulation and Analysis Group, "Blue Grass MPT CFD Modeling Comparison to Pasco TRRP Experiment Measurements," presentation to the committee, September 5, 2007.

[6] Jonathan Berkoe, Manager, Bechtel Advanced Simulation and Analysis Group, "FOAK CFD Models Planning," presentation to the committee, September 5, 2007.

[7] Jonathan Berkoe, Manager, Bechtel Advanced Simulation and Analysis Group, "Blue Grass MPT CFD Modeling Comparison to Pasco TRRP Experiment Measurements," presentation to the committee, September 5, 2007.

[8] Samuel Hariri, Process Design Lead, Bechtel Parsons Blue Grass Team, "Thermal Modeling to Support OTM Design," presentation to the committee, September 5, 2007.

> ily switchable (within 2 hours) to process projectile bodies should the need arise. Testing of the MPTs has shown startup from a cold condition to take 4-6 hours. There is an 8 tray buffer between the MWS and MPT. One MPT can process 8 trays in 8 hours. Negating the GB case because of the fact that there are very few munitions to process compared to rockets, the MPT can process rounds at a faster rate than that scheduled for the NCR-MWS or the LPMD (39 vs 21 projos/hr for VX, and 40 vs 26 projos/hr for H). For VX, it takes the MPT 8 hours to process a full buffer that the NCR-MWS took 15 hours to produce; and for H it takes 8 hours to process what took the LPMD 12 hours. Therefore, even if the second MPT were cold when the first failed, because the buffer size is larger than the heat up time and because the MPT can catch up on a backlog, the NCR-MWS or LPMD could continue operating normally and there would be no net effect change in the processing schedule (BPBG, 2006c, p. B-5).

Average throughput rates are even lower than stated above (see Table 4-5).

The required processing rates are so low that extended processing times due to lower ramp-up rates will have no effect on overall plant munitions throughput. Thus, MPT production rates are not a critical factor in plant production. However, it is possible that lower-than-anticipated ramp-up rates could affect plant closure operations.

TABLE 4-5 Metal Parts Treater/Metal Parts Treater Cooling System Projectile Throughput Rates

System	Munition Type	Installed Operating Rate (rounds/hr)	Average Throughput Rate (rounds/hr)
MPT/MCS[a]	8-in. M426 (GB)	15	7.5
MPT/MCS	155-mm M110 (H)	40	9.9
MPT/MCS	155-mm M121A1 (VX)	39	8.8

[a] MCS, metal parts treater cooling system.

SOURCE: BPBG, 2007.

Finding. Based on the four factors specified above in this section (Ability to Scale Up and Meet Throughput Requirements), the full-scale MPT is expected to meet design throughput rates, and, even if it falls somewhat short of design values, overall plant throughput is not expected to be affected.

5

Applicability of PCAPP Munitions Treatment Unit at BGCAPP

MUNITIONS TREATMENT UNIT DESIGN AND OPERATION AT PCAPP

The Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) in Colorado will decontaminate metal parts from projectiles and mortars using two parallel munitions treatment units (MTUs). The MTUs have a footprint of approximately 90 ft long (with 20 ft of this total located in the munitions washout system [MWS] room, and 70 ft located in the MTU room) by 8 ft wide and an overall height of 12 ft. Off-gas from the MTU is discharged to an off-gas treatment system (OTS) using a bulk oxidizer (BOX) unit and cyclone for each MTU. The cyclones discharge to a common venturi scrubber system. The PCAPP OTS is similar in design and operation to the off-gas treatment system for the metal parts treater at the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP).

The MTU is a continuous-belt muffle furnace with material-handling equipment at the feed and discharge ends. As shown in Figure 5-1, the MTU is an adaptation of a metal annealing furnace. Modifications include new feed and exit sections and a muffle large enough in cross section (10 in. high by 30 in. wide) to accommodate 155-mm projectile bodies riding on the metal conveyor. The muffle section is also long enough to ensure that all parts of the munitions reach 1000°F for at least 15 minutes at the operating speed of the metal conveyor.

Electrical resistance heaters externally heat the muffle walls, which in turn radiate heat to the munitions parts. The MTU OTS draws air into both the muffle feed section and exit section at a velocity sufficient to ensure the flow of any hazardous gases or particulates to the off-gas exit from the MTU muffle. The 20-ft-long feed section is located in the Level A area. The muffle, discharge, and cooling sections are located in the MTU Level C area and are approximately 70 ft long. Hot munitions bodies flowing from the MTU muffle section are cooled by air flowing into the MTU cooling section. The cooled munitions are discharged through a rotary valve onto an inclined conveyor in the Level C area into a bin located in a Level D area. From there, the munitions are shipped to a disposal facility. A paint-residue removal system is being incorporated on the MTU discharge.

Materials fed to the MTU consist of munitions bodies and mortar base plates. Located at the feed end of each MTU is a pneumatically operated tilt frame device equipped with a V-block support for the munitions and a weigh scale. This device, called the discharged munitions weigh station, weighs munitions bodies that have been processed through the MWS cavity access machine. The measured weight is used as the criterion to ensure that a full, unbreached munition is not fed into the MTU.

The MTU conveyor belt is a continuous link-and-pin design with scallops on the top side of each link that form a cradle for the munitions. The belt moves at a constant speed (nominally 4 in. per minute), presenting an open cradle to the MWS robot at regular intervals of time. The 155-mm and 105-mm munitions are deposited on a short ramp by the MWS robot and roll gently onto the furnace belt, cradling into the first available position. The 155-mm munitions are spaced on 7.5-in. center lines; the 105-mm munitions are spaced on 5-in. center lines. To balance mechanical stresses, the orientation of the 155-mm munitions are alternated between heavy-end left and heavy-end right; out-of-balance sequence munitions are limited to 10 or fewer in any running group of 40.

Mortar bodies are also deposited onto a ramp designed only for mortars that permits the accumulation of mortar bodies. Mortar bodies accumulate on the ramp while the MTU belt conveyor continues to move forward, providing empty space on the belt for the loading of base plates. After loading and accumulating four mortar bodies on the ramp, the MWS robot delivers a load of 25 base plates to the MTU conveyor belt. Base plates are deposited into a chute just forward of the mortar body loading ramp. After the base plates are deposited, the gate at the bottom of the ramp retracts, and mortar bodies are permitted to roll down onto the conveyor belt behind the base plates. The loading ramp empties as 16 more mortar bodies are delivered for the next sequence. Mortars are spaced on 5.0-in. center lines on the conveyor belt.

The heated portion of the MTU furnace is divided into six control zones. The temperature of the munitions is ramped up at a controlled rate in the first four zones and allowed to remain at temperature in the last two zones. The zone length is determined by the kinetics of heating the munitions and the desired soaking time at temperature. Munitions leaving the heated portion of the MTU enter a water-jacketed cooling chamber zone designed to cool the munitions and the belt conveyor to approximately 650ºF. Experiments with simulated equipment test hardware munitions have confirmed this temperature.

At the exit end of the cooling chamber, which is also the exit of the MTU, is a rotary valve used to remove treated metal parts. Munitions exiting the rotary valve are deposited onto a discharge conveyor and then leave the discharge conveyor by way of a discharge chute that penetrates the agent processing building wall. The discharge chutes dump the metal parts into a container. After discharging metal parts to the rotary valves, the MTU conveyor belt returns to the loading area, traveling underneath the MTU muffle. This lower return tunnel includes the belt drive components and water seals that prevent the belt return tunnel from becoming contaminated by liquids and gases originating within the MWS room.

Off-gas from the MTU is discharged to the OTS through a vent located at the first heating zone of the MTU. The vent is equipped with a filter to capture large particles from treated munitions (oxidized paint and so on) before the off-gas flows into a flameless thermal oxidizer designated as the bulk oxidizer. The filter is rated for 1200°F, and differential pressure is measured across the filter to provide an indication of the need to clean the filter. Filter cleaning is accomplished by using compressed air to blow particulates from the filter back into the MTU after the system is isolated by closing a damper on the MTU vent line.

Secondary and closure waste is not processed in the MTU. Some of this material is combustible and would burn in the MTU muffle, since the muffle has air flowing through it to the MTU off-gas treatment system. These waste materials will be processed in the PCAPP supplemental decontamination unit (SDU) or in one of two autoclaves. The SDU operates at temperatures up to 400˚F. These temperatures will cause thermal decomposition or pyrolysis of agent to levels meeting guidance requirements of the State of Colorado for shipment to a commercial hazardous waste treatment storage and disposal facility. The SDU and autoclaves are designed to thermally destroy mustard agent contained in closed spaces in various waste items such as valves and pumps. They also will decontaminate demilitarization protective ensemble suits, other plastics, contaminated wiring and hoses, other operating and maintenance waste, and closure waste.

TESTING OF THE MUNITIONS TREATMENT UNIT FOR PCAPP

Testing of the MTU took place at Abbott Furnace Company's facility in St. Marys, Pennsylvania. The testing protocol was designed to verify the ability of the MTU to process at the specified rates, heat all parts of each munition to at least 1000°F, and maintain that temperature for a minimum of 15 continuous minutes. Additionally, the testing was to validate the structural integrity of the MTU, and the ability of the MTU to control air flows and to control particulate matter generated by the thermal decontamination process.

The MTU performed to specification, demonstrating the ability to transfer all munitions types mechanically at the design rate, to heat all munitions types according to the required thermal profile, and to manage the air flows as specified. Generated particulate matter showed no propensity to impair function. Design changes are planned in order to control particulate matter dusting at the discharge to the rotary valves. Operating procedures and control settings are being modified as well.

COMPARISON OF THE METAL PARTS TREATER AND MUNITIONS TREATMENT UNIT FOR BGCAPP

The committee reviewed the applicability of the MTU as an alternate method of decontaminating munitions bodies and secondary waste at BGCAPP. As noted above, the MTU is currently planned for installation at PCAPP for thermal decontamination of 155-mm and 105-mm projectiles and of 4.2-in. mortars that have been drained of mustard agent and passed through a high-pressure wash. In Table 5-1 the committee compares various operating requirements and features of the metal parts treater (MPT) and the MTU and identifies changes that would be required for the MTU to be used at BGCAPP.

Finding. The MTU could be used at BGCAPP for all projectile bodies. Dimensional modifications of the PCAPP MTU would be required to process 8-in. projectile bodies.

Finding. The MTU is not designed for processing secondary or closure waste. If used, it would also require the installation of supplemental decontamination and autoclave units at BGCAPP to treat solid waste, including squibs and fuzes from the energetics batch hydrolyzers and secondary and closure waste.

Finding. Supplemental decontamination units and autoclaves, if used at BGCAPP, would require space in the Level B area of the munitions demilitarization building.

Finding. A change from the MPT to the MTU will require modifications to the environmental permits. The schedule impacts for such a change have been estimated at delays of 7

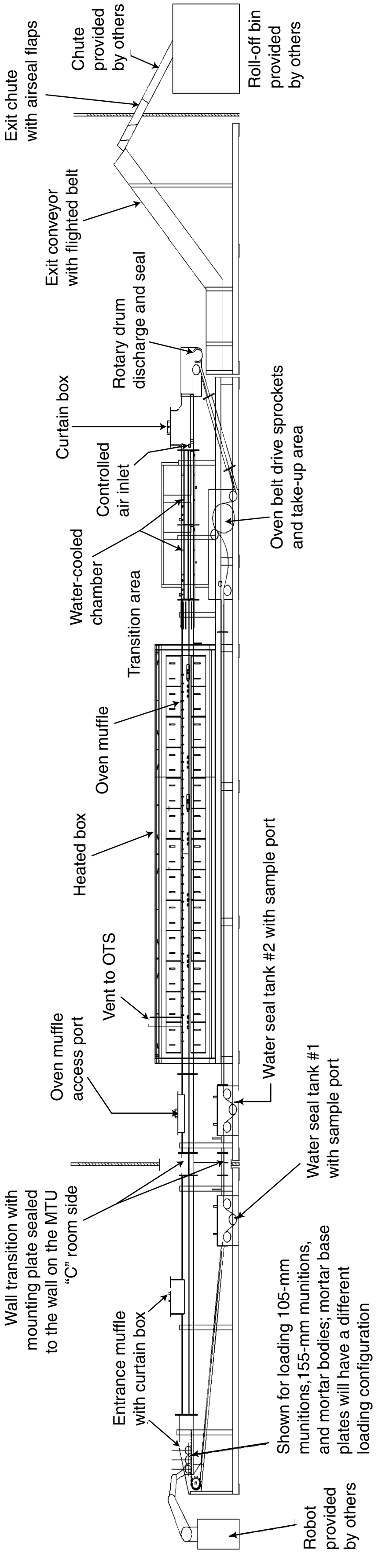
Robot provided by others
Shown for loading 105-mm munitions,155-mm munitions, and mortar bodies; mortar base plates will have a different loading configuration
Entrance muffle with curtain box
Wall transition with mounting plate sealed to the wall on the MTU "C" room side
Water seal tank #1 with sample port
Oven muffle access port
Water seal tank #2 with sample port
Vent to OTS
Heated box
Oven muffle
Transition area
Water-cooled chamber
Oven belt drive sprockets and take-up area
Controlled air inlet
Curtain box
Rotary drum discharge and seal
Exit conveyor with flighted belt
Exit chute with airseal flaps
Chute provided by others
Roll-off bin provided by others

TABLE 5-1 Comparison of the Metal Parts Treater and the Munitions Treatment Unit

Characteristic	MPT at BGCAPP	MTU at PCAPP	Changes for MTU Use at BGCAPP
Status of testing	Prototype (~3/4 scale) demonstrated on surrogate munitions and waste streams. Two full-size MPTs will be built and tested at the manufacturer's facility.	Full-scale unit completed acceptance tests at the manufacturer's facility with surrogate munitions.	Full testing would be required, using the energetic dregs and agent or appropriate surrogate material. Only small design changes from the PCAPP MTU are required. Using the MTU would save extensive testing of the MPT with secondary waste. Treatment of secondary waste in the SDU[a] and autoclaves has already been performed at the other sites.
Feed streams			
4.2-inch mortars and base plates	None	97,106 (HD)	Applies only to PCAPP, no mortar rounds at BGCAPP.
105-mm projectiles	None	383,418 (HD)	Not applicable to BGCAPP.
155-mm projectiles	15,492 (H) 12,816 (VX)	299,534 (HD)	A new permit will be needed to use the MTU at BGCAPP.
8-inch projectiles	3,977 (GB)	None	Muffle height must be increased for use at BGCAPP. The MTU currently has internal height of 9.75 in. and width of 30 in.
M55 rockets; undissolved fragments, including undissolved squibs and fuzes from hydrolysis of rocket warhead and rocket motor segments in EBHs[b]	51,716 (GB) 17,757 (VX) Method for treating squibs and fuzes in the MPT is to be tested.	None	Squibs and fuzes must be thermally decomposed (must be popped). Some fragments are combustible and may require inert gas and special baskets if treated in the MTU or, alternatively, they may be treated in the SDU or autoclave if WCL[c] guidelines for off-site disposal are used.
Secondary waste	Thermal treatment in MPT using special carrying trays.	Treatment in SDU or autoclaves.	SDU and autoclave use based on approach used at ABCDF.[d] Use at BGCAPP may require special permitting and higher temperatures for GB- and VX-contaminated waste. Only limited testing on various waste types has been performed in the MPT.
Closure waste	Thermal treatment in MPT.	Treatment in second SDU.	See comments for secondary waste.
Agents destroyed			
Mustard	Yes	Yes	
GB and VX	Yes	None	SDU and autoclave would be required with the MTU for GB- and VX- contaminated waste streams. This method of decontamination may require higher treatment temperatures to achieve acceptable treatment times to meet WCL guidelines for off-site disposal.
Number of units	2 MPTs with one for projectile processing and one for waste streams and as a backup spare.	2 MTUs with only one ordinarily required to meet PCAPP processing rates.	BGCAPP might require only 1 MTU because the number of projectiles is an order of magnitude less than at PCAPP; MTU availability expected to be higher than that of the MPT.
MDB[e] footprint	~70 ft long × 40 ft wide × 20 ft high Total direct footprint for 2 MPTs plus 50 percent of MPT/washout support room plus MPT cooling room is 4,640 square feet.	~100 ft long × 30 ft wide × 20 ft high Total direct footprint for 2 MTUs is 5,100 square feet plus 216 square feet for collection bin enclosures.	MTU would require changes in BGCAPP MDB layout to accommodate longer processing length and SDU and autoclave units and to provide for collection bins for receiving treated metal parts from MTU discharge chute.
Post-treatment agent clearance	In exit air lock before leaving level A area.	In treated munition collection bin in Level D area.	MTU use at BGCAPP would require permit change for use of current MTU discharge configuration.

continues

TABLE 5-1 continued

Characteristic	MPT at BGCAPP	MTU at PCAPP	Changes for MTU Use at BGCAPP
Atmosphere in unit	Nitrogen in air locks and superheated steam in main chamber.	Air flowing from both ends of muffle to off-gas duct exit from muffle system.	Change in Kentucky permit would be required for use of MTU and SDU or autoclave.
Off-gas treatment system	Flame arrestor, cyclone, bulk oxidizer, venturi scrubber, and reheater.	Flame arrestor, filter media, bulk oxidizer, venturi scrubber, and reheater.	Same components, with different gas flow rates and sizes.
Method of heating	2 induction coils at 450 kW each plus 75 kW resistance heating for steam superheater.	Resistance heaters at 600 kW	None
Method of operation	Batch	Continuous	Would have to change from a batch stream to a continuous stream.
Char and tar buildup from secondary waste treatment	Expected, but the design allows for addressing tar and char buildup.	Secondary waste not processed in MTU.	Secondary waste not processed in MTU.
Method of control of atmosphere in main treatment unit	Doors and seals on air locks attached to main chamber.	Curtains on munitions cold feed end and cooling section exit of muffle.	Curtains on munitions cold feed end and cooling section exit of muffle.
Overall availability (percent of time the system will be operating)	83 percent estimated using spare MPT.	91 percent estimated for single MTU; no estimate given with spare MTU.	Both estimates based on using both treatment units.
Munitions throughput rates			
4.2-inch mortars	None for BGCAPP	~60/hr	
105-mm projectiles	None for BGCAPP	~60/hr	
155-mm projectiles	~40/hr	~40/hr	~40/hr
8-inch projectiles	~15/hr	None	MTU should be capable of modification to achieve BGCAPP 8-inch projectile processing rates.

[a] SDU, supplemental decontamination unit.
[b] EBH, energetics batch hydrolyzer.
[c] WCL, waste control limit.
[d] ABCDF, Aberdeen Chemical Agent Disposal Facility.
[e] MDB, munitions demilitarization building.

SOURCE: Adapted from BPBGT, 2007c.

to 11 months for construction. Because stakeholder concerns are difficult to predict, these estimates could be optimistic, and actual schedule impacts could be greater.

TREATMENT OF ENERGETICS BATCH HYDROLYZERS AND SECONDARY AND CLOSURE WASTE AT BGCAPP

The Bechtel Parsons Blue Grass Team (BPBGT) plans to use the MPT for the treatment of both munitions bodies and energetics batch hydrolyzer (EBH) and secondary and closure waste. If the MPT were to be replaced with an MTU, EBH and secondary and closure waste would have to be treated by alternative methods because they would be subject to combustion and popping in the MTU.

The BPBGT is still evaluating how to thermally treat EBH waste streams, including squibs and fuzes. According to the Technical Risk Reduction Program test report, approximately 360 of these items from five EBH waste batches are combined and placed in a single waste incineration container for thermal treatment. The method of controlling the energetic releases in the MPT or MTU and SDU has not been identified.

The alternatives selected for treating secondary and closure waste at PCAPP are an SDU and an autoclave. The SDU is an industrial convection oven.[1] The units planned for PCAPP are 12 ft 3 in. wide by 6 ft 6 in. deep by 8 ft 8 in. high in internal volume. The door opening is 40 in. by 80 in. The floor loading capacity is 4,000 pounds per bay. The units are designed to operate at temperatures up to 500°F at a slight

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[1] Open discussion on the SDU/autoclave, between Craig Myler, Chief Scientist, Pueblo Chemical Agent Destruction Pilot Plant, and the committee, September 20, 2007.

negative pressure relative to the surroundings. Operating temperatures for materials contaminated with mustard will be in the range of 275°F to 350°F. Total estimated cycle time from start up to cooldown is 19 to 22 hours, depending on the material and the degree of contamination.

The autoclave is an industrial vacuum cycle unit, 26 in. wide by 78 in. deep by 62 in. high in internal volume. The door opening is 26 by 62 in. The floor loading capacity is approximately 300 pounds. The autoclave is designed to operate at up to 267°F at pressures of 2 to 32 pounds per square inch gage (psig). Materials contaminated with mustard will be heated with steam to a maximum temperature of 267°F and then cooled by the application of a vacuum. Total cycle time is estimated between 7.5 to 8.5 hours.

Thus, PCAPP is not planning to heat secondary and closure wastes to 1000°F for 15 minutes, the traditional method for certifying waste as agent-free and suitable for off-site disposal. Instead, PCAPP will take advantage of the approach based on waste control limits (WCLs) that went into effect in June 2004. There are several variations of the WCL approach. The State of Colorado has approved a vapor screening level (VSL) for certifying waste treated in the SDU or autoclave as agent-free. A gas/vapor sample will be taken at the end of each thermal cycle to determine if the cycle was sufficient to achieve the desired decontamination of less than 1 VSL. Monitoring will require at least two consecutive readings below 1 VSL that are not rising. The monitoring MINICAMS® must pass a post-test agent challenge to ensure that the presence of interferents did not suppress the agent readings. The VSL has been set as 1 short-term exposure limit (0.00001 mg/m³), established by the Army in coordination with the Centers for Disease Control and Prevention (NRC, 2007).

The SDU and autoclave planned for PCAPP should be of sufficient size to handle the secondary and closure waste expected to be generated at BGCAPP. The SDU would have to be operated at higher temperature and possibly for longer times in treating waste contaminated with VX. Available data indicate that the half-life for VX is 4 minutes at 482°F and 0.6 minute at 563°F. Assuming that the rate of destruction is first order with respect to time, the estimated times to achieve six nines (99.9999 percent) destruction and removal efficiency are 80 minutes and 11 minutes, respectively. An appropriate WCL and associated sampling and analysis method would need to be approved by the State of Kentucky. Maximum temperatures in the autoclave may be insufficient to handle VX contaminated wastes.

Finding. The BGCAPP permit would require modification if the MTU/SDU/autoclave were to be used instead of the MPT because the process design would be totally different.

Finding. If used at BGCAPP, the MTU, like the full-size MPT, would first require acceptance testing at the manufacturer's facility. Both units would then undergo first-of-a-kind testing during systemization.

Finding. Although the footprints of both the MPT and the MTU are similar in area, the MTU will have a longer and narrower footprint that will require modification of the floor plan at BGCAPP.

Finding. The use of supplemental decontamination units and autoclaves at BGCAPP will be required to treat secondary and closure waste if the MTU is selected for processing munitions bodies at BGCAPP. The supplemental decontamination unit and autoclave operating temperatures will not be the same as at PCAPP because higher temperatures are required for GB and VX than for H or HD to achieve thermal decomposition rates suitable for anticipated waste production rates.

Finding. The use of waste control limit guidelines will be required for the disposal of waste exposed to H, HD, GB, and VX if supplemental decontamination units and an autoclave are used at BGCAPP. These guidelines for waste exposed to these agents have already been implemented at other chemical demilitarization facilities.

Finding. A method has not been developed for treating squibs and fuzes from the energetics batch hydrolyzer waste streams in either the MTU/supplemental decontamination unit or the MPT.

Finding. The off-gas treatment systems for BGCAPP and PCAPP are quite similar for the MPT and the MTU. The MTU does not require a particulate cyclone downstream of the bulk oxidizer unit.

6

General Findings and Recommendations

The following general findings and recommendations are based on the discussions and the detailed findings in Chapters 2 through 5 of this report.

Finding. The full-scale MPT as currently designed for BGCAPP can decontaminate projectile bodies and secondary and closure waste, and it will be able to achieve its target throughput rates provided that the BPBGT is able to resolve the following issues:

- Successful implementation of new designs for door closure and seals, for roller bearings on conveyors, and for the superheated steam header;
- Effective thermal treatment of secondary waste without excessive fouling of the duct work leading to the bulk oxidizer;
- Successful integration of the MPT with its flameless thermal oxidizer (i.e., the bulk oxidizer) and cyclone; and
- Complete destruction of energetic materials in the waste stream of the energetics batch hydrolyzer without adversely affecting the MPT.

Finding. The current range of heat-up times of munitions in the MPT should not affect the overall schedule of BGCAPP operations.

- Heat-up times in the TRRP tests are close to target and appear to be capable of being improved by raising the wall temperature of the full-scale MPT.
- CFD modeling predicts correct trends in temperature-time profiles and locations of cold spots and should be useful in guiding the design and testing of the full-scale MPT.
- The processing rate of projectile bodies in the MPT is not on the critical path of the process throughput. The design calls for two MPTs. The second is intended to be used for secondary waste, but it could also be used for treating munitions bodies in an emergency.

Finding. The MTU could be substituted for the MPT at BGCAPP; however, it would be necessary to do the following:

- Use supplemental decontamination units and autoclaves to treat secondary waste,
- Find another means of treating the detonators in the M417 rocket fuzes,
- Modify the MTU design to accommodate 8-in. projectiles,
- Modify the footprint of the building to accommodate the units, and
- Modify the existing permits.

Finding. For BGCAPP, the TRRP testing did not address a method to thermally treat the fuzes and a limited number of igniters from contaminated propellant that are not decomposed in the energetics batch hydrolyzers.

Recommendation 6-1. The BPBGT needs to develop a method to collect and pop the igniters and fuzes that will not adversely affect the operation of the MPT.

Recommendation 6-2. To reduce the technical risks in treating secondary waste in the MPT, the BPBGT should continue to strive to send secondary waste off-site whenever possible and minimize the use of halogenated materials.

Recommendation 6-3. To reduce the load on the off-gas treatment system, the BPBGT should consider obtaining permits that allow the use of the Airborne Exposure Limit Guidelines to operate the MPT at lower temperatures for the thermal treatment of secondary waste whenever possible.

Finding. TRRP testing demonstrated the validity of using an MPT for thermal decontamination. It also identified many changes and design improvements that will be necessary to achieve an acceptable throughput rate and control maintenance and operating costs. Further testing with varied secondary waste materials including halogenated waste is still required. These changes and improvements may require several iterations before satisfactory results are achieved.

Recommendation 6-4. A test plan should be prepared for all design changes identified for the MPT but not verified in the TRRP tests. This test plan should be conducted at the fabrication facility and should include time for the repeated trials needed to arrive at acceptable performance for the overall full-scale MPT. A similar test plan should be prepared for testing the integrated full-scale off-gas treatment system for the MPT at BGCAPP. This test plan should include the testing of a full range of secondary, energetics batch hydrolyzer, and closure waste at the full-scale design rates.

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Appendixes

Appendix A

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 officer and served at the Jet Propulsion Laboratory as a research scientist. He joined the faculty of the University of Southern California in 1962 and served continuously in the Department of Chemistry until his retirement in 2005. He also has served on Department of Defense committees addressing 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 the chair of an Air Force technical conference on chemical warfare decontamination and protection. He has participated in two 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 served as chair of the Committee on the Assembled Chemical Weapons Alternative Program. Previously, he served as a member of the NRC Board on Army Science and Technology (BAST), as a member of the NRC Committee on Review of the Non-Stockpile Chemical Materiel Disposal Program, and as a BAST liaison to the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program (Stockpile Committee).

Richard J. Ayen, now retired, was director of technology for Waste Management Inc. Dr. Ayen also managed all aspects of Waste Management's Clemson Technical Center, including treatability studies and technology demonstrations for the treatment of hazardous and radioactive waste. His previous experience includes 20 years at Stauffer Chemical Company, where he was manager of the Process Development Department at Stauffer's Eastern Research Center. Dr. Ayen has published extensively in his fields of interest. He was a member of the NRC Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons (I and II) and was also chair of the NRC Committee on Review and Evaluation of International Technologies for the Destruction of Non-Stockpile Chemical Materiel. He received his Ph.D. in chemical engineering from the University of Illinois.

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

Willard C. Gekler is currently an independent consultant working for his previous employer, ABS Consulting Inc. He graduated from the Colorado School of Mines with the degree of Petroleum Refining Engineer and pursued graduate study in nuclear engineering at the University of California in Los Angeles. His extensive experience includes membership on the NRC Chemical Materials Agency and Assembled Chemical Weapons Alternatives committees and on the Mitretek Systems expert panel reviewing the quantitative risk assessments and safety analyses for the Anniston, Umatilla, Pine Bluff, and Aberdeen chemical agent disposal facilities. He also serves on the Technical Oversight Committee provided by the Consortium for Risk Evaluation with Stakeholder Participation for the review of design issues associated with the Hanford Waste Treatment Plant of the Department of Energy's Office of River Protection. He also participated in the consequence screening assessment for the Newport Chemical Disposal Facility. Previously he was project engineer for various nuclear test facility designs and for development of facility design criteria for the Johnston

Atoll Chemical Agent Disposal system. His expertise is in plant design, hazard evaluation, quantitative risk analyses, reliability assessment, and database development for risk and reliability. Mr. Gekler is a member of the American Institute of Chemical Engineers and the American Nuclear Society. He is the author or coauthor of numerous publications.

David A. Hoecke is currently president and CEO of Enercon Systems Inc. He graduated from the Cooper Union with a B.S.M.E. His expertise is in the fields of waste combustion, pyrolysis, heat transfer, and gas cleaning. In 1960 he began working for Midland-Ross Corporation as a project engineer, rising by 1972 to be its chief engineer for incineration. At that time he founded his own company, and he has since been responsible for the design and construction of numerous combustion systems, including solid waste incinerators, thermal oxidizers, heat recovery systems, and gas-to-air heat exchangers. Mr. Hoecke has considerable expertise in incineration technologies employed by the Army in its demilitarization of chemical weapons.

John R. Howell (NAE) is the Ernest Cockrell, Jr., Memorial Chair and Baker Hughes Incorporated Centennial Professor of Mechanical Engineering at the University of Texas in Austin. He recently served (2003-2007) as the director of the Advanced Manufacturing Center at the University of Texas. Professor Howell received his Ph.D. in engineering (1962), his M.S. in chemical engineering (1958), and his B.S. in chemical engineering (1958), all from Case Institute of Technology (now Case Western Reserve University) and joined the faculty of the University of Texas at Austin in 1978. He has received national and international recognition for his continuing research in radiative transfer, particularly for adapting Monte Carlo techniques to radiative transfer analysis. His recent research has centered on inverse analysis techniques applied to the design and control of thermal systems with significant radiation transfer. Professor Howell has served on the NRC Panel on Benchmarking the Research Competitiveness of the U.S. in Mechanical Engineering. He was elected a member of the NAE in 2005.

Nelline Kowbel is vice president and environmental program manager at Malcolm Pirnie Inc., a leading private environmental consulting firm. She is experienced in ordnance explosives and chemical weapons disposal program permitting and operational requirements. Ms. Kowbel has worked directly with regulatory compliance requirements for waste disposal operations, including chemical weapons disposal compliance at the Johnston Atoll, Tooele, Pine Bluff, Anniston, Pueblo, and Aberdeen sites. Ms. Kowbel has more than 25 years of experience in the environmental field and has been the environmental safety and health manager for a 1,500-person workforce. She has also managed a team of 80 contractor staff providing environmental and industrial health services, including environmental compliance and permitting for the Edwards Air Force Base Environmental Department. Ms. Kowbel is a registered professional engineer and a board certified environmental engineer. She holds a B.S. in civil engineering from the University of Kentucky

John E. Morral is a professor and former chair of the Department of Materials Science and Engineering at the Ohio State University and is an emeritus professor from the University of Connecticut. At the University of Connecticut he also served as head of the Department of Metallurgy and Materials Engineering. Dr Morral's major research interest is diffusional kinetics with applications to high-temperature coatings, gas-solid reactions, and the heat treatment of alloys. He is former chair of the American Society for Metals (ASM) Heat Treating Society R&D Committee and helped draft ASM's 1999 R&D Plan. In addition, he is deputy editor of the *Journal of Phase Equilibria and Diffusion* and former chair of the ASM Alloy Phase Diagram Committee, Atomic Transport Committee, and Thermodynamics and Phase Equilibria Committee. With these committees he has helped organize a dozen national and international conferences, including two international conferences for ASM on heat treating. Dr. Morral received B.S. and M.S. degrees in 1964 and 1965 from the Ohio State University and a Ph.D. in 1969 in metallurgy from the Massachusetts Institute of Technology.

Derrick K. Rollins serves as a professor of chemical engineering at Iowa State University, where he also holds a half-time appointment in the Departments of Statistics and Chemical & Biological Engineering. His areas of research and expertise are in predictive modeling and control of chemical processes, process dynamics and control, and advanced statistical modeling in chemical engineering. Dr. Rollins has received a number of technical and professional awards including the National Science Foundation Faculty Fellow Award, the Mentor Award of the American Association for the Advancement of Science, and selection as one of Iowa State University's most outstanding faculty members. He holds a B.S. degree in chemical engineering from the University of Kansas, M.S. degrees in chemical engineering and statistics from Ohio State University, and a Ph.D. in chemical engineering from Ohio State University.

Appendix B

Committee Meetings and Site Visits

FIRST COMMITTEE MEETING: SEPTEMBER 5-7, 2007 PASCO, WASHINGTON

Objectives: National Research Council introduction (administrative actions, including committee introductions and composition/balance/bias discussions for committee members), committee statement of task and background review with sponsor, receive detailed process and equipment briefing presentations (performance requirements, modeling results, and test results) for first-of-a-kind Blue Grass metal parts treater (MPT) and related Pueblo munitions treatment unit (MTU), review preliminary report outline and report writing process, confirm committee assignments, writing teams' first draft, decide future meeting dates, MTU site visit team, and next steps.

Briefings and Discussions

Consideration of Statement of Task with Sponsor: Bob Beaudet, Committee Chair; Joe Novad, Technical Director, Assembled Chemical Weapons Alternatives (ACWA); Darren Dalton, Blue Grass Design Team Leader, ACWA

Overview of the Blue Grass Chemical Agent Destruction Pilot Plant (BGCAPP) Process: Sam Hariri, BPBGT Process Design Lead

Metal Parts Treater Design and Performance Detail: Mark Rieb, Deputy Director, Parsons Technology Development and Fabrication Complex; John Ursillo, BPBGT Pasco Resident Engineer; Jonathan Berkoe, Manager, Bechtel Advanced Simulation and Analysis Group

Overview of PCAPP Process and Munitions Treatment Unit (MTU) and Supplemental Decontamination Unit, MTU Function and Feeds, Comparisons to MPT: Paul Dent, Manager, PCAPP Technical Risk Reduction Program

SITE VISIT: SEPTEMBER 22-23, 2007 ST. MARYS, PENNSYLVANIA

Objectives: Receive detailed process and equipment briefing presentations, including performance requirements, modeling results, and test results for the MTU; visit Abbott Furnace Company to see the MTU.

Briefings and Discussions

Introduction to Abbott Furnace: Mike Gelsick, Director of Marketing, Abbott Furnace Company

Design Overview Using Large MTU Wall Drawing: Tom Jesberger, Chief Technical Officer, Abbott Furnace Company

MTU TRRP Testing and Test Results: Scott Pierce, MTU Project Manager, Abbott Furnace Company

Tour of MTU: Abbott Furnace Company

Review of Upgrades for First-of-a-Kind (FOAK) MTU: Tom Jesberger, Chief Technical Officer, Abbott Furnace Company

SDU/Autoclave Open Discussion: Craig Myler, Bechtel Pueblo

SECOND COMMITTEE MEETING: OCTOBER 16-18, 2007 BECKMAN CENTER, IRVINE, CALIFORNIA

Objectives: Receive additional briefings, review first full message draft, produce preliminary concurrence draft, and determine what is not yet known and how to learn it.

Briefings and Discussions

Metal Parts Treater Design and Performance: Darren Dalton, Blue Grass Design Team Leader, ACWA; Ed Rogers, Bechtel; Roger Dickerman, Washington Group International; Sam Hariri, BPBGT Process Design Lead

THIRD COMMITTEE MEETING: NOVEMBER 6-8, 2007 BECKMAN CENTER, IRVINE, CALIFORNIA

Objectives: Review first full message draft, determine what is not yet known and how to learn it, produce preliminary concurrence draft, sign concurrence documents. *(No briefings scheduled.)*