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Summary Evaluation of the Johnston
Atoll Chemical Agent Disposal System:
Operational Verification Testing

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ABSTRACT

As part of its program to destroy its obsolete chemical warfare munitions, the U.S. Army has constructed a prototype demilitarization plant on Johnston Island in the Pacific Ocean. The plant has completed its 32-month operational verification test. During the test, the plant destroyed over 40,000 munitions of three different types, containing three different chemical agents. There were no public or worker injuries or fatalities from agents or munition fire or explosion. The plant emitted no agent, except for one occurrence which posed no significant worker or public health risk. The plant operated within environmental emission and waste disposal requirements, but did not comply with all procedural and administrative regulatory requirements. The plant generally demonstrated the ability to meet throughput goals for short periods of time, but while showing improvement during the test, the plant did not achieve the long-term average throughput rate goals established prior to testing. Based on the test, MITRE concludes that there are no apparent fundamental safety, environmental, or process-related problems in utilizing the technology used on Johnston Island for disposal of chemical munitions in the Continental U.S. sites. However, it is desirable that improvements be made in each of the areas to increase further the assurance of safe, environmentally-sound operation, and to achieve higher throughput rates. This will require particular attention to the operation and management of future plants.

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EXECUTIVE SUMMARY

Public Law 99-145, as amended, requires that the United States (U.S.) Army destroy (demilitarize) the stockpile of obsolete U.S. chemical warfare munitions and agent. These materials are currently stored in eight different locations in the U.S. and on Johnston Island (JI), which is located about 800 miles southwest of Hawaii in the Pacific Ocean. The Army has constructed a prototype demilitarization facility on JI called Johnston Atoll Chemical Agent Disposal System (JACADS). JACADS was the first full-scale, fully-integrated demilitarization facility to be built and will serve as a prototype for the facilities to be constructed at each of the eight U.S. storage locations. JACADS was designed to destroy chemical munitions stored on JI using a system that separates the different munition components (explosives, agent, and metal munition bodies), and processes each in an incinerator designed for the component. In Public Law 100-456, the Army was required to demonstrate the ability of the JACADS to demilitarize the munitions consistent with the safety and environmental protection goals of the Army's Chemical Stockpile Disposal Program. This demonstration, called the Operational Verification Testing (OVT), consisted of four distinct tests involving different agents and munitions. The testing took place between July 1990 and March 1993.

The Army contracted with The MITRE Corporation to observe and evaluate the results of the tests, and to prepare reports documenting each test and a summary report. This Summary Report provides an overview of the performance of JACADS during the four tests with respect to the overall concerns of safety, environmentally-sound operations, and process performance. In addition, using the JACADS experience as a basis, this report includes projections of the likely system operation for similar munitions at the various U.S. sites.

SAFETY PERFORMANCE

JACADS met the OVT safety performance goals that were established for it. During OVT, there were no injuries or fatalities associated with the handling of agent or munitions, and industrial injuries were within the range typical of industrial chemical facilities. As expected, events did occur that challenged the levels of protection designed into JACADS. The demonstrated safe operating record of JACADS during OVT reinforces the importance of having safety in depth incorporated into the plant design and operating procedures.

Some of the design features of JACADS and planned demilitarization facilities that are especially important include:

- Control of air movement in contaminated areas to prevent migration of agent
- Provision of multiple levels of backup power supply
- Isolation of activities such as explosives removal
- Large margins of safety in the incineration and air exhaust systems
- Separation of people from processes by use of remote and computer control
- Full coverage of the facility using automatic, near real-time agent monitors
- Extensive use of closed-circuit television monitoring
- Extensive use of electronic process monitoring and computer data handling

The JACADS contractor operated an active safety program during OVT. In addition, the Army and other agencies provided extensive oversight and review of the operations.

Challenges to the plant design did demonstrate several notable shortcomings in some of the systems or their operation. In each case, the Army and its contractors have investigated the problems and have installed or plan to install corrections. These areas included:

- Failure of the back-up power and related control system software to operate properly when restarting the plant following loss of power
- Ventilation system failures or inadequacies that on occasion did not fully control agent migration within the facility
- Inadequate control and documentation of software and system design changes
- Control systems that did not maintain accounting of the processing status of each munition

The adequate performance of staff is also essential to the proper operation of the safety systems of the plant. While staff training met minimum mandated requirements, there were instances of performance errors that either led to operating or safety problems, or exacerbated them. The relative effects of other factors (e.g., training, inadequate system designs, faulty or non-existent procedures, or supervisory oversight) in these instances could not be separated in evaluating the causes of these performance errors. The Army's upgraded training program should contribute to improving staff performance at both U.S. plants and at JACADS.

ENVIRONMENTAL PERFORMANCE

The OVT demonstrated that the JACADS process can meet federal regulatory standards and can operate without adverse environmental impact. JACADS operated within applicable environmental regulations with respect to discharge of agent and non-agent air emissions and, with few exceptions, met all operating permit requirements. Waste materials were disposed of in approved locations. Noncompliance with the procedural and administrative requirements in the environmental permits occurred. These included minor non-agent discharges to the ground (without environmental impact), problems in the long-term storage of wastes, and errors in record keeping and inspection. There are no apparent fundamental problems in meeting regulatory standards in future U.S. plants, unless the standards are significantly more restrictive than those in effect for JACADS.

However, there were several areas in which problems have occurred in the past. Programs are underway to address these areas, and will help ensure conformance to the regulations. These areas include the following:

- Emphasize the tracking of the requirements of the applicable permits
- Seek permit conditions that provide for increased flexibility in process operations while protecting environmental quality
- Provide for long-term storage and disposal of agent-contaminated protective equipment
- Achieve reliable operation of the Brine Reduction Area to manage liquid wastes
- Achieve reliable operation of the Dunnage Incinerator to manage solid wastes
- Improve the effectiveness of personnel training concerning environmental regulations

PROCESS PERFORMANCE

During OVT, JACADS demonstrated the ability to demilitarize M55 rockets containing GB or VX, and ton containers and 105 mm M60 projectiles containing HD. During the tests on rockets and ton containers, JACADS generally met its short-term single shift throughput goals, but was unable to meet long-term throughput goals established prior to OVT. Process improvements that have been demonstrated or planned will likely allow similar plants in the U.S. to achieve the JACADS OVT throughput goals, although at least in the near-term still

falling short of the plant design goals established by the Army for the U.S. plants. The projectile test showed that the processes could approach or meet short-term goals. However, projectile operations were not sufficiently reliable or of sufficient duration to draw firm conclusions concerning sustained long-term throughput.

Though the JACADS performance fell short of the desired goals, its efficiency of operation was generally consistent with start-up problems seen in industrial process plants that use similar processes. The experience of such plants typically shows that a two- to five-year period is necessary to identify and correct problems in process design and operation and to achieve the design performance of these plants.

JACADS is a first generation chemical munitions disposal facility, and as such its prototype nature was a major cause of performance shortfalls. In addition, JACADS encountered a variety of munition and agent-specific problems that could not have been foreseen in the tests that were conducted with inert, simulant-filled munitions prior to OVT. These problems are not unusual for a first generation plant processing a unique feedstock, in this case, a substantial variety of obsolete chemical munitions and containers. Operational performance showed that significant engineering development still was needed on several of the systems. While much of the needed engineering has now been conducted, it is possible that additional problems may develop as the JACADS and U.S. plants are run for longer periods and on a more intense, 24-hour per day, schedule. At JACADS, the Army had both successes and failures in diagnosing and correcting system performance problems. However, a program is in place to transfer the lessons learned to the U.S. plants, and additional testing is planned at JACADS to identify solutions for the remaining problems. In addition, to ensure early identification and correction of problems, the Army plans to process those munition types located on Johnston Island before processing similar munition types at U.S. plant locations.

Major process systems that appear to require additional engineering refinement and test to improve system availability include the Deactivation Furnace System, the Liquid Incinerator, and the Multipurpose Demilitarization Machine. Of these, the first two are adapted from systems used in industry, while the third is a special purpose machine. The corrections and improvements needed all appear to be well within the state of the art. Although operating in a support role on JI, the Brine Reduction Area and the Dunnage Incinerator did not achieve full operation. These systems will require additional engineering and testing. Both of these are adaptations of standard industrial systems and were not developed specifically for chemical munition disposal. The backup power systems failed on several occasions during OVT, and require more detailed testing at all sites to ensure reliable operation.

CONCLUSION

The JACADS plant completed its OVT with the destruction of more than 40,000 munitions over a period of 32 months.

There were no public or worker injuries or fatalities from agents or munition fire or explosion, and the plant met the safety goals established for it.

The plant emitted no agent (except for one occurrence that posed no significant worker or public health risk) and operated within permit requirements for other discharges. Although not satisfying all administrative permit requirements, the plant demonstrated its ability to meet federal regulatory standards and to operate without adverse environmental impact.

JACADS demonstrated its ability to destroy rockets, ton containers, and projectiles containing three types of agent. The plant approached or met short-term throughput goals, but did not meet long-term average process rate goals. Although not achieving the throughput goals specified prior to OVT, the performance was within the range of startup performance for similar industrial pioneer processing plants.

The JACADS design has no apparent fundamental problems in achieving safety and environmental goals at planned U.S. plants, although continued improvements in these areas will increase further the assurance of safe, environmentally-sound operation. The implementation of the lessons learned from the OVT combined with additional engineering refinement should enable JACADS and U.S. plant performance to approach or exceed the OVT throughput rate and design goals.

SECTION 1

INTRODUCTION

1.1 BACKGROUND

Public Law 99-145, as amended, requires that the Army destroy (demilitarize) obsolete United States (U.S.) chemical warfare munitions and materials. These materials are currently stored in eight different sites in the Continental U.S. and on Johnston Island (JI) which is located about 800 miles southwest of Hawaii in the Pacific Ocean. Because of concerns for risks in transportation of the materials, the current program calls for the construction and operation of chemical munition disposal facilities at each of the eight locations in the U.S. Figure 1-1 shows the U.S. sites, and identifies the types of munitions* stored at each. The various munitions contain different chemical agents, including nerve agents GB and VX, and blister agent H/HD, also called mustard. Not all munitions are configured for all agents.

As a part of the development of this program, the Army constructed a prototype demilitarization facility on JI called the Johnston Atoll Chemical Agent Disposal System (JACADS). Figure 1-2 shows the location of JI, as well as a drawing of the JACADS facility on the island.

JACADS was designed to destroy chemical munitions stored on JI. The design of JACADS was based on prior testing of prototype and smaller-scale demilitarization facilities. However, JACADS was the first full-scale, fully-integrated demilitarization facility that would serve as a prototype for additional facilities to be constructed in the U.S.

In Public Law 100-456, as a prior condition to proceeding with systemization and operation of demilitarization facilities in the U.S., the Army was required to demonstrate the ability of JACADS to demilitarize the munitions consistent with the safety and environmental protection goals of the Army's Chemical Stockpile Disposal Program. This demonstration was called Operational Verification Testing (OVT).

While not including all munition and agent combinations found in the U.S. locations, the JI inventory is representative of the chemical munitions stored in the U.S. The Army reviewed the various munition and agent combinations, and concluded that tests of three munition types

*The term "munition" technically does not include ton containers or spray tanks; however, for simplicity of terminology, it is used in this report to describe all agent-containing items.

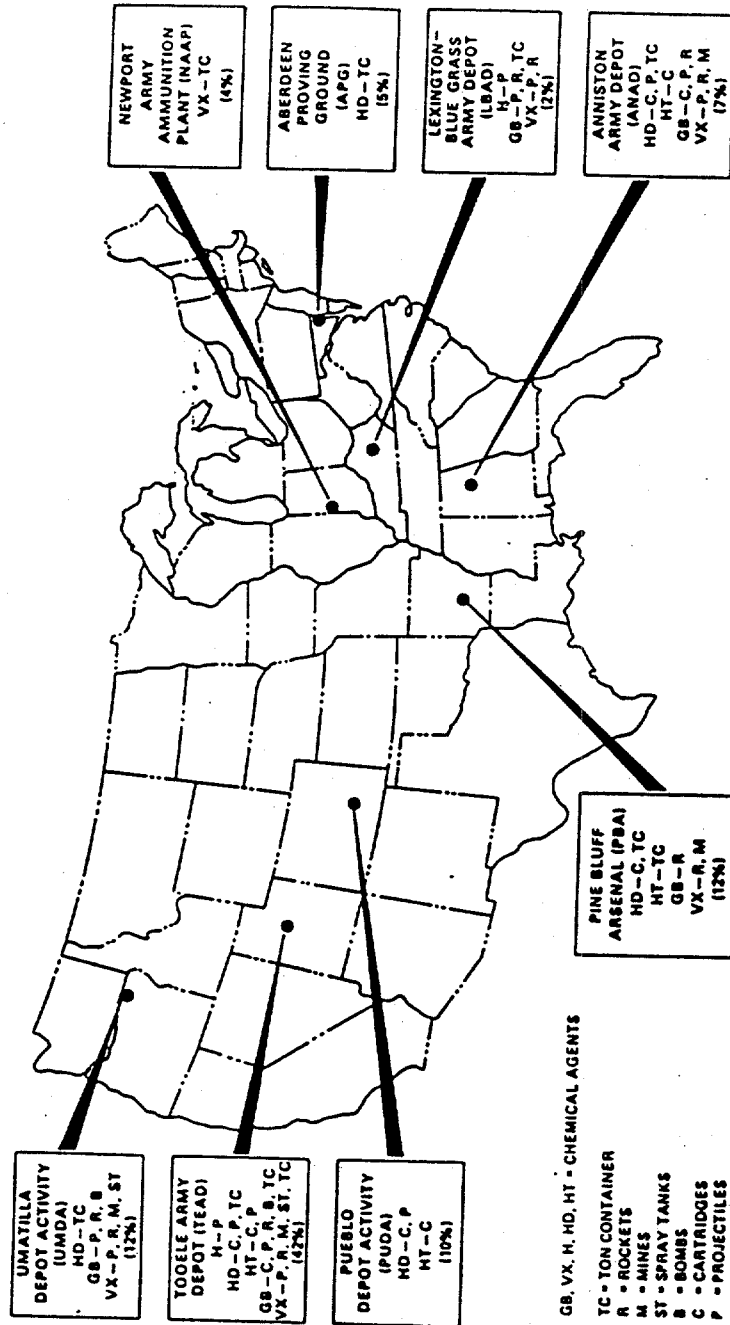


Figure 1-1. U.S. Chemical Munition Storage Sites

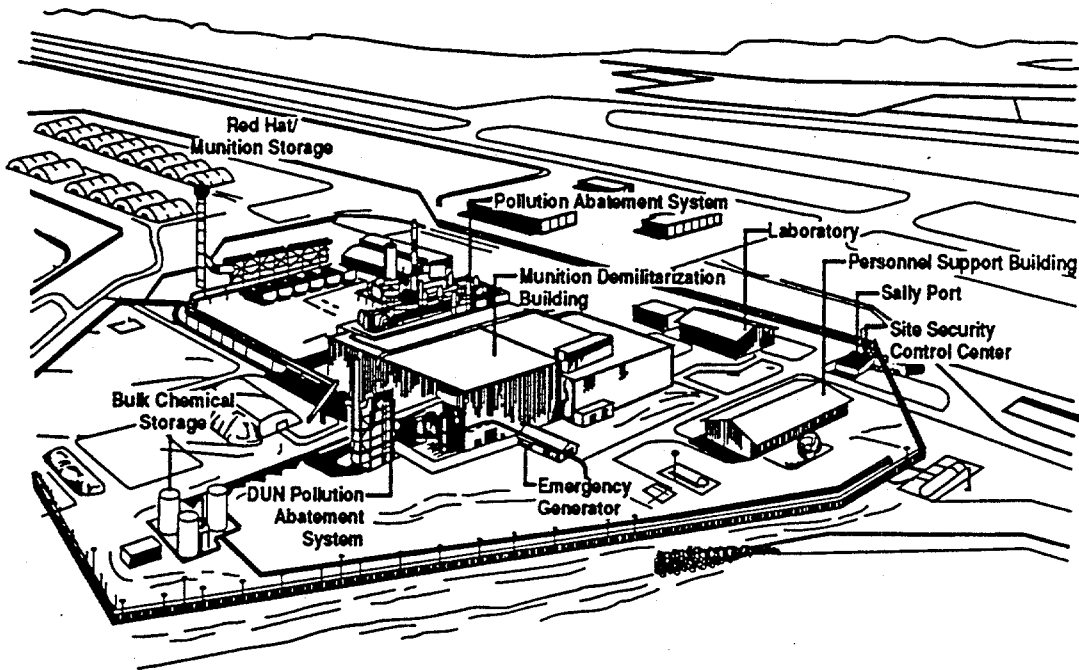
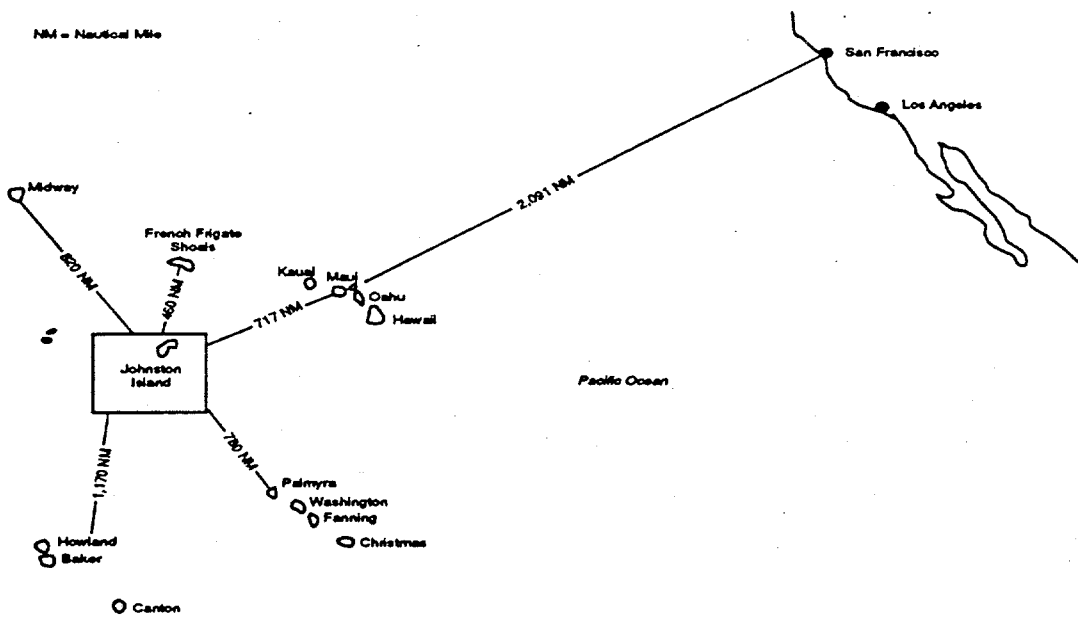


Figure 1-2 Location of Johnston Island and JACADS

containing three different agents would provide the information needed to evaluate the suitability of the JACADS process for the demilitarization of the stockpile munitions. Demilitarization of rockets would test the ability to access and destroy agent and explosive in thin-walled munitions, ton containers of agent would test the ability to destroy materials from large thick-walled containers, while projectiles would test the ability to access and drain agent from thick-walled containers using disassembly procedures. The Army also concluded that testing the destruction of GB, VX, and HD provided a good test of the ability to remove and destroy the types of agents constituting the major portion of the stockpile, while also testing the effectiveness of the necessary agent monitoring systems.

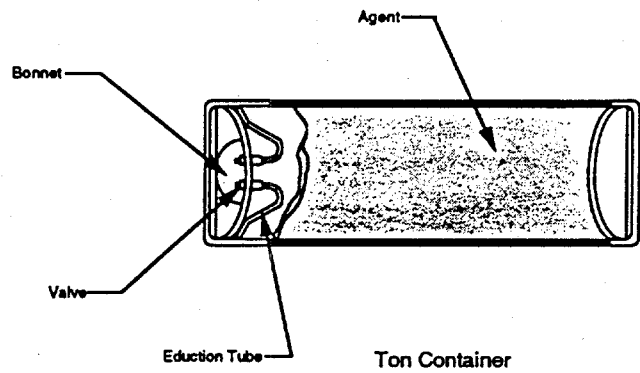
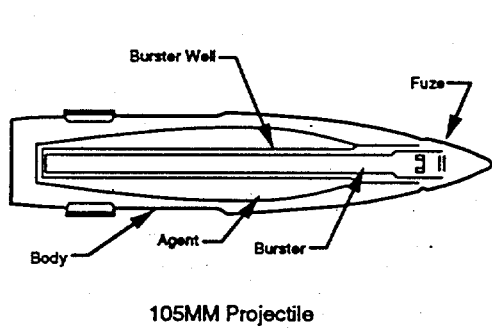
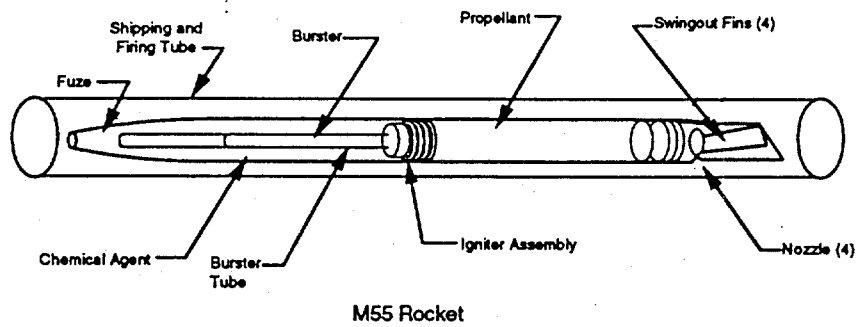
After this review, the Army designed the OVT to include four separate tests:

- OVT1–M55 Rockets containing GB nerve agent
- OVT2–M55 Rockets containing VX nerve agent
- OVT3–Ton (bulk) Containers of HD Mustard blister agent
- OVT4–105mm M60 Projectiles containing HD Mustard blister agent

Each test was designed to demonstrate operation of JACADS on a fully-integrated basis. By the end of OVT4, all major process systems would have been operated. Table 1-1 gives a summary of the properties of each of the agents, while figure 1-3 shows diagrams of each of the munitions. The quantities of munitions destroyed were intended to be sufficient to demonstrate the ability to destroy the munitions stored in the U.S. sites.

Table 1-1. Characteristics of Chemical Agents

Agent	Common Name	Appearance (25 ° C)	Mode of Action
GB	Sarin	Liquid, clear to amber	Nervous system poison primarily by vapor contact
VX	-	Liquid, clear to straw	Nervous system poison primarily by liquid or droplet contact
HD	Mustard	Liquid, amber to dark brown	Blistering of exposed tissue primarily by liquid or droplet contact



Munition	Length	Diameter	Weight	Agent
M55 Rocket	78 in.	4.5 in.	57 lbs.	10 lb. GB or VX
Ton Container	82 in.	31 in.	3100 lbs.	1700 lb. HD
105mm M60 Projectile	19.5 in.	4.1 in.	35 lbs.	3 lb. HD

Note: Dimension and weights are approximate

Figure 1-3. Munitions Destroyed During OVT

The Army contracted with The MITRE Corporation to observe and evaluate the operation of JACADS during the OVT. MITRE established an on-site office, and maintained staff on JI throughout the OVT. Prior to the OVT, MITRE prepared an OVT Test Directive that established more than 250 criteria to guide the detailed performance evaluations. MITRE prepared detailed reports evaluating the performance of JACADS during each of the four tests. The titles of these and related reports are listed in appendix E.

This Summary Report provides an overview of the performance of JACADS during the four tests with respect to the overall concerns of safety, environmentally-sound operations, and process performance (including both the throughput rates and the performance of each major system). In addition, using the JACADS experience as a basis, where possible MITRE has made projections of the likely performance to be expected at the U.S. sites for the JACADS technology operating on similar munitions. The individual test reports provide further information on the details of system performance.

1.2 PROCESS DESCRIPTION

The JACADS includes components and processes tailored to the disposal of each munition or agent. Most of the plant is made up of components used for similar material handling or incineration purposes in industry. Some of the equipment used for accessing and removing explosives or agent is unique to chemical munitions demilitarization.

Because only one munition and agent combination is processed at a time, the processing systems are configured to support each test. Some systems, such as the Liquid Incinerator (LIC) that destroys agent, are used in all of the tests, while other systems such as the Rocket Shear Machine (RSM) are used in only one or two tests. A very brief description of the demilitarization process is provided below, while appendix A provides more detail, as well as schematic diagrams of each of the processing configurations.

- For OVT1 and OVT2 (the rocket tests), the demilitarization process involves punching holes through the shipping/firing tube and the rocket, draining the agent, and burning the agent in a LIC. The rocket is then sheared into pieces using an RSM, and burned in the Deactivation Furnace System (DFS).
- For OVT3 (the ton container test), the process involves punching holes in the metal container (holding approximately 1700 pounds of agent) at the Bulk Drain Station (BDS) and withdrawing and burning the agent in the LIC. The container is then decontaminated by heating it in the Metal Parts Furnace (MPF) to destroy residual agent.

- For OVT4 (the projectile test), the process involves removing the explosive components using a Projectile/Mortar Disassembly Machine (PMD), and burning the components in the DFS. The agent is accessed and withdrawn by the Multipurpose Demilitarization Machine (MDM) and burned in the LIC. The empty projectiles are decontaminated by heating them in the MPF.

The disposal of the munitions is carried out within a Munitions Demilitarization Building (MDB). The demilitarization activities involving explosives or agent are carried out remotely, under the control of computer-actuated equipment. Staff in the Control Room monitor operations, and can process munitions either automatically or may use "manual" (remote) control. Additional support systems include Pollution Abatement Systems (PASS), dunnage incinerator (DUN), Brine Reduction Area (BRA), data management, maintenance activities, and safety. A ventilation system maintains negative pressure in the processing areas (to control agent migration), while a charcoal filtering system removes agent from the air before discharge.

A laboratory supports operation of agent monitors at 91 points within the MDB, and at 12 points in the areas outside the plant. Depending on the location, the monitors include an Automatic Continuous Air Monitoring System (ACAMS) that provides a measurement of agent concentration about every five minutes, and/or a Depot Area Air Monitoring System that provides average agent concentration readings over 1 to 12 hours. Monitors are generally operated in pairs, with the furnace Common Stack also containing backup systems.

Maintenance activities in agent-contaminated areas are carried out by workers using personal protective equipment. Work in the most contaminated areas is conducted by personnel wearing the Demilitarization Protective Ensemble (DPE). The DPE provides a sealed garment for the worker, with the provision of external air and communication equipment.

1.3 SIMILARITIES AND DIFFERENCES BETWEEN JACADS AND U.S. FACILITIES

As noted above, this document not only describes the JACADS OVT experience, but draws on this experience to develop projections for operations at the U.S. sites. The OVT was designed to demonstrate that the basic JACADS processes operating in sustained operation could meet expectations for safety, environment, and process performance for similar plants in the U.S. The degree of similarity and difference between JACADS systems and operations and those at U.S. facilities will affect the reliability of the projection.

These factors include the following:

- JACADS was a prototype facility, while the U.S. plants will have the benefit of the lessons learned from operating JACADS.
- JACADS operated 8-12 hours/day, 6 days/week, 2-4 months/test, while U.S. plants will operate 24-hours/day, 5-6 days/week, 2-16 months per munition.
- In many design areas—especially for those machines and systems having direct contact with munitions, agent, or their products—exactly the same design will be used, modified only as experience at JACADS or other requirements dictate. In other areas, especially in the support systems, the design concepts will be the same, but the hardware used may change depending on availability of equipment or technological advances.
- JACADS tested operations with three different munitions and agents. U.S. plants will destroy additional quantities of these munitions, as well as some types not tested during OVT. The Army plans to test the demilitarization for most munition types at JACADS before processing these munition types at U.S. plants.
- JACADS and the U.S. sites will have similar overall management structures, with each facility operated by a private contractor with on-site Army oversight. U.S. facilities may have different contractors at different sites.
- The location of JI in the central Pacific caused significant operating difficulties for the Army and its contractors. These difficulties included the time and logistics of providing supply to the island, especially of replacement or modified devices and materials. Logistics at U.S. plants should simplify and speed up the response to operating problems. As a result, less management attention will be required to provide basic services at U.S. facilities.
- The location and restrictive living conditions (e.g., non-working dependents are not allowed) on JI may have limited the pool of available workers as compared to the U.S.
- Many performance problems were caused or exacerbated by inadequate JI utilities external to JACADS. This situation should improve in the U.S. plants.

- Since JACADS is not in a state, the operation was not subject to state law and regulation as will be the case for facilities in the U.S.

It is important to note that the Army has in place formal "Lessons Learned" programs. These programs are designed to capture the experience at JACADS and ensure its application in the U.S. plant designs and operation. The Design Lessons Learned program tracks equipment and system design changes made (or considered) at JACADS to improve operation, and ensures incorporation of the changes into the U.S. plants. The Programmatic Lessons Learned program captures the changes to operations such as those embodied in changes in the Standing Operating Procedures (SOPs) and other operational guides that were developed at JACADS. The Lessons Learned programs are essential in transferring experience from JACADS to U.S. plants.

The lessons learned are incorporated into the U.S. plants by several means. Design changes derived from JACADS experience and reviewed by the Army will be included in the designs of the new plants. Operational lessons are similarly controlled by Army direction to its contractors, and by Army review.

Improved training is an essential element in maintaining and improving U.S. plant operations. Since OVT began, the Army has developed a much more comprehensive training program than that used at JACADS, and includes the use of simulators and realistic training on actual demilitarization equipment at the Chemical Demilitarization Training Facility (CDTF), in addition to classroom work. The JACADS experience demonstrated the importance of this program.

Although several differences exist between JACADS/OVT and U.S. plants, it is MITRE's conclusion that the OVT experience did provide a sufficient basis to establish that safe operation, environmental compliance, and adequate process performance can be expected at U.S. plants.

SECTION 2

SAFETY PERFORMANCE

JACADS met the OVT safety performance goals that were established for it. As expected, there were no injuries or fatalities arising from the processing of agent or munitions. Industrial injuries were within the range typical of industrial facilities using analogous processes. Events did occur that challenged the levels of protection designed into JACADS. While none of these presented (nor could have presented) significant public risk, some events increased the probability of agent exposure or injury to workers. The lack of agent or munition injury demonstrates the importance of having "safety in depth" incorporated into the facility design and operation.

2.1 BACKGROUND

The safety evaluation included consideration of injury or potential injury to the workers or the public arising from the three distinct sources of risk: exposure to chemical agent, munitions (fire and explosion), and industrial operations.

It is obviously desirable to conduct a process such as JACADS in a totally safe manner all the time; i.e., without injury or possibility of injury to workers or the public. However, since no activity is totally safe (including leaving the munitions in storage), any demilitarization process must be designed to include multiple levels of safeguards, and must be operated with rigorous attention to the requirements of safe operation. While a process such as JACADS does operate safely virtually all of the time, inevitably there are occasions when errors or faults occur that challenge the successive levels of protection. The safety experience of JACADS OVT includes both the record of normal operation, and those occasions when the design safeguards were challenged.

Risk analyses performed as part of the planning for the U.S. plants have shown, on the average, that more than 5,000 years of operation of a JACADS-type facility would likely occur without fatality to a member of the public. Obviously, a test of JACADS for 1-2 years of actual operation, in a location that has a very low population, would not, by itself, prove that the public safety of plant is as good as predicted. The expected risk of injury or fatality from agent- or munitions-related causes for workers as shown by the safety record of the Army chemical demilitarization program was also so low that no worker fatalities or major injuries were likely in a test of this duration.

Thus, evaluating the safety experience also required examining whether events and incidents occurred that did not lead to injury, but might have done so if some condition of the event had been plausibly different. Of course, judgment is required in identifying the relevant events, and in estimating their degree of significance. The Test Directive that established the methods of OVT evaluation labeled these incidents, as well as all agent discharge events, as "critical events". Critical events were to be identified and discussed in the OVT reports as relevant to the safety concerns of the test. Four significant agent-related critical events occurred in 32 months of testing. None of these resulted in injuries. The events are described in appendix B.

Finally, some problems associated with system design or operations created situations that appeared to increase the possibility of injury, even though not necessarily meeting the criteria of agent-related critical events. These are discussed below in section 2.5 as some of the areas of concern.

2.2 JACADS SAFETY CONSIDERATIONS

The JACADS facility is designed to maintain safe engineering control of agent; exposure to or release of agent under normal and emergency conditions is not possible due to any single human failure or single event failure of the plant systems. One of the best examples of the use of multiple levels of protection are the steps taken to keep agent within the MDB and prevent its discharge into the environment. In addition to airtight doors, in all areas where agent might be present, the plant operates at a pressure below atmospheric, so that any air movement is into the plant, which means agent cannot leak out. The only places where agent can normally leave the plant are through the ventilating system discharge (which is charcoal filtered and monitored), and the furnace exhaust systems (which are subject to high temperature and are monitored). Even if the ventilating system, furnace systems, power supplies, and backup power supplies should fail, the plant remains tight, allowing sufficient time to reactivate these engineering controls.

Another design feature is that virtually all the processing of the munitions and agent is by mechanical and automated equipment, under computer control, with both software and hardware safety interlocks and with human (operator) oversight. Checks and balances are built into the mechanical and the human operating systems to minimize the effects of human error or equipment failure.

These same techniques minimize danger from the energetic material in the munitions (i.e., explosion or fire from the explosives or rocket propellant present). Operations that involve a potentially significant risk (e.g., shearing rockets into parts) are conducted in an explosion-

proof room, with controlled amounts of munitions present. The incineration of the disassembled and sheared munitions is conducted in a controlled manner, so that quantities of energetic materials burned at any one time are limited. The DFS incinerator that destroys explosives, its enclosure, and associated equipment are designed to contain the effect of an explosion if one should occur.

Additional design and operational safety features include:

- Use of extensive staff training and certification programs, as well as the holding of contingency exercises to test emergency operations and training
- Provision of SOPs and related documents to guide most normal operations
- Establishment of Limiting Conditions of Operations, which is a list of requirements that must be satisfied before starting and while continuing demilitarization operations
- Use of intensive inspection and enforcement activities by the operating contractor, the Army on-site personnel, and visiting inspectors and reviewers
- Conduct of formal investigations of events that had potential safety implications

The operating contractor conducted a safety program throughout the OVT. This program was under the direction of the safety department. Although the staffing level and activities varied through the OVT, the safety staff generally performed the following:

- Conduct walks through the facility during each shift
- Identify, write citations for, and follow up on safety violations
- Identify and improve plant practices that could be performed in a safer manner
- Participate in the evaluation and review of safety events
- Provide safety training
- Assist operations and maintenance staff in developing safe procedures
- Conduct all required safety inspections and activities
- Approve safety-related operation or maintenance activities
- Advise and participate in emergency event mitigation
- Review SOPs

The U.S. plants will embody the same general safety approaches used at JACADS. These include emphasis on engineering safety into the building and process design, extensive training

of staff, and oversight of operations. As discussed in section 1.3, lessons learned from JACADS are to be incorporated into both the U.S. plant designs and plant operations.

2.3 WORKER SAFETY

Prior to the beginning of OVT, the Army decided that the measure of worker safety to be used was the Cases With Days Away (CWDA) or lost workday cases. The goal was decided to be 2.1 CWDA per 200,000 hours worked. The Army had demonstrated this level of worker safety at a similar chemical demilitarization plant, and the value is within the range experienced by chemical industrial plants. Figure 2-1 shows the OVT experience by month. The average value over the OVT period was 0.93, which was better than the goal of 2.1.

Although not established as an OVT goal, a second and more sensitive measure of industrial injury is the "recordable case." This includes all CWDA, as well as additional injury cases that do not cause the loss of one or more full days of work. Recordable cases were tabulated during OVT, and the result is shown in figure 2-1. The average rate of recordable cases during OVT was 5.36, which was better than the industrial average of 5.7 per 200,000 hours worked for hazardous waste storage facilities and 14.9 per 200,000 hours worked for refuse incinerator operations.

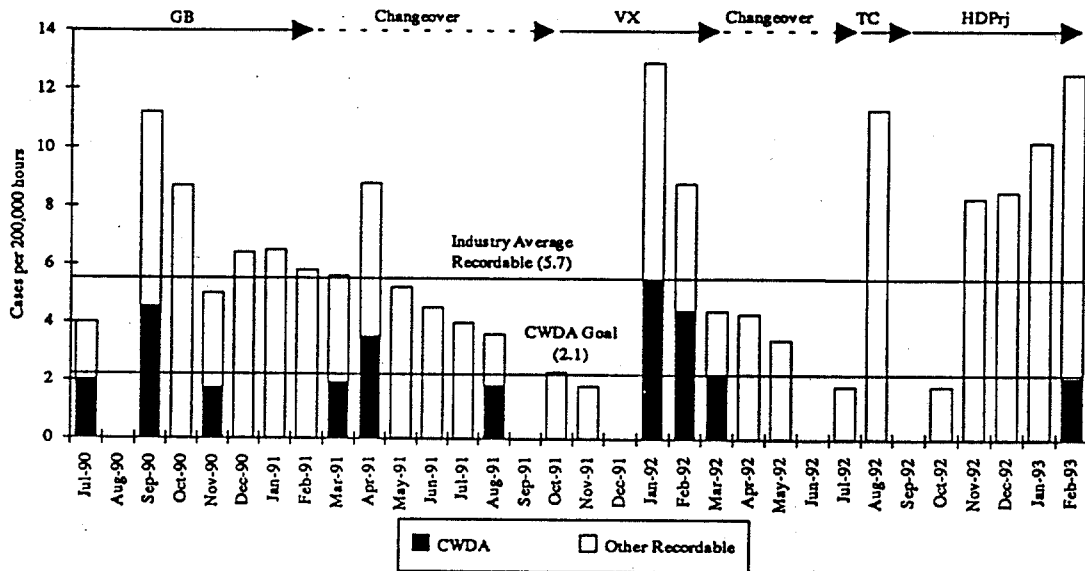


Figure 2-1. JACADS OVT Total Recordable Cases

The recordable case rate was significantly higher in the OVT4 period from November 1992 to February 1993 as compared to the remainder of OVT. The increase resulted primarily from higher rates of injury incurred by maintenance workers in DPE supporting demilitarization operations in the Munitions Processing Bay (MPB). Most of the injuries were related to the manual handling of projectiles which was required as discussed in section 4. Changes in the demilitarization process made in the last week of OVT4 reduced the need for these activities, and will presumably reduce the injury rate in the future. However, the experience demonstrates the importance of monitoring the injury rates of DPE workers operating under physically stressful situations, and the necessity for rapid management response to such experience.

During the OVT period, there were no known cases in which a worker was exposed to agent. Over the course of OVT, approximately 40 clinical lab tests and physical exams were conducted in response to events that made exposure possible, or where the worker expressed concern about a possible exposure. In no case was there evidence of exposure.

There were only two events that MITRE classified as critical events relating to worker safety (appendix B provides additional detail). One event involved mishandling a sample that was erroneously thought to have very low concentrations of agent. In this event, the apparent risk to workers was substantial, although subsequent laboratory and clinical tests showed that no worker had actually been exposed to agent. The second event occurred when an exterior door was kept open into a contaminated area to expedite maintenance activities. Measurements performed after the event showed that the likelihood of agent release to the outside or exposure to workers was very small; however, monitoring outside the door was not performed during the open-door period. In neither case did injury occur, and in both cases procedures were amended to preclude a repetition.

The planned U.S. facilities will embody the same basic process design and safety features as JACADS. Assuming that U.S. plants are at least as aggressive as JACADS in maintaining safe practices, it is likely that the worker safety experience at the U.S. plants will be similar to or better than that of JACADS.

2.4 PUBLIC SAFETY

The major concern of the public is the release of agent to the environment, and subsequent exposure and injury of the public. Because the JACADS facility is located on an edge of JI and downwind from most Island residents, there is little risk to the JI population of about 1000 people even in the event of an agent release. However, for purposes of evaluating the risk to the public at U.S. plants, MITRE has taken this into account by, in effect, assuming

that the public fully surrounds the plant on JI, and by identifying *any* agent discharge as a critical event.

All expected points of possible agent emission from JACADS were continuously monitored. All monitors were checked (by direct challenge with actual agent) every 24 hours, with critical monitors on the common stack checked as often as every 4 hours during operations. Virtually all monitors had backup systems of some type, with the common stack monitors having multiple backups. The monitoring system thus provided a very high degree of assurance that any agent emission would have been detected.

There were no detected releases of agent from any source during normal or transient (e.g., furnace upset) operations of JACADS. One event occurred during cooling of the LIC after a shutdown (this and the event described in the following paragraph are discussed in more detail in appendix B). During OVT1, monitoring evidence during shutdown of the LIC showed that a very small amount of agent was discharged from the common stack for about an hour, with a concentration so small as to be below the reporting requirement. Even though the discharge was insignificant in terms of public (or worker) risk, this event is counted as a critical event, and resulted from inadequate procedures (subsequently modified) during furnace shutdown.

Other than the OVT1 event, there was no measurable discharge of agent from JACADS during OVT. Thus, virtually all normal operation and all transient operations met the Army policy of maintaining zero measurable agent release, rather than just keeping it below permit levels.

The public experienced no injury or fatality relating to munitions or industrial accident events during OVT. In addition, no critical events from these sources were identified.

Transport of rockets from a storage area to a chemical disposal facility's MDB is a particular activity that has raised public safety concerns at U.S. sites. The transport system at JACADS uses trucks to carry the munitions about one-half mile from the storage areas to the MDB. The JACADS OVT munitions transport activity presented no safety events. However, concerns have been raised that the type of transport system used at JACADS may provide insufficient physical protection for the munitions in the event of a transport accident at U.S. locations. Given these transport risk concerns, the Army has decided to use a more robust container for the U.S. sites. With this container system, any risk present in the transport of munitions at JACADS will be greatly reduced in the U.S. plants.

2.5 SYSTEM AND OPERATIONS SAFETY CONCERNS

While the safety record of the OVT was good, there were system or operations inadequacies or failures that, while not causing injury or being identified as critical events for this report, still raised safety concerns. These failures challenged the safety features of the facility and increased the likelihood of critical events. It should be noted that none of these events or activities led to the release of agent or to worker or public injury. In each area, the Army has or is in the process of addressing the concern, both at JACADS and in the U.S. plants.

- **Back-up Power.** Repeatedly, the diesel backup power system did not operate properly, either by failing to start or by failing to connect to the proper loads in a timely fashion. Complete correction of these problems had not been fully demonstrated at the end of OVT. Even more important, early in OVT the Uninterruptible Power Supply, designed to provide very short-term emergency power to vital plant monitoring and control equipment, failed on several occasions due to operator error. This caused plant control and vital data to be lost. This problem was corrected, and the system operated properly during the remainder of OVT.
- **Fire Suppression.** A small fire occurred during OVT4 in the Explosion Containment Room (ECR). Although there was no release of agent or injury to personnel, the fire led to a four-week downtime. After the fire, several design changes were made to reduce the probability of ignition of energetic material, procedural changes were made, and a fire suppression system was added. The Army is continuing to review the possible desirability of additional fire suppression systems.
- **Ventilation System.** On several occasions, generally after power outages and after at least partial loss of plant control, the ventilation system was restarted improperly. This caused damage to internal walls of the MPB on one occasion, and on others, the potential for inappropriate agent movement within the plant. These problems appeared to have been resolved through equipment and procedural changes by the end of OVT.
- **Projectile Processing.** As discussed in section 4.4, during OVT4 the projectile processing system required the continuous presence of workers in DPE. The use of DPE workers on a continuous basis was not a part of the planned operation. In addition to increasing the cumulative hours spent in DPE, the workers were exposed to risk of injury from moving machinery. The projectile processing system requires

additional engineering modifications and testing to reduce the need for DPE worker maintenance and/or to reduce the risk to the workers.

- **Munition Tracking.** As discussed in section 4, the control systems were unable to track each munition item being destroyed, or to maintain an accurate record of what processing steps had been performed on each. While there were occurrences of loss of tracking during each test, the problems were most serious during OVT4 when several projectiles were inadvertently fed to the MPF without having been drained of agent, and one projectile left the ECR with its burster still in place. Although no discharges of agent occurred and the occasions were not critical events, they did indicate a degree of inadequacy of the control and record keeping systems. Designs for the U.S. plants have been modified to correct most of these problems, and some corrections have been installed at JACADS. Additional testing will be required to demonstrate the full effectiveness of these changes.
- **Agent Alarm.** An event of interest also occurred during OVT2 when an agent monitor at the base of the plant's stack alarmed just above the reporting level during one 10-minute cycle. However, due to incomplete data, this event could not be confirmed as an agent discharge. The Army and its operating contractor conducted an investigation and concluded that the agent monitor alarm was due to an interfering chemical.

The adequate performance of staff is essential to plant safety. Failure to operate process or support systems properly can lead to events that challenge the safe design of the plant. While the training of the staff met mandated requirements, there were many instances of performance errors that either led to problems or exacerbated them. This was true for all staff, whether in the laboratory, maintenance, or operations areas. In general, however, MITRE was unable to determine the relative contribution of staff training and plant design errors in any particular event. Experience showed that some of these performance failures arose from missing or inadequate procedures, but most were the result of staff error which is expected to decrease with improved training.

There were several areas which appeared to include both procedural and worker training issues. As OVT progressed, the Army modified its procedures to correct these problems. While conditions improved significantly, full correction has not yet been demonstrated due to the short duration of OVT. These areas included:

- **Housekeeping.** In general, the plant was not maintained at a high level of cleanliness, but rather, was cleaned in an episodic manner. This was a particular problem early in the OVT, when excessive litter was present in many areas, and it

remained a problem later in the OVT, since adequate storage or disposal was not initially provided for used (contaminated) personal protective gear.

- **Design Changes.** Improved control is needed of design changes in the physical plant. There were multiple occasions of the "as built" drawings not conforming to the physical reality of the plant.
- **Jumper Control.** Improved control is needed of the installation of both hardware and software "jumpers". "Jumper" is a term used to describe a temporary bypass or removal of an interlock that controls some particular action (e.g., a high temperature cutoff in a software control program). The use of jumpers during test and operation is appropriate; however, during OVT there were multiple events of jumpers being installed without authorization, inadequate testing, or insufficient documentation. These actions resulted in systems not operating as expected. In addition, on multiple occasions, software changes were made without appropriate authorization, testing, or proper documentation. These problems were cited in several audits during OVT, but were not fully corrected.

Areas in which additional training or emphasis may lead to performance improvements affecting safety include:

- Identification of the precursors to potential contingency (emergency) events, and what should be done in response to them
- Improved understanding of agent, and how it should be handled
- Training in the requirements of environmental regulations as they affect the operation of the incinerators including the reasons for the regulations, and the importance of proactively identifying problem areas
- Additional training in following procedures that require review of all valve positions, cleanup, and other activities at the conclusion of maintenance activities (There were occasions when failure to follow procedures led to operational problems or events that could have caused injury or equipment damage.)

These are all areas that should benefit from the new, more comprehensive training programs and the CDTF. The new program is to emphasize developing worker understanding of why the systems are designed as they are, so that unusual occurrences can be handled more efficiently in the U.S. plants. The Army plans to apply major portions of this program to JACADS workers. As described in section 1.3, the lessons learned programs help

ensure that the problems and solutions identified during OVT will be transferred to the U.S. plants.

SECTION 3

ENVIRONMENTAL PERFORMANCE

The OVT demonstrated that the JACADS process can meet federal regulatory standards and can operate without adverse environmental impact. Emissions of environmental pollutants during the OVT were within regulated limits. The furnace systems used during OVT demonstrated a destruction and removal efficiency (DRE) for each designated principal organic hazardous constituent (POHC) in the environmental permits that met, and in many cases exceeded, federal requirements. Waste materials were disposed of in approved locations. However, as can be expected from a prototype facility, there were noncompliances with the procedural and administrative requirements in the environmental permits. These occurred particularly during the early part of the OVT, and did not result in adverse environmental impact. These included minor discharges of hazardous waste to the ground, storage of hazardous waste beyond 90 days in buildings that were not under the Resource Conservation and Recovery Act (RCRA) permit, errors in record keeping, and not meeting or conducting inspection requirements in accordance with the RCRA permit. These noncompliances suggest the need for increased attention to procedural and administrative environmental requirements as they apply to U.S. plants.

This section provides a general description of JACADS environmental performance during OVT. Additional details are given in appendix C and in the individual OVT test reports listed in appendix E.

3.1 BACKGROUND

Concerns have been raised regarding possible adverse effects of chemical demilitarization activities. These include:

- Release of toxic chemical agent to the environment
- Release of non-agent pollutants such as carbon monoxide (CO), nitrogen oxides (NO_x), and dioxins from the exhaust stacks
- Release of hazardous substances as a result of handling, treatment, and storage of process-and non-process-related liquid and solid wastes
- Release of waste water effluents into bodies of water

These concerns are addressed by regulations that establish limits on emissions, hazardous waste handling, and operating conditions. These include:

- Resource Conservation and Recovery Act (RCRA). A RCRA operating permit imposes regulations on the management of hazardous wastes, and incorporates standards for emissions and for the minimum DRE that must be demonstrated by the facility. Incinerator trial burns are required to verify conformance to permit requirements.*
- Toxic Substances Control Act (TSCA). The shipping and firing tubes of some M55 rockets contain PCBs, which are regulated under TSCA. Trial burns for the DFS are required to verify conformance to TSCA requirements.
- National Pollutant Discharge Elimination System (NPDES). An NPDES permit, under the Clean Water Act, controls the direct discharge of a pollutant water from a point source to navigable waters. For JACADS, limits on temperature, pH, and suspended solid and copper concentrations are imposed on noncontact cooling water discharged to the Pacific Ocean.
- Hazardous Materials Transportation Act (HMTA). Regulations under HMTA, as implemented by the Department of Transportation (DOT), establish the requirements for transport of hazardous materials, such as container specifications, use of shipping manifests, and hazardous materials classification.
- Internal Army Policies. The U.S. Army has also adopted its own performance standards. For example, the Army requires that emptied munition parts be decontaminated in the MPF or DFS to the XXXXX level (i.e., heated to 1000°F for 15 minutes) to ensure complete destruction of agent.

Although the requirements of the Clean Air Act (CAA) did not apply to JACADS, measurements were made of the discharge levels of some of the pollutants for which national ambient air quality standards have been established by U.S. Environmental Protection Agency (EPA). This data will be used to help project facility performance at U.S. sites where the CAA will apply.

The discussion of JACADS environmental performance is organized into the following categories:

*The term "trial burn" is used in this section to describe any special test or trial burn run to demonstrate that performance meets permit conditions. The various permits and regulations use different terms for this activity.

- Agent air emissions
- Non-agent air emissions
- Liquid and solid wastes
- Environmental procedural requirements

These categories encompass the areas of requirements mandated in the various Federal environmental regulations cited above.

3.2 JACADS ENVIRONMENTAL PERFORMANCE

Among the activities conducted during the OVT were a series of trial burns to demonstrate operational compliance with RCRA and TSCA requirements. The RCRA trial burns were intended to demonstrate compliance with the standards for destruction of chemical agent and other POHCs, hydrochloric acid (HCl) emissions, and particulate matter emissions. For a TSCA authorization, trial burns were conducted to demonstrate the efficiency of the destruction of Polychlorinated biphenyl by the DFS. An extensive set of data were collected before, during, and after the trial burns, which were analyzed to establish furnace performance.

During OVT, JACADS operated within the pollutant discharge limits established by the various permits. Some of the design and operational features that helped achieve this goal include the following:

- Each furnace system includes not only the primary combustion chamber, but also a secondary combustion chamber or afterburner, as well as an extensive PAS. The series combination of these components provides a margin for protection for reduction of emissions both during normal and upset operations.
- Extensive instrumentation and computer control of the furnaces and associated equipment contributed to the high level of conformance to environmental requirements.

Although more data were obtained during the trial burns as compared to normal operation, all critical emission parameters such as agent concentrations (if any), CO, and O₂, and most furnace conditions, were continuously monitored and recorded, and it is this entire record that provides the basis for evaluating the environmental performance of JACADS during OVT.

3.2.1 Agent Air Emissions

No agent was detected from the exhaust stacks during the RCRA and TSCA trial burns, and no agent release was detected during either normal or transient conditions (e.g., furnace upset). An occurrence during cooling of the LIC after a shutdown was discussed in section 2.

The RCRA DRE requirement for the incinerators was also met. For agents GB, VX, and HD, DREs greater than 99.9999 percent were achieved for the LIC. The HD DREs for the MPF trial burn were greater than 99.9996 percent. The slightly lower DRE for the MPF was due to the limitation in the agent detection technology and the smaller quantities of agent fed into the MPF as compared to the LIC. In all cases, since no agent was detected in the stack gases during the trial burns, the actual DRE is better (i.e., higher) than the calculated DRE.

The JACADS RCRA permit also imposes requirements that the temperature of each furnace be maintained within prescribed limits during agent operations. That is, if the furnace goes into an upset condition and the temperature decreases below the permit limit, a low temperature interlock shuts off the feed of the agent or munition. On one occasion during OVT3, this stop feed interlock did not shut off the agent feed to the LIC for about five minutes. However, the primary chamber temperature only dropped 5°C below the permitted lower limit of 2550°C. Moreover, the LIC secondary chamber (afterburner) remained on line, and no agent was detected in the exhaust gases.

3.2.2 Non-Agent Air Emissions

Particulate matter, HCl, CO, and O₂ emissions from exhaust stacks were within regulatory limits during the trial burns. Stack emissions during the trial burns were also analyzed for volatile and semi-volatile products of incomplete combustions, as well as for presence of dioxins and furans. Dioxins and furans in the common stack emissions were low, ranging from 0 to 0.16 ng/m³. None of the dioxins found were the 2, 3, 7, 8 - tetrachlorodibenzo-p-dioxin (2, 3, 7, 8 TCDD) isomer, which is the most toxic form of dioxin. In comparison, municipal incinerators emit dioxins in the 50-7,000 ng/m³ range. Quantities of substances that are listed as hazardous organic constituents by EPA (e.g., benzene, dimethyl phthalate, and toluene) were also detected at levels well below regulatory concern. These substances were most probably fuel contaminants and not products of agent combustion.

Control of CO emission from a furnace system's secondary chamber is a RCRA permit condition which correlates with complete destruction of hazardous wastes. CO remained within permitted levels during agent operations for all furnaces except for five times while the LIC was processing agent or spent decontamination solution. In compliance with the permit,

in each case agent feed was stopped immediately and no agent was detected. Hence, these were not considered noncompliances.

The O₂ concentration in the furnace secondary chamber is also an indirect measure of the relative efficiency of combustion in the furnace since O₂ is necessary to reduce the formation of CO. Throughout the OVT, there were numerous occasions when O₂ emission alarms occurred in the DFS and LIC because the permit limits were exceeded while hazardous waste was being processed. The majority of the O₂ alarms experienced during OVT were attributed to plugging of the O₂ sensing probes. The Army instituted some modifications, which resulted in a significant reduction in furnace downtime from this cause. In each case, hazardous waste feed was cut off, and such events never resulted in any environmental impact. As per agreement with EPA, exceeding the permit limits was not considered a noncompliance as long as new material feed to the furnace is shut off immediately.

The operation of the MPF (during OVT3) did not result in any O₂ and CO emission limits exceedences.

The DFS trial burn surpassed the 99.99 percent RCRA DRE requirement for nitroglycerin. In three out of four test runs, the DRE for PCBs was better than the required 99.9999 percent TSCA DRE. One of the four burn tests resulted in a DRE of 99.999896 percent. However, the PCB emission rate for this test run was below the corresponding emission rates of three commercially-operated PCB incinerators, and below that of the U.S. Army Chemical Agent Munitions Disposal Facility at Tooele, Utah.

JACADS is exempt from CAA regulations, hence there were no required limits for NO_x and sulfur oxides (SO_x) concentrations. However, control and monitoring of NO_x and SO_x pollutants was an operational goal. The emission levels during the trial burns and normal processing were generally below 500 ppm.

3.2.3 Liquid and Solid Wastes

Both solids and liquids were properly disposed of pursuant to the relevant permits. However, handling, storing, transporting, and disposing of liquids and solids from JACADS presented major difficulties that largely centered on administrative and procedural noncompliances with storage and record keeping requirements (e.g., holding material for more than 90 days). There were minor discharges of RCRA hazardous waste during the OVT. Response to these minor occurrences was prompt. These occurrences did not result in any adverse environmental impact.

The liquid waste of greatest quantity was the brine (solution of salts in water) created by the PASs for the furnaces. The brine sometimes was classified as a hazardous waste, due to the presence of heavy metals (agent was never found in the brine). The brine was planned to be dried in the BRA to produce dry salt for disposal. However, the BRA and BRA PAS did not function properly during OVT1 and OVT2, leading to large quantities of brines to be handled, stored, and disposed of by shipping to the U.S.

Tank and other overflows were experienced on several occasions. For example, during the HD projectile test, 20 gallons of brine containing concentrations of cadmium, chromium, and lead at levels slightly above the hazardous waste limits leaked out of the drum dryer exhaust duct onto the ground. Ground sampling showed that no detectable level of heavy metal contamination remained.

The solid residue handling systems did not function as well as planned. The original system which was to shred the waste for transport in fabric-reinforced plastic bags was not operated. The system was modified to control fugitive dust emission. The design for the residue handling system for U.S. plants is very different from JACADS. The residue handling area (RHA) fill station will be located inside the process utility building. Moreover, the system is capable of processing two different types of waste containers: (1) DFS and DUN wastes collected in a waste bin container, and (2) the brine salts collected in a salt container. A key feature of the system will be a slide gate assembly that is hydraulically retracted onto the bins to provide a seal between the assembly and the bins, thus preventing dust emission.

Solid wastes*, including residue from the furnaces, also needed to be handled, stored, and disposed of (by shipping off Island). Difficulties in waste handling were exacerbated by failure of the DUN to function as planned, requiring handling and offsite disposal of a larger volume of solid waste than originally anticipated. In addition to noncompliance of storage and shipping regulations, some minor discharges of furnace residue took place, including one 17-pound loss of DFS residue to the ground. These discharges were classified as hazardous because they contained concentrations of heavy metals at levels above the RCRA threshold values. Ground sampling showed no detectable level of heavy metal contamination remained.

JACADS was generally in compliance with the NPDES requirements. The only problem was demonstrating that the temperature rise limit for the receiving water was met, because the temperature could not be measured properly. The temperature rise of the receiving water has also been shown to be influenced by solar heating, regardless of JACADS operations. This necessitated application for an NPDES permit modification to raise the temperature limit from

* The term "solid waste" is used throughout this report to refer to waste in solid form and is not intended to have the same meaning as solid waste defined in various EPA regulations.

1°C to 2°C. There has been no apparent adverse environmental effect from the seawater cooling system.

3.2.4 Environmental Procedural Requirements

Throughout the OVT period, RCRA procedural noncompliances neither resulted in any release of chemical agent nor did it lead to a release of other hazardous substances to the environment. Nevertheless, the noncompliances may be indicative of the need for improvements in quality control, standing operating procedures, record keeping, and personnel training. Foremost among these non-compliances were the filling of brine and spent decontamination solution tanks beyond the high-level limit, and the intermittent use of the PAS secondary containment for supplemental brine storage. Moreover, there were occasions during the early part of OVT when waste was either improperly analyzed, shipped out of JI with improper labeling, or disposed of safely but without proper authorization. Such noncompliances with DOT regulations involved less than two percent of the total waste shipped out of JI. The Army and Operations and Maintenance Contractor have initiated corrective actions to ensure that these noncompliances do not occur or, at least, are minimized at JACADS.

The Army has submitted a variety of modifications to the JACADS RCRA permit ranging from Class 1 (minor and generally administrative in nature) to Class 3 (substantial alteration to the facility). Although the majority of these modifications fall under Class 1, there were four Class 2 and three Class 3 modifications. The Army submitted Temporary Authorization Requests to EPA for four Class 2 and 3 modifications to allow continued JACADS operations while EPA was reviewing the modification request. Class 2 and 3 modifications require public comment and a public meeting during the comment period; in addition, EPA must consider and respond to all significant comments received on Class 3 modifications.

Some modifications were required because the conditions established in the permit did not reflect the actual design of the equipment in use. Other permit modifications were needed to handle additional waste material (e.g., clean up debris) not originally planned for incineration in the MPF or DFS. The nature of most of these modifications reflect the restrictive operating limits or conditions the Army has adopted, which in many cases exceed (are more restrictive than) Federal minimum standards. A significant number of these modifications might have been avoided by obtaining more realistic permit conditions while still maintaining safety and environmental protection.

3.3 ENVIRONMENTAL PERFORMANCE: AREAS REQUIRING INCREASED ATTENTION

The following areas deserve continued attention to help ensure future conformance to the regulations:

- **Tracking of Permit Requirements.** It took more than a year after the OVT was initiated before the Army and its contractors fully tabulated the RCRA permit requirements and compared them to actual operations. This process of mapping permit requirements with actual operations, as well as the results of environmental audits, identified permit conditions (such as inspection requirements) that could not be met because either the system design or the equipment in use differed from what was assumed in the permit. Although the Army has recognized this problem and instituted operational permit changes, it had not completely resolved all procedural and administrative noncompliances at JACADS by the time OVT ended. Indeed, the lessons learned from this experience underscore the need for increased attention in tracking environmental requirements early in the environmental program at U.S. plants. The Army has directed its TOCDF contractor to prepare an environmental compliance database that identifies all permit requirements. A program is in place to achieve more comprehensive tracking of requirements, and stronger environmental staffing at U.S. plants (as compared to JACADS startup).
- **Realistic Permit Conditions.** The Army found it necessary to obtain numerous permit modifications. These were needed because the original permit contained conditions that artificially restricted use of the furnaces for designed operations. For example, permits unnecessarily limited the types of waste to be fed to the DFS and MPF, thus requiring permit modifications to accommodate the waste materials to be disposed of. Permits should be sought that allow reasonable response to actual operational needs consistent with environmental protection. It should be noted that this may be difficult to achieve since permit conditions are established by federal and state regulatory bodies.
- **Waste Management Systems.** A number of difficulties were experienced in the overall waste management program. Operation and permit compliance of the DUN and BRA were not demonstrated fully during OVT. As a result of the DUN's unavailability, dunnage was disposed of by open burning at JI—an option not likely to be approved in the U.S. Failure of the BRA to operate properly during OVT1 through OVT3, resulted in a substantial problem in handling and disposing of brines generated in the various PASs. While the basic technology of the BRA appears sound and its capability to dry brines has been demonstrated during OVT4,

compliance of BRA source emissions with RCRA requirements has not been demonstrated. Approximately 3.4 million pounds of brine from OVT1 and OVT2 were shipped offsite. Had the BRA operated efficiently, this quantity of brine could have been reduced to about 509,840 pounds of salt. While U.S. plants may have more options available to them for dealing with similar waste management problems (e.g., availability of commercial hazardous waste sites), more advanced planning for contingencies and backup systems would benefit the waste management program.

- **Control and Monitoring of Operational Parameters.** Some difficulty was encountered in maintaining the proper pH for the brine circulating in the packed bed scrubber of the LIC PAS during destruction of HD agent at high feed rates. Such pH control is required to ensure that acid gases are removed by the caustic brine. JACADS also encountered difficulty in monitoring the temperature of cooling water (sea water) discharge as required in its NPDES permit with very few months of having all required monitoring data collected. The Army has adopted corrective measures to address these problems. U.S. plants would benefit from this experience. While the specific events described here (e.g., sea water temperature monitoring problem is site-specific) may not occur in U.S. plants, consistent control and monitoring of operational parameters is necessary to ensure acceptable environmental performance.
- **Waste Disposal.** The RCRA permit was modified during OVT4 to allow destruction of agent-contaminated miscellaneous (non-DPE) debris in the MPF and DFS. This modification provided a much-needed means of disposing of debris accumulated during maintenance activities; some of which was previously shipped offsite for disposal in a hazardous landfill. Used DPE suits were originally intended to be burned in the DUN. However, although the Army decided to dispose of decontaminated DPEs in landfills; at the end of OVT, agent-contaminated DPEs remained in storage at JI. Final disposal has not been resolved. Contaminated DPEs make up the majority of approximately 125,000 pounds of waste contaminated with agent that is stored at JI. Large quantities of DPEs are expected to be used at U.S. plants. The Army is conducting a DPE study at the Chemical Agent Munitions Disposal System (CAMDS) facility in Tooele, Utah to evaluate various decontamination methods and decontamination solutions to achieve a XXX decontamination level. The JACADS experience and future U.S. plant operations underscore the need for increased attention to this issue.
- **Personnel Training.** The presence of agent and the Army regulations governing its handling made the management of waste streams even more complex than in a typical chemical process facility. Such complexity contributed to the difficulty of

ensuring effective operator training, particularly regarding compliance with environmental regulations. The Army and its contractors have not only increased the number of environmental compliance staff, but have also taken concrete measures to improve personnel training on environmental issues. An important aspect of the new training philosophy is the establishment of the CDTF in Edgewood, Maryland. JACADS and U.S. plant personnel will undergo extensive training at the CDTF not only to understand how systems and equipment are operated, but also why they are operated as designed. It is expected that training on environmental standards will be an important aspect of the overall training program.

3.4 POTENTIAL ENVIRONMENTAL ISSUES AT U.S. SITES

The JACADS experience provides extensive data to help address many of the state regulatory concerns for the environmental safety of U.S. plants. For example, the State of Utah has required the development of extensive additional information to ensure that breakthrough of agent from the ventilation system's carbon filters will not occur. JACADS data demonstrated a very large safety margin in the filter design. The Army is currently conducting a study, using JACADS and other test data, to provide the basis for requesting Utah to rescind this requirement.

Another example relates to Indiana and Kentucky regulations requiring monitoring data from a comparable facility to show that there are no emissions from stacks or fugitive sources that present a risk of an acute or chronic health effect on humans. The JACADS experience showed only one occasion when agent was released to the environment, and even then the amount released was insignificant in terms of adverse health effects. The toxic effects of chemical agents are well understood, and standards for the protection of both workers and the public have been developed under the guidance of the U.S. Department of Health and Human Services (DHHS). In addition, using data obtained from the DFS and LIC trial burns, an Army study (reference listed in appendix E) showed that the carcinogenic and noncarcinogenic risks from operating these furnaces are negligible and substantially below the levels of concern set by DHHS and EPA. Although the Army's experience to date strongly supports the contention of no significant risk to human health, additional data may be needed depending on how state regulators interpret and implement these regulations.

There are other areas, however, where JACADS experience alone does not provide sufficient data to demonstrate that state environmental concerns can be addressed fully. Additional information would be needed to address the following state requirements:

- Indiana and Kentucky require more stringent agent DREs (99.9999 percent) for all furnaces as compared to the Federal RCRA requirement (99.99 percent). Utah also requires a 99.9999 percent DRE for the LIC, but only 99.99 percent for the other furnaces. The DFS and LIC at JACADS have been demonstrated to meet these more stringent DRE requirements. The MPF has not demonstrated a 99.9999 percent DRE, but this was largely due to limitations in agent detection technology and not in the ability of the furnace to completely destroy the agent. The State of Utah also requires trial burns to demonstrate a 99.9999 percent DRE for all furnaces using surrogate agents. Additional attention will be needed to address this requirement.
- Chemical agent is a listed hazardous waste under Indiana, Kentucky, Maryland, and Utah regulations. The Army may need to petition for delisting residues from demilitarization, treatment, and testing of chemical agents. These residues include all solid and liquid generated from agent-contaminated furnace fuels, including decontaminated projectile bodies and other materials suitable for recycling. The State of Maryland has delisted liquids and residues from chemical decontamination of chemical agents, but it does not appear that residue resulting from thermal decontamination is part of Maryland's delisting. The Army currently has a program in place to identify test methods and procedures necessary to delist selected waste streams. This program specifically addresses Utah regulations. The Utah Department of Environmental Quality is currently reviewing the Army's delisting plan as it applies to materials stored at Dugway Proving Ground and the Tooele Army Depot.
- Maryland's Toxic Best Available Control Technology (T-BACT) rule requires the installation and operation of a T-BACT and an analysis showing that emissions of toxic air pollutants will not seriously endanger human health (mustard is classified as a carcinogen). Since JACADS operations did not lead to any release of mustard agent to the environment, meeting the substantive portions of these requirements should not be a problem. However, the Army's ability to satisfy the regulation may depend on the detailed interpretation of the regulation.

SECTION 4

PROCESS PERFORMANCE

During OVT, JACADS demonstrated the ability to demilitarize M55 rockets containing GB and VX, and ton containers and 105mm M60 projectiles containing HD. During the tests JACADS generally met or came close to meeting its short-term (one shift) throughput goals, but did not meet the long-term average throughput goals established prior to testing. Process improvements that have been demonstrated or planned will likely allow similar plants in the U.S. to achieve improved results substantially closer to the JACADS throughput goals, although still falling short of the original process design goals at least in the near term.

4.1 BACKGROUND

Process performance describes how efficiently the demilitarization plant accomplishes its purpose. This includes considerations of how well the various systems operate, how well the staff runs the plant, the pattern of operation, and the bottom line: the rate at which munitions are destroyed, as averaged over hours, days, or even months of operations. The cost and schedule projections for the disposal of the U.S. munitions are based in part on achieving system design throughput rates, as adjusted by the Army for life cycle costing. The cost and schedule also depend on achieving the planned operating schedule, i.e., the number of shifts and operating days per week (taking into account expected equipment failure rates and repair times). The calculation of the actual effects of the projections presented in this report on the programmatic life cycle cost and schedule is outside the scope of this report.

In this section, the demilitarization rates demonstrated at JACADS will be discussed and the likely rates in U.S. facilities will be projected. System performance and the major factors that affect throughputs are also described.

Throughput

The performance of a demilitarization plant is measured by the rate at which the plant destroys munitions over some specified averaging time, i.e., the throughput. For example, during the VX rocket test (OVT2), JACADS destroyed the following:

- 32 rockets per hour (R/hr) average during the best 10-hour day (shift)
- 6436 rockets during the last 40 calendar days of the test

Since JACADS operated only during one or two shifts and U.S. facilities will operate 24 hours/day, the JACADS data must be adjusted onto a **24-hour basis** to reflect the best estimate of what the throughput would have been if the plant had been operated for 24 hours. Using the data for the last 40 calendar days of OVT2, we estimate that if JACADS had operated 24 hours/day as well as it actually did during OVT2, it would have processed 14.4 R/hr. Appendix D provides a more detailed description of the 24-hour basis calculation.

Different throughput calculations are useful for different purposes. If one is interested in the fastest demonstrated operation of the plant (to compare to peak design rates), then one might use the throughput from the best hour as the reference. However, if one is interested in the demonstrated ability to operate over the long term (taking downtime into account), one might use the 24-hour basis adjusted data.

The Army and its contractors established design average throughput rates for each of the demilitarization processes at JACADS. To do this they used the best available estimates of the performance characteristics including design peak rates, probable failure rates, and repair times of the individual hardware items in the system. Taking into account the likely startup problems for JACADS, its prototypical status, and the likelihood that the relatively-limited test duration would not be sufficient to reach the ultimate design rates, two OVT goals were established for each test:

- The first goal was to demonstrate that the process designer's average throughput rate could be achieved during at least one operating shift (about 8 hours) during the test.
- The second goal was to demonstrate a reasonable average throughput rate over a planned extended period of operation in the last portion of each test (the "full-rate" phase). This goal was about 2/3 of the designer's average rate to allow for the fact that JACADS is a first generation plant undergoing startup operations. This rate is computed on a 24-hour basis as discussed above.

Since each OVT test would require operation with a new munition or agent, each test (except for OVT3 which was too short to allow full phasing of operations) was further divided into three phases to allow for identifying and correcting initial problems. The first phase would have a duration of about eight weeks, with a planned attempted throughput rate of 1/3 the full-rate goal, the second phase of four weeks at 1/2 the full-rate goal, and the final four weeks at the full-rate goal. In practice, the plant was operated to maximize the throughput during each phase and the reduced rates were used as subsidiary goals for the phases. As expected, none of the tests followed the precise plan; however, in each case

MITRE has identified an appropriate period corresponding to the "full rate" period originally planned.

The U.S. plants will be of somewhat different configuration from JACADS, will operate under different conditions, and will have the benefit of lessons learned. Therefore, projected rates for the U.S. plants, while derived from the 24-hour basis throughput demonstrated at JACADS, will be somewhat different. The U.S. plant projections presented here exclude time spent in startup activities, including "debugging" systems and equipment, and also exclude time spent changing the systems from one munition or agent to another. The projections include consideration of the major physical and operational characteristics of the U.S. plants and the lessons learned from the OVT. Of course, as the detailed planning for each site develops, and as additional operating experience is gained, additional modifications can be made to the projections.

4.2 OVT1 AND OVT2 ROCKET TESTS

The first test during OVT was the planned destruction of M55 rockets containing GB nerve agent; the second test was the planned destruction of identical rockets containing VX nerve agent. Both nerve agents are liquid at normal temperatures. Since the two tests involve virtually identical processes, this report treats them together in this section.

Although the demilitarization techniques for the two munitions are virtually identical, the monitoring system must be aligned and calibrated for the agent being handled. This was done during a changeover period between OVT1 and OVT2. This period, originally scheduled to last for 1-2 months, also included performance of substantial repairs and upgrading of plant systems, as described below. The changeover period was extended to 8 months to allow for x-ray and other testing of several of the piping systems in the plant.

Table 4-1 summarizes the overall results of OVT1 and OVT2, while figure 4-1 shows the number of rockets destroyed on each day. As can be seen, the number of rockets destroyed per day was substantially higher in OVT2 as compared to OVT1. This increase was due to improved process operation (i.e., higher throughputs during operating hours), and to operation for more hours per day. Figure 4-2 shows the number of hours operated at each throughput rate for both tests. This figure shows that even with a shorter OVT2 test period, there were more operating hours accumulated (i.e., hours with at least one rocket destroyed), as well as a higher rate achieved during the operating hours. The increase in hours operated per day was achieved primarily through a greater number of scheduled hours per day, made feasible in part by improved operations.

As can be seen in figure 4-1, operations during the last ten days appeared to improve further with all days showing processing. This period occurred after modifications of the DFS including changes to the air handling in the DFS room that lowered the room temperature and may have reduced failures of the heated discharge conveyor, and improved cooling to the thrust bearing. Although the duration of this period was too short to verify the long-term ability to operate at higher rates, the period does demonstrate that the JACADS system, even without the planned major modifications, has the potential for further rate improvements.

Table 4-1. Summary of Rocket Tests

Item	Planned	Performance
OVT1		
Duration	16 weeks	32 weeks
# Rockets	9,984	7,449
Best Shift	32 R/hr (goal)	27 R/hr
Full Rate (24 hr basis)	24 R/hr (goal)(note 1)	15.3 R/hr (note 2,3)
OVT2		
Duration	17 weeks	19 weeks
# Rockets	13,889	13,889
Best Shift	32 R/hr (goal)	32 R/hr
Full Rate (24-hr basis)	24 R/hr (goal)(note 1)	20.6 R/hr (note 2,4)

- Notes:
1. 24-hour basis
 2. Modified operating window data from OVT2 report
 3. Excludes modification shutdown period.
 4. Excludes downtime due to kiln detonation.

Both tests produced throughput results that were substantially less than the original goals, especially when averaged over weeks of operation. This shortfall arose from lower than expected peak (hourly) rates, and undocumented as well as documented downtimes.

The average 24-hour basis throughputs over OVT1 and OVT2 were 6.9 and 11.1 R/hr, respectively, and the last five weeks of OVT2 (the full-rate part of the test) showed a 24-hour basis rate of 14.4 R/hr. In contrast, the expected average throughput rate goal for

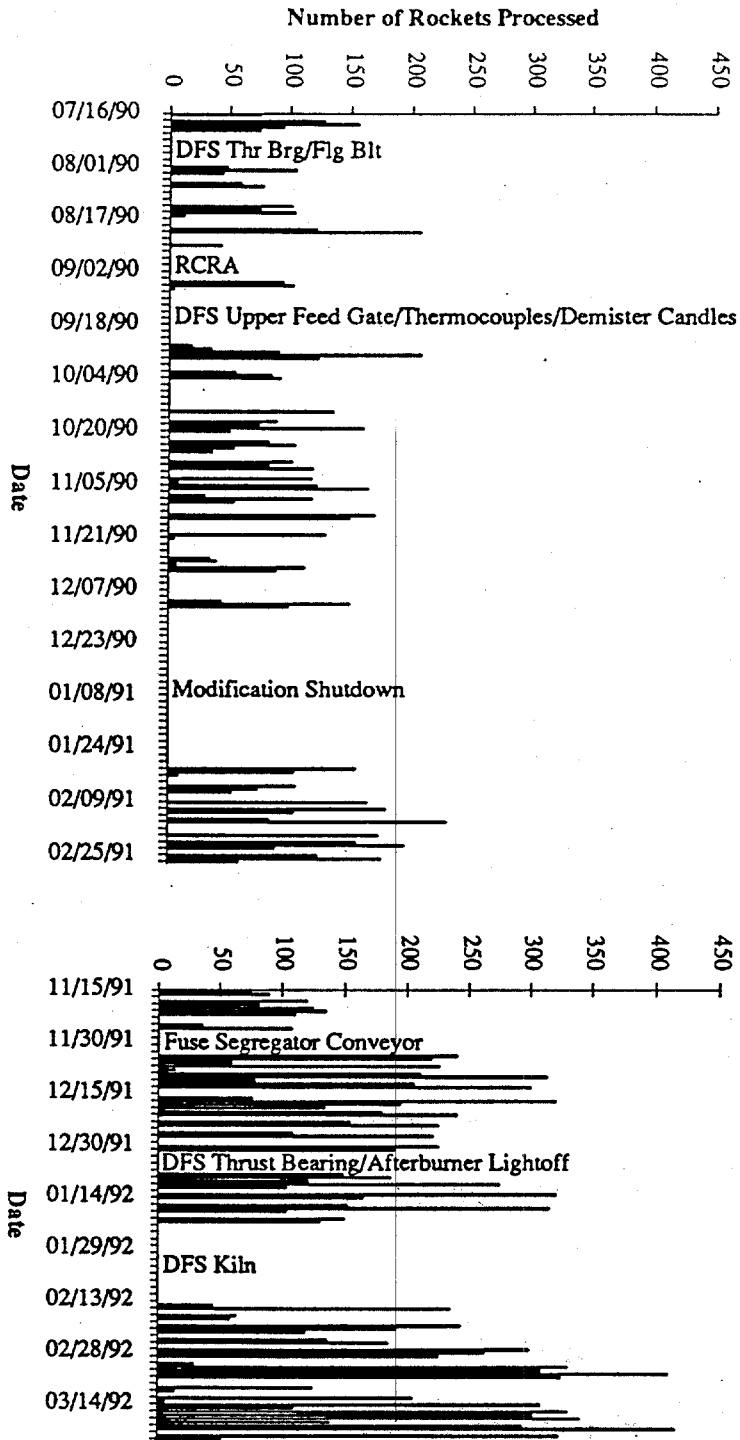


Figure 4-1. Number of Rockets Processed Each Day

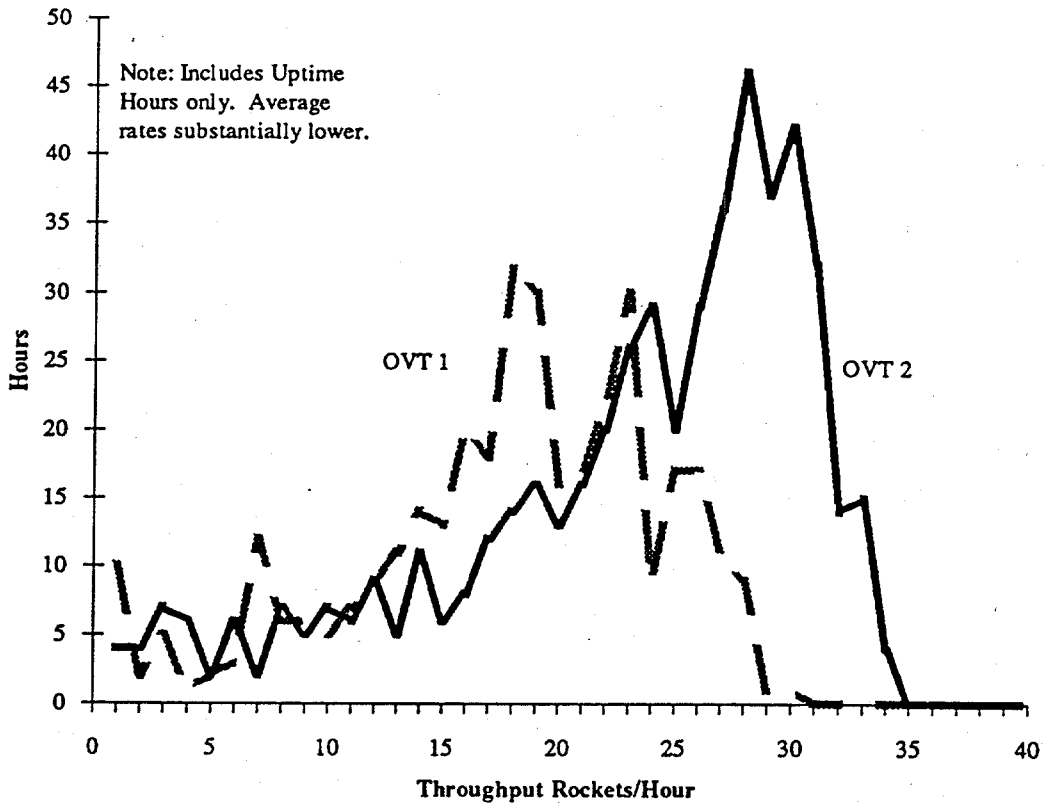


Figure 4-2. Rocket Tests: Number of Hours at Throughput

the full-rate portion (final phase) of each test was 24 R/hr. As discussed in more detail below, the reasons for the shortfall included:

- The inability (primarily caused by the DFS) to operate at its design peak rate (44.3 R/hr)
- The effects of undocumented downtime (outages or interruptions of fewer than 15 minutes)
- The effects of documented downtime (outages of more than 15 minutes)

The average throughput goal of 24 R/hr for JACADS was based on using automated operations to achieve a peak design throughput rate of 44.3 R/hr, a limitation set by furnace capacity. For several reasons enumerated in the OVT1 report (see appendix E for listing), the furnace capacity limited the peak throughput to about 30–34 R/hr (in contrast to the 44.3 R/hr assumed when the goal was set). Using this peak processing rate, and other factors remaining equal, the expected average throughput rate would have been about 18 R/hr (vs. the 24 R/hr goal). Since the average throughput achieved during the last portion of OVT2 was only 14.4 R/hr, it is clear that the failure to achieve the expected peak rate was one of the major contributors to the low average throughput during OVT1 and OVT2.

During both OVT1 and OVT2, there were many short downtimes or slowdowns in operations. Lasting from a few seconds to 10–15 minutes, in this report these are referred to as undocumented downtimes because they were not individually catalogued. However, analysis of the data showed that they were a significant cause of reduced throughput for operating hours with fewer than 32 rockets per hour, but which had no documented downtime. The main causes of undocumented downtimes were handling minor operating problems in the RSM (e.g., shifting from computer to manual control to reposition a rocket) and responding to equipment alarms (e.g., low water flow) elsewhere in the plant. The amount of undocumented downtime was significantly reduced in OVT2.

There were many contributors to documented downtime. Although there were many short downtimes of 15–30 minutes, the majority of documented downtime ranged from many hours to many days. As JACADS operated through OVT1 and OVT2, causes of downtime were identified, and corrections designed and implemented. Most, but not all, of these were successful.

Several problems accounted for a large portion of the documented downtime. These included:

- **Kiln Bolts.** DFS kiln flange bolts failed due to the use of inadequate materials of construction. This was corrected by redesign and replacement of the bolts during the December 1990 shutdown in OVT1.
- **HDC Slag.** Melted aluminum from the rocket warheads was discharged from the kiln onto the Heated Discharge Conveyor (HDC), which was constructed of stainless steel mesh. The slag built up on and dripped through the mesh, causing damage to the heating elements, conveyor drive system, and HDC discharge gates. During the OVT1, various corrections were attempted, but with only partial success. During the OVT1-OVT2 changeover, the mesh conveyor belt in the HDC was replaced by a bucket conveyor system to contain the molten slag and prevent it from damaging the system. An explosion-proof enclosure was constructed around the HDC residue bin to allow the HDC discharge gates to remain open during operation. These corrections effectively solved these problems.
- **RCRA Permit.** The RCRA permit for JACADS imposed specific discharge (emission) limits, various operating requirements such as furnace temperatures and oxygen levels, and also data recording and record keeping and other administrative requirements. During the OVT1, it was found that not all the operating data were being recorded on the time scale required by the permit, and that certain other inspection and record keeping requirements were not being met. Although the data records were sufficient to demonstrate that the plant had, in fact, operated within the emission and operating limits of the permit, the plant was shut down for ten days while the computer programs for the data recording were corrected.
- **Kiln Detonation.** During OVT2, a detonation in the kiln occurred that created a hole in the kiln wall of about 2x8 inches. The explosion was presumably caused by a burster or other energetic material in the kiln. The explosion caused no other damage and no agent release, thus verifying the protective design of the DFS, including the new receiving bin structure. The kiln was repaired and operations restarted. The CONUS plants will have a much thicker kiln wall, further reducing damage from such an event. JACADS is also to be retrofitted with a kiln having thicker (2 inches vs. 0.5 inch) walls.
- **Thrust Bearings.** During OVT2, the thrust bearings that hold the kiln in place overheated and failed. This had been a problem during OVT1 as well. Although cooling was applied to the bearings and to the DFS room, the resolution of the problem has not been fully demonstrated. The Army plans to remove the bearings from inside the kiln shroud to reduce the heating load placed on them.

- **Fuze Segregation Conveyor.** As part of the RSM design, the first shear of the rocket removed the fuze from the rocket. This was placed on a separate fuze segregator conveyor, while the remainder of the rocket (including rocket propellant) was sent to the kiln. After an appropriate number of fuzes were accumulated, they were sent separately to the kiln. This was designed to reduce the risk of explosion by separating the fuzes from the rocket burster. Part way through OVT2, the fuze segregator conveyor had accumulated sufficient operating problems that the decision was made to abandon its use, and to separate the fuzes and rocket burster by operational means. This solution proved to be effective.

Although there had been some expectation that the RSM reliability might be a major factor in limiting the throughput during OVT1, the RSM actually demonstrated a relatively high availability of 87 percent. On the other hand, in addition to limiting the peak rate, the DFS had an availability of 44 percent; lower than the design rate of 89 percent. The DFS was the largest source of documented downtime.

The planned durations of OVT1 and OVT2 assumed that there would be a period of about three months at the beginning of each test when the performance would be below the OVT goals. That is, all the major performance problems would have been corrected by three months into each test, allowing the "full rate" goal to be achieved. In retrospect, it is clear that this was optimistic, and that the time required to achieve close to full performance (as shown by similar industrial plants) is closer to two years.

It is important to note that the portions of the plant that are most innovative with respect to demilitarization, such as the rocket shear machine and the agent monitoring system, were not the major causes of downtime during OVT1 and OVT2. Rather, the more conventional portions of the plant dominated both downtime (e.g., the DFS) and the failure of systems to achieve effective operation (e.g., DUN and BRA). An important implication of this observation is that corrections that are required to achieve improved performance do not appear to require new, state-of-the-art advances in demilitarization processes, but rather, a more effective diagnosis of problems and corrective application of known engineering solutions.

Projection of Rocket Performance Rates at U.S. Sites

U.S. plants will be operated differently from JACADS. OVT1 and OVT2 were operated on a one or two shift basis, while the U.S. plants are to operate on a 24-hour basis. Thus, process performance data from the OVT must be adjusted to a 24-hour basis. A major consideration is the choice of the appropriate baseline period from the OVT. Review of OVT1 and OVT2 data showed that the performance of JACADS during the last five-week

period (actually 40 calendar days) of OVT2 was much more uniform than the remainder of the tests, while being of sufficient duration to be representative of long-term operation. This five-week period was chosen as the baseline period.

The data from the baseline period were first converted to the 24-hour basis as discussed in appendix D.

Each downtime was then evaluated to determine whether the cause of the downtime was planned for correction in the lessons learned program. If so, the downtime was removed and downtime from that cause was assumed not to occur in the U.S. plants. If the downtime cause was assumed not to be corrected, the projection contained the effects of the downtime. Downtime that began when not attempting to operate (i.e., at night) was assumed to be caused by the passage of time, and not from rocket processing (the contrary assumption would have reduced the projected throughputs by 10 percent).

Other differences between JACADS and U.S. plants, beyond the incorporation of lessons learned are discussed below.

A major configuration difference between JACADS and U.S. plants is that the U.S. plants are planned to operate two ECRs simultaneously. Although JACADS has two ECRs, it was decided to operate only one during OVT. Two ECRs (each with its own RSM) allow a slightly higher rate of operation since one ECR can continue to operate while the second is in a maintenance or repair condition (especially important for 24-hour operation).

The second difference is that the U.S. plants will incorporate changes to increase the peak rate at which the DFS can process. As noted above, the reduced peak rate imposed by the DFS during OVT was a major factor in reducing the average throughput. Provision of thicker kiln walls and other changes will allow higher DFS processing rates, projected by the Army to be at least 38.8 R/hr.

While there are no apparent fundamental obstacles in achieving these two changes from JACADS, neither has actually been demonstrated in OVT. Therefore, the projections for the U.S. plants have been prepared both with and without these changes. The results of the projections are shown in table 4-2.

Table 4-2 shows the OVT2 entire test average, and the baseline period average for comparison. Future Intermediate Estimate 1 assumes only one ECR and a peak rate of 32 R/hr, i.e., the same conditions as during OVT. However, Estimate 1 includes the effects of correcting those problems seen during the baseline period for which corrections are identified and planned in the lessons learned programs. These have the effect of increasing the expected

24-hour rate from 14.4 (JACADS) to 18.9 R/hr (U.S. plants). Future Intermediate Estimate 2 assumes the same conditions, except that a second ECR is in use. The second ECR increases the throughput from 18.9 to 22.0 R/hr.

Future Intermediate Estimate 3 projects the performance for one ECR, but assuming the planned higher peak throughput of 38.8 R/hr. The single ECR rate of 23.5 R/hr should be compared to the OVT goal of 24 R/hr and the design goal of 32 R/hr.

The U.S. plant estimate assumes the planned U.S. plant operation of two ECRs and the higher peak rate of 38.8R/hr. This compares to an original two ECR OVT throughput rate of 29 R/hr and a two ECR design rate of 39 R/hr.

Table 4-2. U.S. Rocket Throughput Projections

Item	Average Rate 24-hour basis R/hr	Lessons Learned Applied	Number ECRs	Peak Rate R/hr
OVT2 Test Average	11.1	No	1	32
OVT2 Baseline Period	14.4	No	1	32
Future-Intermediate Estimate 1	18.9	Yes	1	32
-Intermediate Estimate 2	22.0	Yes	2	32
-Intermediate Estimate 3	23.5	Yes	1	38.8
-U.S. Plant Estimate	28.3	Yes	2	38.8

It is difficult to assess the reliability of these estimates. Certainly, the projections must be compared to the actual performance during OVT, both as averaged across each test, and as shown during the baseline period in table 4-2.

The assumption that the lessons learned modifications will be fully effective is optimistic. To put this issue in perspective, the downtime causes during the baseline that were assumed to be fully corrected include problems related to the DFS thrust bearings, rocket system hydraulics and photo sensors, DFS home switch, discharge gates, and other mechanical and operating problems that had occurred repeatedly during the tests, and that did not have demonstrated correction before the baseline period. However, in each case the Army has concluded, and MITRE has accepted as reasonable, that the solutions will be effective and applied to the U.S. facilities. On the other hand, if none of these corrections are effective, the

throughputs are reduced by approximately 20 percent. The computations also assume that no new problems imposing substantial downtime will develop.

On the other hand, as shown by the improvement between OVT1 and OVT2, improvements can also be expected on a wide variety of problems as the plants continue to operate. None of the problems noted appear to be fundamental design problems, and all should be feasible to correct with reasonable engineering and testing efforts. Overall, the estimates above appear to be reasonable, with the assumptions that engineering and development work will continue as the plants are brought on line and operated, and that the projected rates should not be expected to be achieved early in U.S. operation.

There continues to be significant uncertainty in the future estimates with regard to the availability of the LIC. Since agent storage capacity was available, the rocket demilitarization process line could continue until the two agent holding tanks were full, even if the LIC was unavailable. The capacity was equivalent to agent from about 1100 rockets. In practice, because of the low rocket throughput rates, the LIC (even with downtime) was not a major factor limiting rocket processing during OVT. However, for 24-hour U.S. operation at the higher rates projected, the LIC may become the limiting system, especially with the smaller agent storage tank capacity planned for U.S. plants. Detailed evaluation of this issue could not be performed with the available data.

In summary, the rocket demilitarization process demonstrated that it can operate effectively and safely, though at less-than-anticipated throughput rates. The shortfall in performance was not caused by the demilitarization technology (e.g., RSM), but rather by the adapted commercial systems (e.g., DFS) in JACADS. As such, it is reasonable to conclude that the process is fundamentally sound, and that significant improvements in throughput can be achieved by a more effective application of known engineering solutions to the demonstrated problems.

4.3 OVT3—TON (BULK) CONTAINER TEST

The HD Ton Container test (OVT3) was conducted over a four-week period as scheduled. There were a total of 67 HD ton containers in the JI stockpile, and all were emptied and decontaminated during OVT, and all the HD removed from the containers was incinerated in the LIC.

The production goals for the ton container process were established in a similar manner as for rocket processing. Complicating the analysis of OVT3 were the effects of the limited duration of the test, the small number of containers, and the need to accumulate inventories of

containers to satisfy the requirements for the trial burns conducted during OVT3. The throughput goals and the actual results are shown in table 4-3.

The design performance for the HD ton container demilitarization system is limited by the maximum capacity of the LIC to burn agent. The design capacity of the LIC for mustard is 1,330 lb/hr, which is equivalent to about 0.78 ton containers per hour based on a nominal 1,700 pounds of mustard per container. The design capacity of the BDS and MPF to drain and decontaminate the ton containers is about 1.71 containers per hour. Thus, the capacity of the LIC is well below the capacity of the BDS and MPF for draining and decontaminating the ton containers. There is also buffer capacity for agent in the agent storage tanks, and for the drained ton containers in the buffer storage area. Thus, it is not necessary for the BDS and MPF to operate continuously in an integrated manner at their respective design rates to meet overall demilitarization goals.

Demonstrating the capability of the JACADS system to drain and destroy agent from ton containers was made very difficult because of the small number (67) of ton containers available on JI. This number limited the duration of the test, and reduced the time available to investigate and correct operational problems that occurred. The test was made even more difficult because of the requirement to conduct RCRA trial burns with the LIC and the MPF to verify that incineration permit requirements could be met. This required that agent and drained ton containers be stored, so that adequate supplies of each were available for the trial burns. Combined with the operating problems that were encountered, these constraints resulted in intermittent operation of the system except for two reasonably steady days of operation during the trial burns.

On one of the four trial burn days, six ton containers were drained while six were detoxified in the MPF. Because of the staging problems noted above, in actual fact the ton containers processed were those stored from earlier operations; however, in effect, continuous processing by the BDS and MPF was demonstrated.

Although the operations were very limited, the simplicity of the process, plus the previous and subsequent operations of the LIC and MPF, allow a reasonably realistic qualitative assessment of the operation at JACADS. However, because the operation was so limited, it is not possible to develop an accurate projection for the capacity of the BDS. This is not critical for U.S. facilities, however, because the LIC will be the limiting factor in ton container processing, even for those U.S. facilities planned to have two LICs.

JACADS Ton Container Performance

The BDS and MPF operated at about 2/3 of the design rate during the trial burn days, which was still above the LIC design rate. Even during that time, the actual LIC operation would have limited the throughput to about 0.70 per hour.

The major limitation on throughput arose from limited availability and throughput capacity of the LIC. However, there were some processing problems with the BDS and associated systems. These included:

- The Air Quantification System (AQS) contains a pump which is designed to withdraw the agent from the ton container. The pumping process presented numerous difficulties including loss of prime and clogging. These problems were only partially resolved during the test.
- The weight of the agent removed was to be determined by an electronic load cell which was to measure the weight of the agent removed. However, accurate tare (empty) weights for the containers were not available. This required that draining be verified by workers wearing DPEs manually measuring the remaining contents to provide the data for the trial burns and DRE calculations.

Neither of these problems appear to present serious, long-term difficulties, but they could not be resolved within the short duration of OVT3.

Table 4-3. Summary of Ton Container Tests

Item	OVT Goal	OVT Performance
OVT3		
Duration	4 weeks	4 weeks
# Containers	67	67 (Note 1)
Rate BDS, MPF, LIC (8 hrs)	0.70 per hour	0.70 (Note 2)

- Note: 1. Plus one additional after the close of OVT
 2. Limited by LIC rate; based on trial burn data only

U.S. Ton Container Throughput Rate

The demilitarization rate and schedule for ton containers is directly dependent on the performance of the LIC. During OVT2 and OVT3, the availability of the LIC was about 55 percent (excluding salt removal time). With incorporation of lessons learned, the availability of the LIC in the future is calculated to be about 71 percent, still below the design basis availability of 90 percent. Assuming the LIC operates consistently at design capacity when burning agent and an average 71.4 percent availability, the JACADS throughput rate for HD ton containers will be about 0.56 ton containers per hour, which is about 80 percent of the design throughput rate. The throughput rate at plants with two LICs would be 1.11 HD ton containers per hour, except at Tooele Army Depot where, due to its elevation above sea level, the rate would be 0.86 ton containers per hour. This is about 70 percent of the design rate for the Tooele chemical demilitarization facility. The requirement to periodically remove accumulated salt from the LIC might further reduce the overall demilitarization rate and thus increase the schedule for demilitarization of HD ton containers.

Although MITRE could not compute a 24-hour availability for the BDS or the overall processing system, it remains clear that the LIC will likely be the throughput limiting system in the U.S. sites.

4.4 OVT4—PROJECTILE TEST

Background

The 105mm M60 projectile includes a fuze, fuze well cup, a burster inserted in a burster well in the agent cavity, and the agent within the agent cavity. The projectile weighs about 35 pounds, and contains about 3 pounds of HD (mustard) chemical agent. The projectile was designed to permit mechanical removal of the fuze and burster, but was not originally designed to permit agent removal. However, the design of the projectile permitted development of a machine that can disassemble the projectile to gain access to the agent cavity. The discussion below assumes familiarity with the projectile demilitarization process as described in section 1, and in appendix A.

An important aspect of the projectile demilitarization process is that it includes several activities that can be conducted independently. For example, as with other munitions, agent removed from the projectile can be stored and incinerated at a later time in the LIC. More importantly, there are relatively large buffer storage areas between the major steps in demilitarization. For example, there is storage capacity for eight trays of projectiles (each designed to hold 96 projectiles) between the PMD (which removes the fuze and burster), and the MDMs (which remove the burster well and drain the agent). Similarly, there is capacity

for eight trays between the MDMs and the MPF (which detoxifies the projectile bodies). Therefore, if the operating patterns of the PMD and the MDMs are highly variable, causing the storage areas to fill and empty, it is difficult to analyze the JACADS data to estimate 24-hour-per-day operation.

The throughput goals for OVT4 were established in a manner similar to that used for OVT1 and OVT2. Specifically, design-based reliability and maintainability data were used in computer models to determine expected peak and average throughputs to be expected in a full performance, 24-hour operation. This design assumed one PMD, and three MDMs to be available (with two actually operating at any time), and that the projectiles would be processed in trays holding 96 projectiles each. The computer models predicted that the PMD would be the limiting factor in the overall process throughput rate.

These design throughput estimates were then reduced to take the prototype nature of JACADS into account, thus producing the OVT4 goals. However, the original goals were based on the Army's plan to use 155mm projectiles for the test. Prior to OVT4, the Army concluded that with the greater supply of 105mm M60 projectiles on JI, full-rate destruction could be demonstrated for a longer time period than with the 155mm projectiles. As a result, goals were adjusted to reflect the throughput expected with the 105mm projectiles. The goals and other relevant estimates are shown in table 4-4.

For the purposes of comparing performance to goals during OVT4, the Army and MITRE agreed that a ten-hour window would be designated during each operating day. Data for processing and downtime from the ten-hour window would be used in computing the performance and for comparison to the values of the original goals. Operations (both production and downtime) outside the window would generally be recorded, but not counted in the ten-hour window throughput calculation.

Using operating data to compute the 24-hour basis throughput requires that a number of factors be considered. For example, the downtime spent in repairing and maintaining the equipment outside the window must be accounted for, and allowances made for the faster repairs expected in 24-hour operation. When calculating either the operation of particular machines, or the whole system, one must consider that failure of a downstream machine, such as the MDM, or filling of the buffer storage (exacerbated by space taken by empty trays), may artificially reduce the throughput of the upstream PMD. Similarly, the PMD on occasion did fail to keep up with the MDMs (even though the PMD was often run outside the 10-hour window to build an inventory for the MDMs). Finally, the variability of operation, and the constraints on throughput imposed by the RCRA permit (discussed below), increase the uncertainties in the calculations.

Table 4-4. OVT4 Operating Window Goals and Performance Results

Component	Goal	Performance (Note 1)
Best 10 hour shift		
PMD	82.7 P/hr	74.2 P/hr
MDMs	N/A	71.9 P/hr
Full Rate Period		
PMD	56 P/hr	35.0 P/hr
MDMs	N/A	31.4 P/hr
Total Projectiles		
Within Window	N/A	18,949 (Note 2)
Total Time	N/A	23,978 (Note 3)

N/A = Not Applicable

- Notes: 1. See next subsection for discussion of performance constraints
 2. Drained and thermally decontaminated during scheduled processing window
 3. Total thermally decontaminated through MPF by the end of OVT

Consistent with the Test Directive, in December 1992, the Army designated the final four weeks of OVT4 (later extended by one week) as the baseline or full-rate portion of the test providing the definitive data for throughput calculations. As can be seen in figures 4-3 to 4-5, the last two weeks of that period (including the week extension) did produce significantly improved operations.

To summarize, the OVT4 goals were used, but applied only to performance within the 10-hour operating window of the full-rate period. The resulting full-rate period average throughput is not on a 24-hour basis. While the data did not allow a 24-hour basis calculation for the whole projectile demilitarization system, a series of assumptions did allow calculation of the 24-hour basis throughput rates for the individual PMD and MDMs.

OVT4-Projectile Throughput Results

Figure 4-3 shows the number of projectiles detoxified each day during OVT4 by the MPF, while figures 4-4 and 4-5 show the number of projectiles demilitarized by the PMD and MDMs.

The performance of the MDMs was generally the limiting factor on daily operations, although other equipment also contributed to reducing throughput, as described in the following subsection. These figures show that the operations were highly variable, especially early in OVT4. Early in the test, it was very difficult for the PMD or the MDMs to demonstrate a several-hour operation even at reduced rates. That is, the machines might operate for a short time, but then break down and require maintenance before resuming operation. During the last several weeks of the test, operations became more stable, although still substantially below the OVT goals. Since the components did not operate in a sufficiently reliable manner to achieve steady state operation, it was not possible to estimate a valid, long-term 24-hour throughput for the overall system.

As table 4-4 demonstrates, the best shift throughput rates, as calculated using only data from within the operating windows, came relatively close to meeting the throughput goals. The PMD has a design peak rate of 126 P/hr (Projectiles per hour) and a design average rate of 82.7 P/hr. The best shift goal was set at 82.7 P/hr and the PMD demonstrated a best shift of 74.2 P/hr. It should be noted that the 24-projectile-per-tray limitation artificially constrained PMD operation and prevented attainment of this goal. The MDMs each have a design peak rate of 75 P/hr and a design average rate of 59 P/hr. Although individual goals were not set for the MDMs, it was expected that two MDMs should be able to more than match the PMD. The best shift for each of the MDMs were 38.4 and 33.6 P/hr, approaching but not quite reaching the PMD rate.

The goal for the full-rate portion for the PMD was 56 P/hr, and the performance demonstrated was 35 P/hr. However, although there were operating periods when the PMD could not supply projectiles to the MDMs, it was more frequently the case that the PMD was artificially constrained by the limited amount of storage area for trays and the lower performance of the MDMs. During the full-rate portion of the test the MDMs operated with throughputs of 16.4 P/hr and 14.6 P/hr.

Since the PMD and MDMs demonstrated the ability to operate at rates approaching the single-shift rate goal, the failure to achieve the longer term throughput was clearly due to the effect of downtimes, and not to a failure to achieve peak design rates.

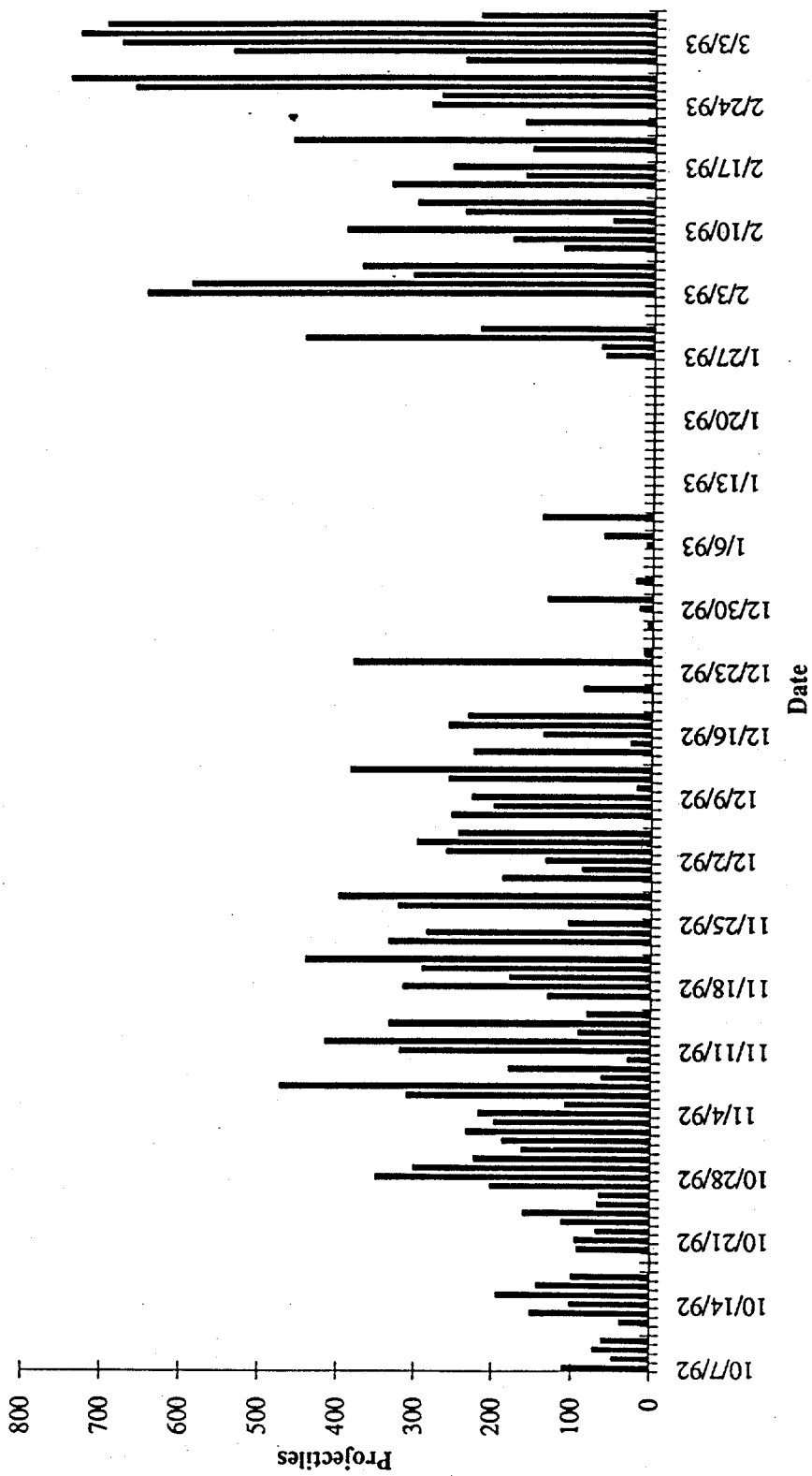


Figure 4-3. Daily MPF Projectile Demilitarization

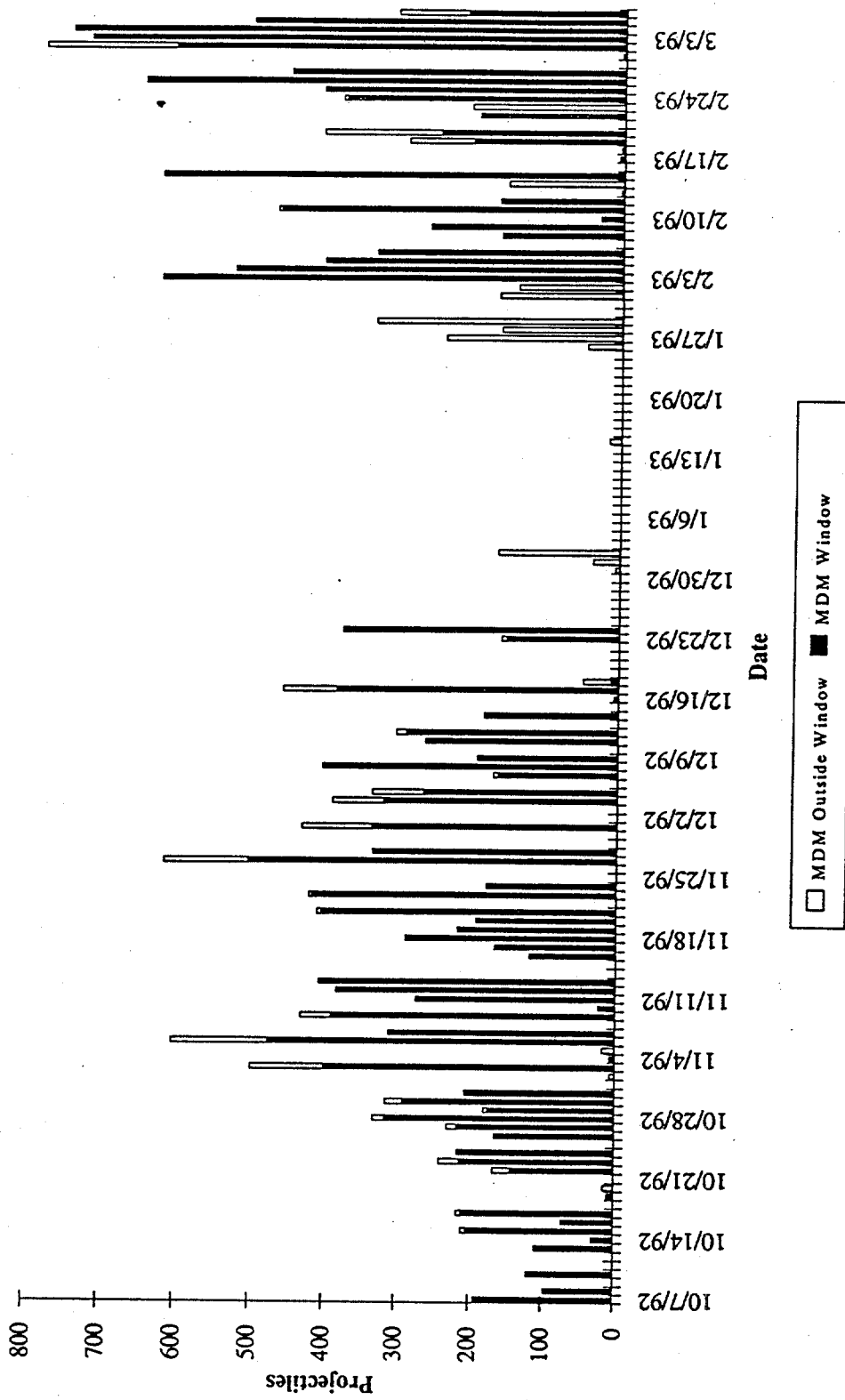
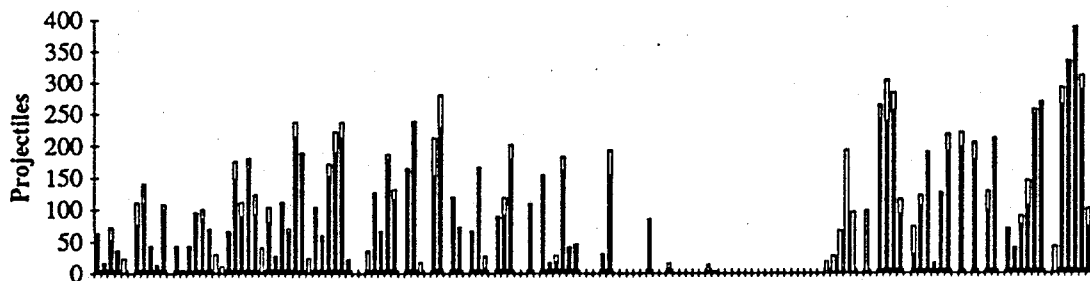
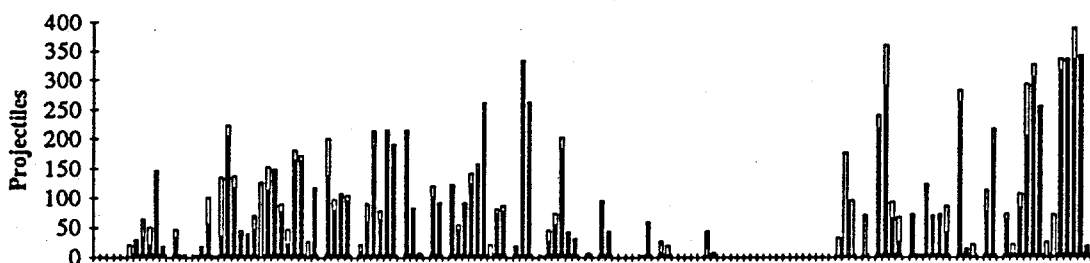


Figure 4-4. Daily PMD Operation

MDM 101 Production



MDM 102 Production



MDM 103 Production

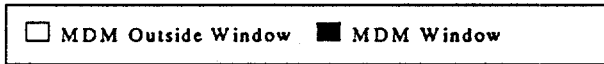
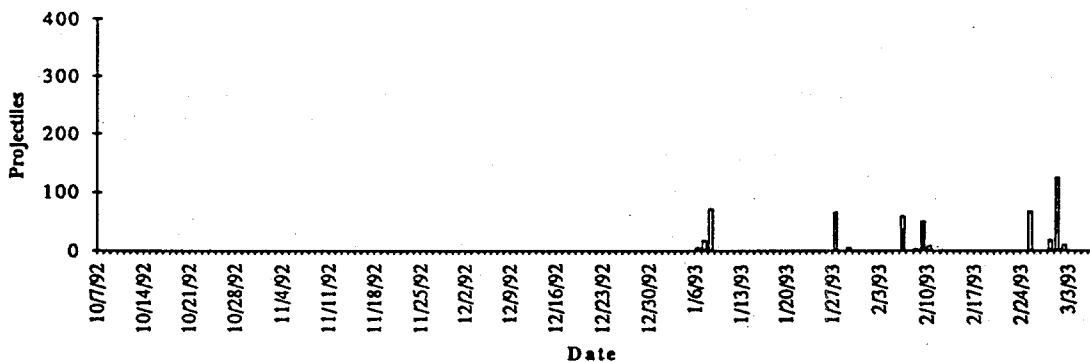


Figure 4-5. Daily MDM Operation

As discussed below, the variability of the operation, the limitations of the tray capacity caused by the drainage problems, and the consequent difficulty of accounting for the effects of the storage, make preparing an overall 24-hour basis throughput problematic. Since the U.S. plants are planned to operate on a 24-hour basis, MITRE has analyzed the data from OVT4 to estimate the 24-hour basis equivalent throughput rates for each machine. The method used is the same as that used for OVT1 and OVT2, and is described in appendix D. Because the operating records do not always allow precise identification of the status and timing of maintenance activities, the analysis is based on data from those days of the full-rate period which have the most complete data. It was assumed that the recorded preventive maintenance durations would have been unchanged with actual 24-hour operation. If a machine operation stopped because buffers were full or munitions were unavailable, the time was treated as potentially available for processing. For this calculation, processing that occurred outside the window was treated the same as processing inside the window. During the full-rate period, about 20 percent of the projectiles were processed outside the window.

The resulting 24-hour throughput estimates are shown in table 4-5, along with the throughputs computed from the operating window data only. As can be seen, the results show the relatively small differences between the two methods of computing throughputs. Note that the window performance data for each machine includes the adverse effect of operational problems in other parts of the demilitarization system. Removing these effects gives PMD and MDM throughputs, during the window, of 47.6 and 35.0 P/hr, respectively.

Table 4-5. Full-Rate Period 24-Hour Basis Projectile Throughput

Component	Window Performance	24-hour basis
PMD	35.0 P/hr	39.7 P/hr
MDMs	31.4 P/hr	30.0 P/hr

During the last week of OVT4, performance improved after changes to process methods were made. These changes included improvements in the agent draining and burster well removal operations. Although the data for the PMD for several of the days were not sufficiently detailed to support analysis, 24-hour basis throughputs were computed for those days for which data were sufficient. Positive adjustments included allowances for the

continuing adverse effects of the 24-projectile-per-tray limitation and burster well handling. Corrections were not included for possible adverse effects of DPE preparation time (since DPE workers would not normally be present) and burster well processing time. The resulting 24-hour basis estimate reflects what the rate would be on a 24-hour basis when the performance problems described below are fully resolved.

The window throughputs of the PMD and MDMs were 61.3 and 61.1 P/hr, respectively, for the last week. The adjusted 24-hour basis calculations for the last week of operation showed a PMD rate of 58.2 P/hr, and MDM rates of 35.6 and 35.3 P/hr. Comparing these rates to those shown in table 4-5 illustrates what appears to be a very significant improvement in processing rates as a result of the improved availability during the operating window. While the data are from a very limited time period, the results tend to indicate that the projectile demilitarization system has the capability of operating at rates close to the OVT goals.

Although the projectile demilitarization system did not operate in a sustained, full-production mode for a sufficient period to evaluate its long-term ability to process projectiles, by the end of OVT4 each major component of the system did demonstrate that it was capable of meeting a substantial portion of at least short-term OVT goals. The performance shows that this technology is capable of successfully demilitarizing this munition. Indeed, as discussed below, there are no apparent fundamental obstacles to approaching the design performance goals. It is clear, however, that additional engineering, testing, and demonstration work remain to be done before reliable operation can take place at design throughput rates for this munition. It must be emphasized that the M60s with HD create unusually difficult disassembly and drainage problems that are not necessarily typical of other projectile types.

Factors Affecting Performance During OVT4

The early portion of OVT4 showed a wide variety of design and operating problems. These problems were not unexpected, given that OVT4 was the first fully-integrated test of all of the projectile disassembly and draining equipment using live stockpile munitions. Examples of some startup problems include an undrained projectile entering the MPF on 7 October. The burster well tube had not been pulled and the agent had not been drained at the MDM. This tube was ejected from the projectile body in the MPF, causing some damage to the refractory on the ceiling of the MPF. This occurred again on 29 November and twice on 1 December. Also, minor problems occurred involving PMD chuck jaws being out of tolerance, dropped bursters, MDM hydraulic leaks, plugged drain tubes, and sensor failure. These were corrected early in the test.

By December 1992, operations were showing signs of improvement. However, on 2 January 1993, a fire occurred in the ECR. The fire was fully contained by the ECR, and posed no worker or public risk. The investigative team identified the probable cause as friction from a booster cup wedged in the conveyor igniting debris from punched booster cups and other material that had not been cleaned up by maintenance workers. Although the initial fire intensity decreased after several minutes, it ignited a conveyor belt which then burned slowly for two hours. After television monitoring showed that it was safe to enter, the fire was extinguished by workers. The fire destroyed a conveyor and other equipment related to the PMD. During January, demilitarization was shut down while the incident was investigated, equipment repaired, and a fire suppression system installed. Maintenance and inspection procedures were also modified.

Other factors affecting OVT4 performance include the following:

- AQS reliability and limit on MPF feed rate
- Collet problems
- Use of DPE workers in continuing maintenance
- Munition tracking

AQS Reliability. The AQS operates to pump the agent out of the agent cavity in the projectile (after the MDM removes the burster well), and it measures the amount of agent removed. Knowing the amount removed allows approximate calculation of the amount of agent remaining in the cavity. This is important because the RCRA permit for the MPF for OVT4 included a limit of 52.8 lbs/hr of HD agent into the furnace. Experience showed that many projectiles contained sludge or solids which interfered with operation of the agent drain system so that agent removal was not ensured. In addition, undrained agent combined with the solids resulted in as much as one pound of material remaining in the projectile. Uncertainties in the original tare (empty) weights of the projectiles contributed to the difficulty of determining the precise amount of material in the projectiles. The design of the projectile demilitarization system provided for the processing of trays containing 96 projectiles. With the theoretical possibility of up to one pound of material remaining in each projectile, and with two trays present at once in the MPF, the decision was made to limit each tray to 24 projectiles to ensure that the RCRA limit would not be exceeded.

These problems, and the consequent tray limits, had several adverse effects on operations. Because of the uncertainty in draining projectiles, DPE workers were required to inspect projectiles for proper agent drainage. This was one of the major reasons for the requirement (discussed below) that DPE workers be present in the MPB during processing. The tray limits caused reduced throughput because more trays were handled at a given processing rate, thus greatly increasing the fraction of time devoted to tray processing. This constraint alone

appears to have caused as much as a 10-20 percent reduction in time available for processing in the operating window. In addition, the buffer storage available between machines was, in effect, reduced by 75 percent, increasing the sensitivity of machine throughput to upstream and downstream failures.

In the last two weeks of OVT4, modifications to the AQS appeared to improve the operation of the drainage system thus reducing but not eliminating the uncertainties in the material remaining in the projectiles. Further work is continuing to ensure more effective drainage of projectiles. The Army is working with EPA to relax the restriction of 24 projectiles per tray, based on the increased assurance of effective drainage, and on the fact that the MPF has shown the ability during OVT3 to process over 140 lb/hr of agent, in contrast to the lower limit adopted for OVT4 of 52.8 lb/hr.

Collet Problems. A collet is a device used by the MDM to grasp and remove the burster well, and then to re-insert the burster well after removal of the agent from the agent cavity. Originally expected not to be a maintenance problem, collets demonstrated the ability to handle only a limited number of burster wells before failing. Collet life was highly variable. In the last few weeks of OVT4, a decision was made to modify the process to remove but not re-insert the burster wells (the burster wells were collected, and fed to the MPF separate from the tray of projectiles). During the final days of OVT4, collet life appeared to improve; however, the test ended before definitive results were obtained. Over the course of OVT4, the collet problems were one of the main contributors to lower-than-expected performance.

DPE Workers. As noted above, MDMs showed serious operating problems through most of OVT4. Since the MDMs operate in a contaminated area, maintenance requires use of workers in DPE. DPE operations require workers to operate in pairs (for safety), with backup and control staff to ensure safe operation. Depending on the advance notice, a DPE entry may take 30-60 minutes after the beginning of preparation before the worker begins the planned maintenance operation. Since this lead time reduced the available time for operation, the Army decided early in OVT4 to maintain DPE workers in the MPB on a virtually continuous basis during operations.

The DPE workers engaged in a variety of activities to help maintain the throughput of the MDMs. In response to the agent drain problems, the workers used dipsticks and visual inspection to ensure that projectiles had been properly drained of agent. The problems with collets discussed above, as well as other malfunctions of the MDMs and other machines in the MPB, required that the workers repair the equipment, as well as move projectiles off of and onto the processing lines. The workers were actively involved in identifying problems, and devising and installing corrections to improve operations. Finally, the workers conducted preventive maintenance as required.

These activities were physically demanding and were conducted on a greater scale than had been anticipated. The result was increased risk of injury due to a larger number of hours of activity, but also a higher rate of injury compared to DPE work earlier in OVT when no DPE injuries were experienced. Most of the six injuries that occurred during OVT4 were related to the need to handle projectiles.

The equipment in the MPB was not designed and configured for this type of on-line, continuing maintenance. Although efforts were made to ensure safe operations, heavy reliance was placed on administrative controls, as opposed to designed-in safety measures. The most significant injury to a DPE worker during OVT occurred when the tip of one finger was severed by a machine in the MPB. The worker was not exposed to agent. It is clear that if this degree of on-line DPE maintenance is to be used in the future, additional engineering will be required to improve maintenance efficiency and to ensure worker safety.

As discussed earlier, in the last 7 to 10 days of OVT4, both the agent drain and collet problems decreased, reducing the demands on the DPE workers. The Army is planning to continue identifying more effective solutions to the operating problems seen during OVT4, and, if successful, these should largely eliminate the need for continuous DPE workers in the future. However, it should be noted that changing the processing to different projectile types or to different production runs (lots) within the same projectile type, may create substantial operating problems requiring extensive DPE work to resolve. Thus, care will be required to prevent a recurrence of the injury rates seen in OVT4.

Munition Tracking. The final issue of concern relates to the problem of munition tracking. Munition tracking is the ability of the control software to "know" where every projectile is, and what processing has been done to it. During rocket and ton container processing, there were occasions when the control software lost track of munitions. However, because there was little buffer storage in the rocket system and only a limited number of ton containers, the consequences of error were relatively minor. However, on at least eight different occasions during projectile processing, projectiles were sent to the MPF without having been drained of agent at all. The result in each case was violent expulsion of the burster well into the ceiling of the MPF, and a pressure transient in the furnace as the agent ignited. In each case, the MPF and its afterburner successfully destroyed the agent, and none was detected in the common stack.

In a more serious case, a projectile with its burster intact left the ECR and reached the MDM. After two collets were damaged in an attempt to remove the burster well, examination showed that the burster had not been removed by the PMD. It appears that the risk of explosion or fire was extremely low; however, the presence of this explosive in the

MPB, with DPE workers present, in violation of the design concept, raises safety questions. It is theoretically possible that the burstered projectile could have bypassed the MDM, as did at least some of the projectiles discussed above. The consequences of such a projectile in the MPF has not been evaluated; however, the MPF and its enclosure is not designed to handle explosives.

The lack of munition tracking data prevented identification of exactly when the projectile was on the PMD, and what actions took place there. It appears, however, that an interlock sensor in the downstream robot projectile handler that should have detected the presence of the burster had been disabled, with no record made of why or by whom. After the event, the interlock was reinstalled, and administrative modifications were made to test the interlocks.

The Army is continuing to evaluate and correct the inadequacies of tracking the location and the processing done to each munition item. Work performed at the Army's training and simulation facility has confirmed that many of the shortcomings of the tracking system observed during OVT were caused by control software not keeping track of munitions as control was switched between automatic and manual operating modes. Corrections are being installed at JACADS and in the U.S. plants.

4.5 OVT1-4 PROCESS PERFORMANCE SUMMARY

The previous sections have separately discussed each of the four OVT subtests. This section provides a summary reference for each of the major operating systems, with emphasis on noting the problem areas that have been identified but not fully resolved by the end of OVT. All the problem areas identified are in active stages of investigation and/or correction. As already mentioned—with the exception of the actual demilitarization machinery used for the rockets, ton containers, and projectiles—the majority of the plant uses commercial/industrial equipment as adapted for this application. Thus, corrections to operating problems while perhaps difficult, should be well within the state of the art. Correcting problems of the demilitarization machinery may require a somewhat higher degree of innovation.

- The DFS appears to operate relatively well although there remain problems with bearings, home switch, feed chute, and related components. During OVT, the Army achieved major improvements in the HDC, as well as in other parts of the DFS. The thicker DFS kiln wall planned for U.S. plants (and for retrofit at JACADS) will help achieve a more robust design. The demonstrated availability for rocket processing was significantly less than the 85 percent planned.

- The RSM appears to operate well, except for possible problems relating to corrosion by some of the decontamination liquids used.
- The BDS appears to operate well, except for continuing problems with the associated AQS (load cell) for the ton containers.
- Portions of the projectile demilitarization system appear to operate well. The PMD and the robotic equipment for handling projectiles came reasonably close to meeting performance goals. However, even with virtually continuous tending by maintenance staff in DPE suits during most of OVT4, the MDMs did not demonstrate sustained, consistent operation. During the final week of OVT4, the MDMs operated more reliably, but the test concluded before definitive results were obtained. The MDM clearly requires substantial additional experience and refinement to meet throughput goals. A major concern, not fully resolved during OVT, was that the process control logic did not maintain control of munition accountability. Although corrections have been identified and are being installed in the first U.S. plant, operation has not yet been fully demonstrated at JACADS.
- The MPF operated well, although the automatic control of the furnace temperature was slow to respond to changes in the chamber temperature.
- The AQS appears to have operated reasonably well for rockets, but not for ton containers or projectiles. The major problems appear to be both agent removal (draining) problems and measurement of agent quantities. Difficulties in draining HD due to the presence of sludge apparently contributed to the agent draining problem.
- The LIC operated effectively in disposing of agent; however, if not improved, its relatively limited availability will significantly restrict processing of munitions that generate large amounts of agent. One unresolved problem that limits availability continues to be the removal of the salt that accumulates in the LIC secondary chamber, although methods to reduce this problem are under evaluation by the Army. The smaller planned agent storage capacity at the U.S. sites (compared with JACADS) increases the probability that any failure of the LIC will have an adverse effect on processing both rockets (as higher daily processing totals are achieved), and bulk containers. This increases the importance of achieving a high LIC availability, or of reconsidering the agent storage capacity.

- The DUN did not operate satisfactorily during OVT. The DUN requires additional engineering work, as well as extensive operation to demonstrate that problems have been resolved. A trial burn must also be performed to demonstrate compliance with RCRA permit requirements.
- During most of OVT, the BRA did not operate satisfactorily. However, after modifications, the BRA did process the brines generated during OVT3 and OVT4, although some operating problems remain and the required BRA PAS compliance test has not yet been performed.
- The munitions transport system operated without any significant problems or safety events.
- The unpack area operated without any significant problems or safety events.
- The DPE system of personal protective equipment functioned well, with excellent protection against agent exposure and no worker agent injury. This performance was achieved even though workers were called upon continuously to support active operations during OVT4. The DPE system requires continuing attention to ensure safety for the workers. Responding to the problems generated by the high-level DPE work in OVT4, the Army instituted a health monitoring program and began procurement of a cooling system for DPE air.

SECTION 5

CONCLUSIONS

5.1 JACADS PERSPECTIVE

The JACADS facility, as well as the process it represents, is the world's first and only fully-operational facility for the destruction of chemical nerve and blister agents, and for the demilitarization of chemical munitions. Prior to the construction and operation of JACADS, the Army had conducted tests of individual plant components with inert, simulant-filled munitions and with rockets at its test facility in Utah (CAMDS). The army had destroyed several thousand M55 rockets at CAMDS using the Rocket Line System at that location and, in the 1970s, destroyed over six million pounds of GB and mustard in bulk containers at Rocky Mountain Arsenal in Colorado.

Prior to OVT at JACADS, no pilot plant or demonstration plant existed in which the fully-integrated JACADS process, including demilitarization machines, incinerators, pollution abatement equipment, agent monitors, conveyors, robots, and all support systems, could be tested. Thus at JACADS, the processing of live munitions containing lethal chemical agent represents a quantum increase in process complexity with respect to previous component testing with inert, simulant-filled munitions.

Before OVT began, the Army anticipated that a variety of processing problems would occur that could not have been predicted or identified in the component tests. To account for this, rampup periods were incorporated into the OVT campaign schedules with full processing rates only planned to occur during the last two to four weeks of each test, depending on the test duration. The relatively short time duration of each test—one to four months—combined with the rampup periods, placed an upper limit on the time period allowed for demonstration of full-rate processing and did not provide sufficient time for all processing problems to be addressed prior to the end of each test. In hindsight, the test periods were probably too short to permit JACADS to demonstrate its full-rate throughput goals, although substantial performance improvements within each test period were observed.

5.2 SAFETY PERFORMANCE

JACADS met the OVT safety performance goals that were established for it. During OVT, there were no injuries or fatalities associated with the handling of agent or munitions, and industrial injuries were within the range typical of industrial chemical facilities. As

expected, events did occur that challenged the levels of protection designed into JACADS. The demonstrated safe operating record of JACADS during OVT reinforces the importance of having safety in depth incorporated into the plant design and operating procedures.

Some of the design features of JACADS and planned demilitarization facilities that are especially important include:

- Control of air movement in contaminated areas to prevent migration of agent
- Provision of multiple levels of backup power supply
- Isolation of activities such as explosives removal
- Large margins of safety in the incineration and air exhaust systems
- Separation of people from processes by use of remote and computer control
- Full coverage of the facility using automatic, near-real-time agent monitors
- Extensive use of closed circuit television monitoring
- Extensive use of electronic process monitoring and computer data handling

The JACADS contractor operated an active safety program during OVT. In addition, the Army and other agencies provided extensive oversight and review of the operations.

Challenges to the plant design did demonstrate several notable shortcomings in some of the systems or their operation. In each case, the Army and its contractors have investigated the problems and have installed or plan to install corrections. These areas included:

- Failure of the back-up power and related control system software to operate properly when restarting the plant following loss of power
- Ventilation system failures or inadequacies that on occasion did not fully control agent migration within the facility
- Inadequate control and documentation of software and system design changes
- Control systems that did not maintain accounting of the processing status of each munition

The adequate performance of staff is also essential to the proper operation of the safety systems of the plant. While staff training met minimum mandated requirements, there were instances of performance errors that either led to operating or safety problems, or exacerbated them. The relative effects of other factors (e.g., training, inadequate system designs, faulty or non-existent procedures, or supervisory oversight) in these instances could not be separated in evaluating the causes of these performance errors. The Army's upgraded

training program should contribute to improving staff performance both at U.S. plants and at JACADS.

5.3 ENVIRONMENTAL PERFORMANCE

The OVT demonstrated that the JACADS process can meet federal regulatory standards and can operate without adverse environmental impact. JACADS operated within applicable environmental regulations with respect to discharge of agent and non-agent air emissions and, with few exceptions, met all operating permit requirements. Waste materials were disposed of in approved locations. Noncompliance with the procedural and administrative requirements in the environmental permits occurred. These included minor non-agent discharges to the ground (without environmental impact), problems in the long-term storage of wastes, and errors in record keeping and inspection. There are no apparent fundamental problems in meeting regulatory standards in future U.S. plants, unless the standards are significantly more restrictive than those in effect for JACADS.

However, there were several areas in which problems have occurred in the past. Programs are underway to address these areas, and will help ensure conformance to the regulations. These areas include the following:

- Emphasize the tracking of the requirements of the applicable permits
- Seek permit conditions that provide for increased flexibility in process operations while protecting environmental quality
- Provide for long-term storage and disposal of agent-contaminated protective equipment
- Achieve reliable operation of the Brine Reduction Area to manage liquid wastes
- Achieve reliable operation of the Dunnage Incinerator to manage solid wastes
- Improve the effectiveness of personnel training concerning environmental regulations

5.4 PROCESS PERFORMANCE

During OVT, JACADS demonstrated the ability to demilitarize M55 rockets containing GB or VX, and ton containers and 105mm M60 projectiles containing HD. During the tests on rockets and ton containers, JACADS generally met its short-term single-shift throughput goals, but was unable to meet long-term throughput goals established prior to OVT. Process improvements that have been demonstrated, or have a high probability of success, will likely allow similar plants in the U.S. to achieve the JACADS OVT throughput goals, although at least in the near term still falling short of the plant design goals established by the Army for the U.S. plants.

The projectile test showed that the processes could approach or meet short-term goals. However projectile operations were not sufficiently reliable or of sufficient duration to draw firm conclusions concerning sustained long-term throughput.

It should be pointed out that a significant improvement in JACADS performance was achieved over the period of performance of two sequential tests, both with the same munition (M55 rockets) and with only the agent in the rockets differing. This permitted the learning experience from the first rocket test to be applied to the second test and, in effect, provided for a longer and more realistic test of JACADS' ability to process rockets than was the case for the other items processed during OVT. In the first rocket test JACADS achieved a 24-hour average destruction rate of 6.9/hr, and in the second test achieved 11.1 R/hr for a 61 percent improvement. The availability of JACADS to process rockets also increased from 33 percent in the first test to 47 percent in the second test.

In contrast, there was only one OVT campaign that demonstrated JACADS' ability to process projectiles, the most complex item in the chemical munitions stockpile. The Army deliberately selected the M60 projectile for this test. The M60 projectile contains the blister agent mustard, known to be more heterogeneous in composition and thus more difficult to drain than the nerve agents. The M60 also contains a variety of internal components, some of which are explosive, and has fairly tight tolerances, making disassembly and partial reassembly more difficult than for other projectiles. In spite of a substantial number of processing problems resulting from the internal configuration of this projectile, over 20,000 M60s were disposed of during 17 weeks of processing. The average throughput rate achieved when full-rate production was attempted was 30.9 projectiles per scheduled hour of operation. While lower than the desired process test goal of 56 projectiles per hour, this throughput rate is still within reasonable expectations, given the five-week time period available for demonstrating this rate.

JACADS is a first generation chemical munitions disposal facility, and as such its prototype nature was a major cause of performance shortfalls. In addition, JACADS

encountered a variety of munition and agent-specific problems that could not have been foreseen in the tests that were conducted with inert, simulant-filled munitions prior to OVT. These problems are not unusual for a first generation plant processing a unique feedstock, in this case, a substantial variety of obsolete chemical munitions and containers. Operational performance showed that significant engineering development was still needed on several of the systems. While much of the needed engineering has now been conducted, it is possible that additional problems may develop as the JACADS and U.S. plants are run for longer periods and on a more intense, 24-hour-per-day schedule. At JACADS, the Army had both successes and failures in diagnosing and correcting system performance problems. However, a program is in place to transfer the lessons learned to the U.S. plants, and additional testing is planned at JACADS to identify solutions for the remaining problems. In addition, to ensure early identification and correction of problems, the Army plans to process these munition types located on Johnston Island before processing similar munition types at U.S. plant locations.

JACADS can be considered to be a "pioneer process plant" in that it is the first full-size facility to process and destroy chemical munitions and agent, it uses a number of unique processing steps, and it has only been operated in a startup mode during OVT. The only evaluation of the initial operating experience of comparable facilities was carried out in a series of reports by the RAND Corporation in the early 1980s (reference listed in appendix E.). The evaluations covered over 40 such plants. For those plants processing solid materials, similar to JACADS, it took 6 months to achieve a mean processing rate of 59 percent of design capacity.

There are several difficulties in comparing JACADS OVT performance with the results of the RAND studies. For example, the RAND reports do not specify the number of hours per day during which operations were attempted for the pioneer processing plants and thus, it is not possible to state whether performance was predicted on an operating hour basis or a 24-hour per day basis, as given in this report. Also, the RAND reports do not state whether different kinds of operations with varying feedstocks were attempted during startup operations as was the case with JACADS during OVT. Keeping these limitations in mind, a rough comparison of JACADS performance, as measured by munition throughput, can be made with the facilities in the RAND study.

The two OVT rocket tests taken together lasted for 44 weeks (10.2 months) during which time processing occurred or could have occurred. This does not include planned shutdown periods and closures due to factors beyond the Army's control (e.g., weather). For the last 5.5 weeks of the second (VX) rocket test full rate operation was attempted. During this time, 6,436 rockets were processed in 406 scheduled hours corresponding to a throughput on a 24-hour basis of 14.4 RPH. This was 45 percent of the design goal, and is in the middle of

the performance range of the plants studied in the RAND report having a similar duration of experience. The experience of the projectile test showed a similar trend in performance growth.

Taking the above caveats into account and recognizing data limitations, we conclude that while the JACADS processing performance to date did not reach the throughput goals established prior to OVT, this performance was well within the range of the startup performance experience of roughly similar pioneer processing plants that had been evaluated in the past. We also conclude that substantial learning experience was obtained during each test and that further performance improvements are likely to occur.

Major process systems that appear to require additional engineering refinement and testing to improve system availability include the Deactivation Furnace System, the Liquid Incinerator, and the Multipurpose Demilitarization Machine. Of these, the first two are adapted from systems used in industry, while the third is a special purpose machine. The corrections and improvements needed all appear to be well within the state of the art. Although operating in a support role on Johnston Island, the Brine Reduction Area and the Dunnage Incinerator did not achieve full operation. These systems will require additional engineering and testing. Both of these are adaptations of standard industrial systems and were not developed specifically for chemical munition disposal. The backup power systems failed on several occasions during OVT, and require more detailed testing at all sites to ensure reliable operation.

5.5 CONCLUSION

The JACADS plant completed its OVT with the destruction of more than 40,000 munitions over a period of 32 months.

There were no public or worker injuries or fatalities from agents or munition fire or explosion, and the plant met the safety goals established for it.

The plant emitted no agent (except for one occurrence that posed no significant worker or public health risk) and operated within permit requirements for other discharges. Although not satisfying all administrative permit requirements, the plant demonstrated its ability to meet federal regulatory standards and to operate without adverse environmental impact.

JACADS demonstrated its ability to destroy rockets, ton containers, and projectiles containing three types of agent. The plant approached or met short-term throughput goals, but did not meet long-term average process rate goals. Although not achieving the

throughput goals specified prior to OVT, the performance was within the range of startup performance for similar industrial pioneer processing plants.

The JACADS design has no apparent fundamental problems in achieving safety and environmental goals of planned U.S. plants, although continued improvements in these areas will increase further the assurance of safe, environmentally-sound operation. The implementation of the lessons learned from the OVT combined with additional engineering refinement should enable JACADS and U.S. plant performance to approach or exceed the OVT throughput rate and design goals.

APPENDIX A

JACADS PROCESS DESCRIPTION

The chemical munitions on Johnston Island are in munition storage buildings located in an area about one-half mile from the Johnston Atoll Chemical Agent Disposal System (JACADS) complex and linked to it by paved roads. The major structure at JACADS is the Munitions Demilitarization Building (MDB), a 73,000 square foot, two-story building containing disassembly machinery, incinerators, and supporting equipment. Four pollution abatement systems, an air purification (filter) system, a laboratory, and a personnel support facility are adjacent to the MDB. Together, these and other supporting facilities constitute JACADS.

Pallets of M55 rockets are sealed in a Single Pallet Only Rocket Transport container and transported by truck to the MDB. Projectiles and ton containers are transported by truck from storage to the MDB. At the MDB, in an automated process, special machines disassemble the munitions, and access and drain the agent from the munitions. Four specialized incinerators, each with its own pollution abatement system (PAS), incinerate the munition pieces, explosives, packing materials, and drained agent.

JACADS contains four incinerators designed to destroy material from different parts of the demilitarization process. Each incinerator has a primary chamber which provides the temperature, oxidizing conditions, and residence time to provide the desired destruction, and a secondary chamber to provide additional assurance that any agent vapors remaining will be fully destroyed. Each incinerator has a PAS that reduces the pollutants in the exhaust gas to below the levels established in the environmental permits.

The Liquid Incinerator (LIC) is designed to incinerate liquid agent. Agent is injected into the primary chamber which operates at a nominal 2700°F. The exhaust gases pass to the secondary chamber operating at 2000°F, and are then treated in a PAS (including acid gas scrubbing), before being released from the common stack. Decontamination solutions from the demilitarization operations are collected and injected into the LIC secondary chamber to ensure destruction of any residual agent or organic byproducts of agent neutralization.

The Deactivation Furnace (DFS) primary chamber is a rotary kiln designed to incinerate solid materials including rocket propellant and explosives, as well as agent-contaminated materials. Solids remain in the kiln for about 12 minutes, then the incinerated residue passes through a heated discharge conveyor for at least 15 minutes at 1000°F to ensure thorough decontamination before discharge to a residue bin. The gases from the kiln pass through an afterburner operating at 2000°F, and are then treated in the DFS PAS before discharge from the common stack.

The Metal Parts Furnace (MPF) is a refractory-lined furnace designed to thermally decontaminate drained metal parts (ton containers, bombs, or trays of projectile bodies). Trays of drained metal parts are conveyed through the furnace during which time any residual agent is destroyed by incineration. The metal parts are heated to at least 1000°F for 15 minutes to ensure decontamination, then they are removed and cooled before disposal. The exhaust gases pass through the afterburner at 2000°F, are treated in the MPF PAS, and are then discharged from the common stack.

The Dunnage incinerator (DUN) contains a refractory-lined furnace designed to incinerate packing materials (dunnage) and other miscellaneous solid wastes that may be agent contaminated. The DUN operates at 1400°F, the exhaust gases pass through an afterburner at 2000°F, are treated in the DUN PAS, and are discharged from the DUN stack. The solid residue (ash) is cooled and removed for disposal.

Rockets, ton containers, and projectiles were demilitarized during Operational Verification Testing (OVT). Only one type of munition and agent was demilitarized at a time. The sequence of operation for demilitarization of each item is briefly described below. Figures A-2, A-3, and A-4 show diagrams of the JACADS process configuration for each of the munitions demilitarized during OVT.

Rockets (Figure A-1)

- The rocket shear machine (RSM) is used to drain agent from the rockets by punching precisely-located holes through the exterior of the rocket and its shipping/firing tube. The agent is then pumped from the rocket to an agent storage tank.
- The RSM then shears the rocket into pieces that drop into the rotary kiln of the DFS.
- The DFS incinerates the residual agent, explosives, and propellant; a heated discharge conveyor ensures thermal decontamination of the rocket pieces.

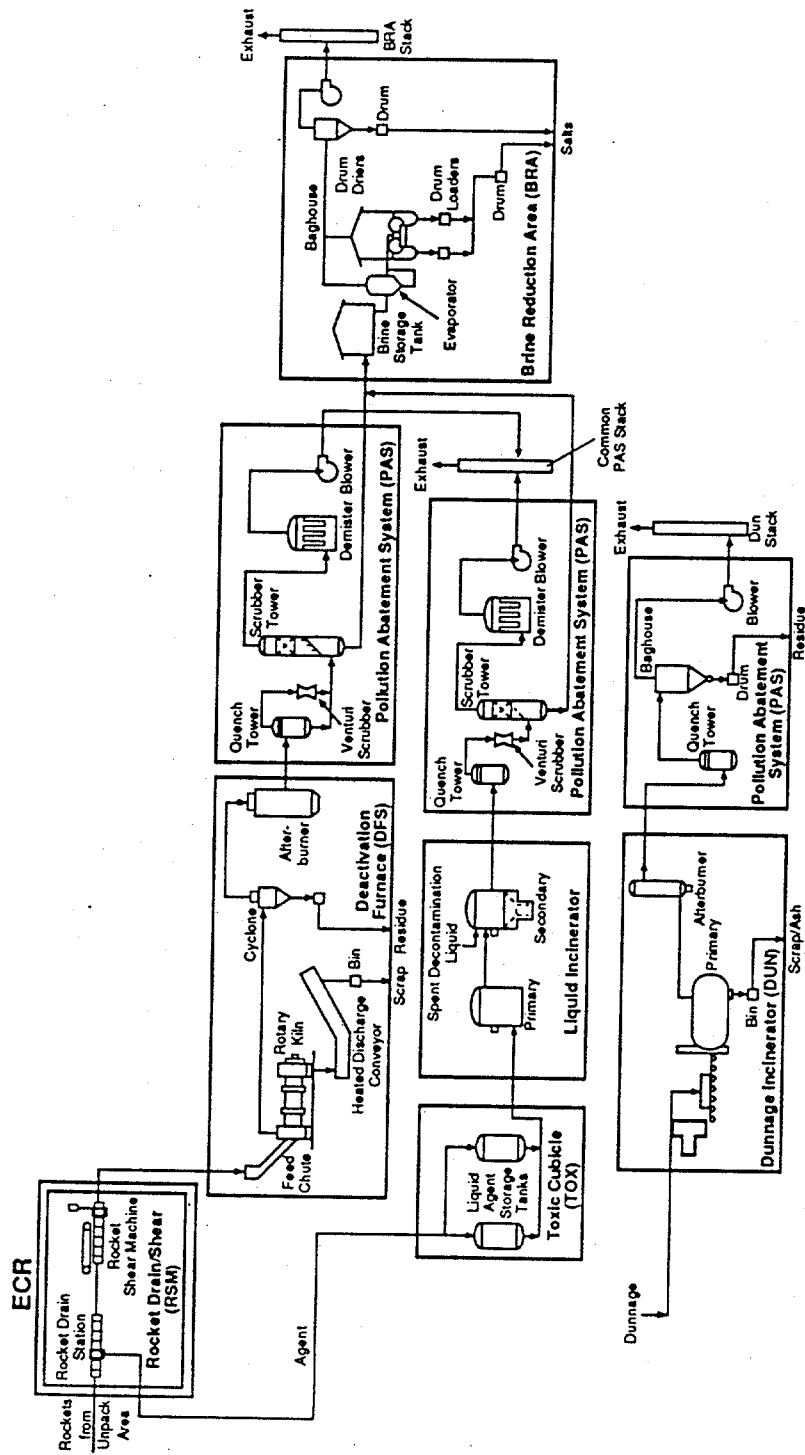


Figure A-1. Rocket Demilitarization Process Flow

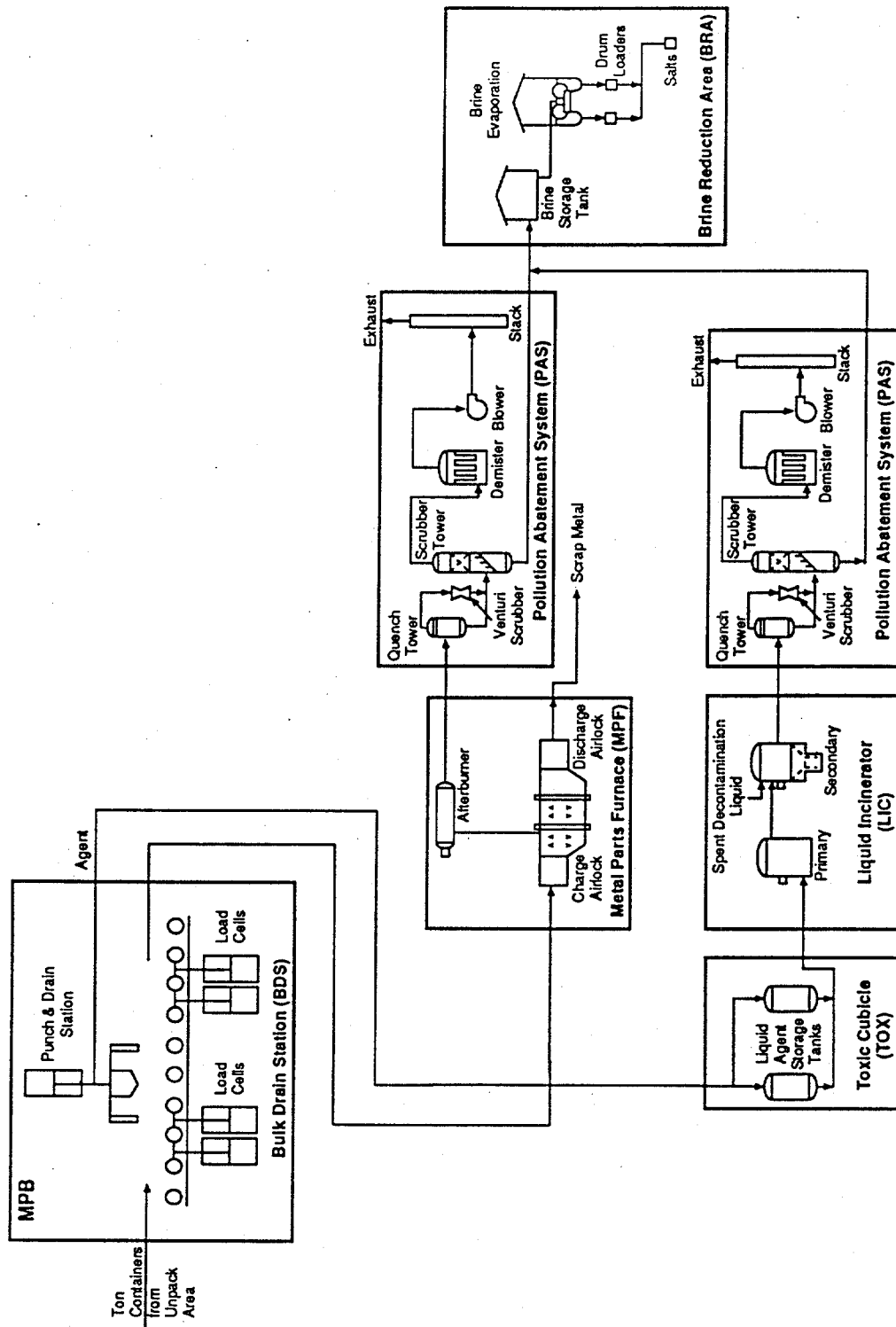


Figure A-2. Ton Container Demilitarization Process Flow

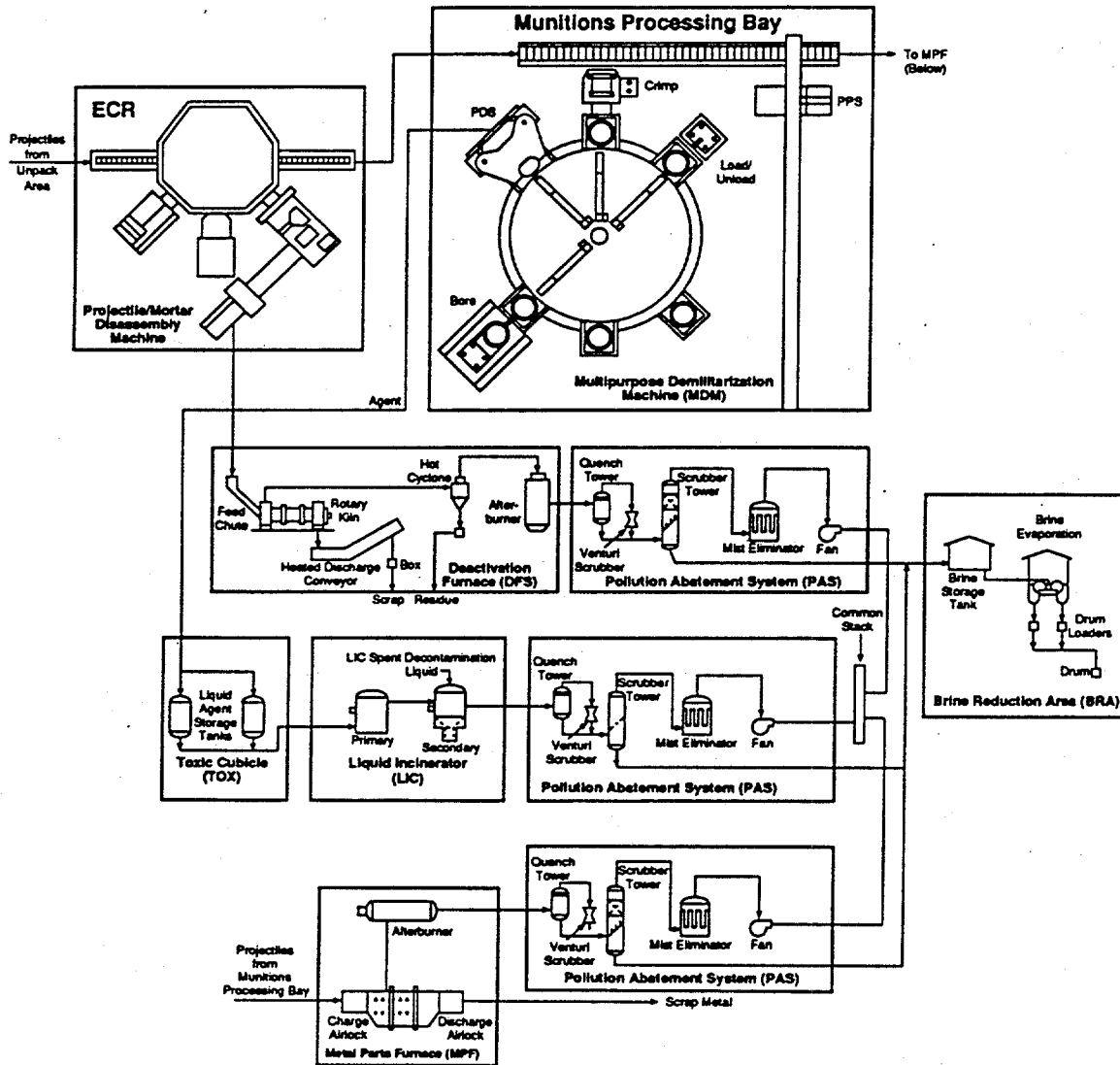


Figure A-3. Projectile Process Flow

- The agent is burned in the LIC.
- The wooden pallets are burned in the DUN.

Ton Containers (Figure A-2)

- The bulk drain machine is used to pierce access holes in the ton container and pump agent from the container.
- The agent is burned in the LIC.
- The residual agent in the ton container is destroyed by heating in the MPF.
- The ton container is decontaminated by continued heating in the MPF.
- The detoxified container is disposed of as scrap.

Projectiles (Figure A-3)

- The projectile/mortar disassembly machine (PMD) located in the Explosion Containment Room (ECR) is used to remove explosive components from the projectile.
- The explosives are incinerated in the DFS.
- The multipurpose demilitarization machine (MDM) in the Munitions Processing Bay (MPB) is used to pump the agent from the projectile when the burster well in the projectile is removed.
- The drained agent is incinerated in the LIC.
- The residual agent in the projectile body is destroyed by heating the projectile body in the MPF and incinerating the vaporized agent.
- The projectile body is decontaminated by continued heating in the MPF.
- The wooden pallets and strapping are burned in the dunnage incinerator.

The MDB houses the demilitarization system on two floors. Munitions enter the system on the upper floor where they are disassembled and drained of agent. The incinerators are located on the first floor. The second floor consists of an unpack area, an explosion containment room vestibule (ECV), two ECRs, a munitions corridor, an MPB, and some supporting services areas.

In the unpack area, munitions are received, manually separated from packaging materials, and placed on conveyors that transport the munitions to the processing areas. The ECV is isolated from the unpack area by a wall and airlocks. In the ECV, operators wearing demilitarization protective ensembles (DPE) suits can unpack leaking munitions for subsequent processing.

The ECRs are separated from the ECV by blast doors. The ECRs are reinforced concrete enclosures designed to totally contain the effects of an accidental explosion, as well as the associated agent during the processing of rockets, projectiles, and mortar cartridges, all of which contain explosives. Explosive components and rocket propellant sections that are sheared or removed from the munitions in the ECR drop through blast gates in the floor in the ECR into a deactivation furnace located on the first floor of the MDB. Machines located inside the ECR include the RSM and the PMD. Mine machines, where used, will also be installed in the ECRs.

The munitions corridor is separated from the ECRs by blast gates. Trays containing projectiles and mortar shells that have had their explosives removed in the ECR and trays containing bulk items, which have no explosives, are stored on conveyors in the corridor until they can be moved into the MPB. The MPB contains two parallel conveyor lines which receive the trays containing the munitions or bulk items. In the MPB, agent is drained from the bulk items and projectiles and pumped to an agent storage tank located in the toxic cubicle on the first floor of the MDB. Machines located inside the MPB include two bulk drain stations for the bulk items, and three MDMs for the projectiles. Projectiles are transferred between the trays and the MDMs by pick and place robots associated with each MDM.

The first floor of the MDB contains a buffer storage area (BSA), a toxic cubicle, the control room, a DFS, a LIC, an MPF, a DUN, and various supporting services areas. The BSA stores trays with drained munitions and bulk items until they can be transferred into the MPF where residual agent in the munitions and bulk items is thermally destroyed. The toxic cubicle contains two agent storage tanks from which agent is pumped to the LIC where it is thermally destroyed. The toxic cubicle also contains storage tanks for spent decontamination solution generated by the washing of agent-contaminated surfaces and cleanup of agent spills in the MDB. The spent decontamination solution is pumped to the secondary chamber of the LIC. The DUN is used to burn solid waste resulting from the unpacking operations as well as

laboratory waste, spent carbon, and used DPE suits. Each incinerator has its own PAS located outside the MDB.

From the time the rockets and projectiles are fed into the ECR until waste is collected from the incinerator discharges, the process is largely automated to minimize both the exposure of operating personnel to agent and explosion hazards, and the possibility of human error in the performance of the required tasks. A variety of support systems and equipment are also provided to maintain continuous and safe operation of the plant. These include the following:

- Ventilation systems to remove and clean contaminated air, and to protect equipment and personnel
- A decontamination system to treat agent spills or to clean agent-contaminated munitions or equipment surfaces as required for safe operation or maintenance
- A control room to safely and productively control the process
- A mechanical equipment room with a variety of process support equipment
- A personnel area used for the donning of protective clothing and to protect workers in contaminated areas
- A communications system

Ventilation is provided to areas within the MDB in accordance with expected agent contamination in those areas. Toxic areas including the ECV, the ECR, and the MPB, and intervening corridors are provided with a cascading ventilation system of negative pressure to prevent migration of agent vapors to areas where there may be unprotected workers. Areas with the highest potential for being contaminated are at the greatest negative air pressure so that MDB air always flows from cleaner areas to the more toxic areas. Air collected from the toxic areas is passed through a carbon filter system before being exhausted to the atmosphere. The control room is provided with its own filtered clean air supply and is under positive pressure with respect to the other areas of the MDB and outside ambient air.

Support activities for the JACADS operation are housed in additional buildings in the JACADS complex. These include a site security control center, a laboratory, personnel support complex, a boiler house/brine reduction area (BRA), and a mechanical maintenance building. Various fuel tanks, a bulk chemical storage area, a residue handling area, and an emergency generator shed are also found within the JACADS security perimeter.

APPENDIX B

REFERENCE SAFETY EVENTS

Note: These events are synopses of those agent-related events that have raised safety concerns or issues. In each case, additional information is available in the particular OVT report. It must be emphasized that none of the events presented significant risks to the public since built-in controls and protections prevented public injury or potential injury in each case.

Event #1 Common Stack Agent Discharge

Event #1 occurred on 8 December 1990 during OVT1 when the LIC was in the process of cooling after a shutdown. During approximately one hour, residual agent evaporated from the LIC injector and passed through the cooling furnace system to the common stack where it discharged. The discharge lasted for about an hour, and reached a peak of about 0.22 Allowable Stack Concentration (ASC), which is less than a reportable discharge. As expected, agent was not detected in the off-site monitors around the plant since the quantity was far too small to measure. There was no significant public health risk. However, the event is listed here because the discharge itself was verified, and it was unexpected. As a result of the incident, the LIC shutdown procedure was modified, and there were no additional outside discharges from this cause.

Event #2 Common Stack Agent Alarm

Event #2 occurred on 17 February 1992 during OVT2 and involved an Automatic Continuous Air Monitoring System (ACAMS) monitoring the PAS common stack that alarmed at a reading of 1.19 ASC during one ten-minute cycle of the monitor. This event is not considered a critical event. Investigation of this incident showed that the Depot Area Air Monitoring System (DAAMS) tubes that normally monitor the PAS common stack had been removed for routine exchange when the ACAMS alarm occurred. Thus, (DAAMS) analysis could not be used to confirm whether the VX agent actually caused the alarm. As a result of this occurrence, the DAAMS sampling apparatus was modified so that DAAMS tubes are always sampling the stack gases even while changing tubes. Additional analysis of the evidence led the Army and operating contractor to conclude that agent had not been discharged, and that the monitor had responded to an interfering chemical in the furnace gases. Off-site agent measurements were negative, and even if agent was present, there was no significant public health risk. Monitor operations were changed to improve the ability to resolve events such as this.

Event #3 Deactivation Furnace Room Doors

Event #3 occurred during OVT2. During repair work on the DFS, the outside doors to the DFS room were blocked open, allowing large amounts of ventilation air to be drawn into the DFS room. Air drawn into the room was passed through the ventilation system charcoal filters before being exhausted to the outside, and there was no agent discharge from this source. While smoke tests subsequently showed that air containing agent would not have left the room, unusual wind or traffic conditions, or a failure of the ventilation system while the doors were open could have affected the air flow at the open doors. There were no measurements to show that agent did not leave the doorway when workers disturbed the airflow as they moved in and out of the room. The likelihood is that no discharge occurred; however, the open doors did represent possible discharge point and source of potential exposure to nearby workers. The Army has recognized that this situation was inappropriate and has implemented policies to prevent a recurrence.

Event #4 Agent Sample Mishandling

Event #4 occurred on 12 April 1992, during the changeover between OVT2 and OVT3. The event involved the unknowing and only partially-protected movement of two samples (about 500 ml each) of agent solution outside of the MDB and potential exposure of lab personnel. No one was injured, but the event demonstrated a series of failures to follow procedures and good practice.

The event began when the operations staff began decontamination of the VX agent storage tank as part of the preparations for changeover to OVT3. An error was made in a valve setting, and decontamination solution that was to have circulated in the tank did not circulate, thus preventing neutralization of the agent in the tank to what was predicted to meet "drinking water" agent levels. The first plastic sample bottle was taken of the supposed decontaminated material, but a sampling of the outside of the bottle showed high agent levels. Glass bottles were then used, and the outside decontaminated. The bottles, thought to contain nearly agent-free decontamination solution, in fact contained 9 percent and 16 percent VX in water. The bottles were put into plastic bags (without "overpack" rigid protection) and carried outside the MDB to the lab. The bottles were placed on a work bench (not in a hood) and sampled. The initial and subsequent samples overloaded the detectors. Nearly 24 hours of testing involving seven workers were done before a staff member recognized that the "problem" was not with the detectors, but that the samples contained VX concentrations beyond the capability of the detectors, and that the samples should be handled and tested accordingly. Although there was little protection against contact with the agent, there was no injury to the lab workers.

There was no release of agent to the environment. Dropping and breaking the sample bottles during the sample transfer could have resulted in agent on the ground if the plastic bags failed. This could have potentially exposed workers to agent, but would not have caused significant off-site risks to the public unless contaminated shoes or other materials had been taken off the site. At JACADS, the lab is within the facility complex (one U.S. site will have a lab outside the plant boundary).

Corrections were made to lab procedures to prevent potential worker exposure from a similar event in the future.

APPENDIX C

ENVIRONMENTAL PERFORMANCE

This appendix supplements the environmental performance discussion presented in section 3.

C.1 OVERVIEW OF ENVIRONMENTAL REGULATIONS

Table C-1 lists the environmental requirements that apply to chemical demilitarization facilities. Most environmental regulations require issuance of operating permits before a facility can be operated to ensure compliance with environmental standards.

The environmental regulations cited in table C-1 apply to JACADS, although JACADS is exempted from the requirements of the CAA. Nevertheless, a monitoring program for some air pollutants regulated by the CAA, such as NO_x and SO_x , has been conducted to gather data to demonstrate that U.S. facilities can meet air quality standards imposed by specific states.

Table C-2 provides an overview of JACADS environmental performance during the OVT period as measured against certain regulated parameters. Details of JACADS experience are discussed further in sections C.2 through C.6.

C.2 AGENT AIR EMISSIONS

In this and following sections, a more detailed discussion will be presented of the major waste streams and areas where increased attention is needed.

The analytical method used for the detection of chemical agent must be able to discriminate the presence of chemical agent from other chemicals present in the sample, and be able to quantitatively measure the concentration of the chemical agent. The probability of detection is increased with the simultaneous use of two different analytical techniques—the Automatic Continuous Air Monitoring System (ACAMS) and the Depot Area Air Monitoring System (DAAMS).

The ACAMS instruments monitoring the stacks and the Heating, Ventilation and Cooling (HVC) filters collect samples from the gases exiting the stacks and filters. The ACAMS is a near-real-time monitor (with cycle time of about 3 to 10 minutes), whereby a detection level equivalent to the lower limit of quantification (LOQ) triggers an LOQ alarm.

**Table C-1. Environmental Requirements for
Chemical Demilitarization Facilities**

Regulated Emissions/Wastes	RCRA	TSCA	CAA*	CWA	DOT
Agent Air Emissions:					
Agent release outside MDB	X				
Agent (DRE for LIC and MPF)	X				
Non-Agent Air Emissions:					
Particulate matter	X	X	X		
HCl	X	X			
CO	X	X	X		
O ₂	X	X			
NO _x			X		
SO _x			X		
Pb			X		
CO ₂		X			
Opacity			X		
Fugitive dust containing heavy metals (e.g., Cd, Cr, and Pb)	X				
Nitroglycerin (DRE for DFS)	X				
PCB (DRE for DFS)		X			
Hazardous Wastes					
Liquid (containing hazardous constituents)	X				X (if shipped offsite)
Solid (e.g., HDC and BRA residues; contaminated DPE suits)	X				X (if shipped offsite)
Water Quality:					
Discharged cooling water				X	

*JACADS is not covered by the CAA requirements.

Table C-2. Summary of JACADS Environmental Performance

Requirements	JACADS Experience ¹
Agent Air Emissions:	
Agent from stacks: Release >1.0 ASC is reportable to EPA	0.22 ASC for less than 1 hr (GB rocket test): confirmed GB agent
Agent DRE	
LIC: 99.99% (GB, VX, & HD)	Met requirement
MPF: 99.99% (HD)	Met requirement
Non-Agent Air Emissions:	
Particulates	
Furnace PAS: 180 mg/dscm, corrected to 7% O ₂	DFS, LIC, & MPF: met requirement
BRA: 30 mg/dscm	BRA: Compliance test not successfully performed during OVT
Analysis of exhaust gas for PICs and metals (trial burns only)	Very low levels of hazardous constituents found in volatile and semi-volatile PICs (most likely from the furnace fuel)
Dioxins and furans (trial burns only)	Very low levels (0 to 23.64 µg/hour during trial burns)
HCl: 4 lb./hr	DFS, LIC & MPF: met requirement DUN: no trial burn performed during OVT
CO: 100 ppm over 1-hr rolling ave.	DFS, LIC & MPF: within permitted limits DUN: no trial burn performed during OVT
O ₂	
DFS AFB ³ : 6-14%	Within permitted limits
LIC sec. chamber: 5-10%	Within permitted limits
DUN AFB: 8-14%	Not operational during OVT

Table C-2. (Concluded)

Requirements	JACADS Experience ¹
MPF AFB: 2.5 - 11.5%	Within permitted limits
NOx (concentration monitored as an Army goal only)	Below 500 ppm except on one occasion during OVT2
SOx (concentration monitored as an Army goal only)	Same as NOx
Nitroglycerin DRE (99.99%)	DFS: Met requirement
PCB DRE (99.9999%)	DFS: R&D burn--requirement met, demonstration burn--requirement met in 3 of 4 trials
Hazardous Waste Management:	
Brine spills/storage	PAS secondary containment intermittently used as supplemental storage for brine; brine tank high-high alarm overridden in control room--overflow occurred but contained in secondary containment ; large amounts of brine residue accumulated in the brine exhaust duct; no release to the environment
Fugitive dust (containing metals such as Pb, Cd, and Cr)	Several instances of release in reportable amounts not reported to National Response Center in a timely manner
Internal inspections and record keeping	Several cases of noncompliance
DOT packaging 90-day storage	HDC residues shipped in FIBCs before DOT certification obtained Numerous instances of noncompliance
NPDES Effluent:	
Heated water discharge	Receiving water temperature exceeded permit requirement--permit modification pending

¹JACADS is not covered by CAA regulations, but monitoring of NOx and SOx pollutants is an operational goal.

²Trial burn test results are still undergoing EPA review.

³AFB = Afterburner .

For the stack and blower ACAMS instruments, the LOQ alarm is normally set at 0.2 ASC, while the "action" alarm is set at 0.8 ASC (0.7 ASC for VX and HD), to allow for instrument variation. The DAAMS system is not a real time monitor; contaminants in the sampled air are concentrated for 1 to 12 hours, and then brought to the laboratory for analysis. However, the DAAMS is more discriminating against non-agent chemicals than the ACAMS, and can more accurately measure low-level agent concentrations.

The agent monitoring system is composed of 91 sampling stations within the JACADS facility and 12 perimeter sampling stations outside the boundaries of the facility. An ACAMS instrument or DAAMS or both are present at each of these sampling stations. There are five exhaust pathways that are monitored continuously for chemical agent—common PAS exhaust stack, DUN exhaust stack, BRA exhaust stack, MDB HVC exhaust stack, and operational laboratory HVC filter stack. Table C-3 presents a summary of the agent air emissions experienced at JACADS during the OVT.

Table C-3. Agent Air Emissions Experienced During the OVT

Test	Agent Processed* (Lbs)	Test Duration (Weeks)	Total ACAMS Analyses	Stack ACAMS Alarms	Confirmed Agent Release
OVT1(GB)	75,000	32	N/A	62	1
OVT2(VX)	134,961	19	327,120	21	0
OVT3(HD)	112,951	4	33,940	5	0
OVT4(HD)	35,485	17	347,900	55	0

*Agent destroyed in the LIC.
N/A = Not Available

The JACADS Resource Conservation and Recovery Act (RCRA) permit requires that an agent release exceeding 1.0 ASC from any of the stacks or to the atmosphere outside of the MDB must be reported to the U.S. Environmental Protection Agency (EPA). Although there were several occasions where the ACAMS instrument alarmed, there was no confirmed chemical agent emissions above the RCRA regulatory limit. Most of the alarms experienced were determined to be false positives and caused by operator error, by system malfunction, or by an interfering chemical. The difficulty of identifying the specific compounds causing the

false positive alarms (arising from interfering chemical species detected by the ACAMS) was never satisfactorily resolved during OVT, although the Army is working actively to resolve this problem.

As described in section 2 of the main report, during OVT1, there was a confirmed emission of agent release that occurred as a result of agent entering the LIC. The emission level was less than 0.22 ASC for less than one hour and had no adverse impact on public health or the environment. On another occasion, during OVT2 (startup of DFS furnace), the ACAMS alarmed at 1.19 ASC during one 10-minute cycle of the ACAMS monitor, but the substance causing the alarm could not be conclusively identified. The release was of short duration, and even if actually agent, would have had no adverse effect on public health or the environment.

The effectiveness of a furnace in destroying agent is measured by the Destruction Removal Efficiency (DRE). The DRE for a particular agent and furnace is measured by comparing the amount of agent entering the furnace with the agent concentration in the exhaust gases. For example, the permitted agent limit for the LIC ranges from 700 (VX) to 1330 (HD) lb/hour, while that for the MPF ranges from about 53 (HD projectiles) to 146 lb/hour (for HD ton containers). Since no agent was measurable in the exhaust of the furnaces, the actual DRE is higher (better) than what could be computed theoretically based on the level of quantification of the ACAMS instrument; the measurement for the MPF was less sensitive than for the LIC because of the small amount of agent fed.

Table C-4 summarizes the agent DREs demonstrated during the trial and demonstration burns for the furnaces. DREs much greater than the RCRA-required 99.99 percent were achieved during the LIC GB and VX trial burns, as well as during the LIC HD demonstration burn. For the MPF trial burn, the DRE for HD was greater than 99.9996 percent. The smaller DRE for the MPF was due to the much smaller amount of agent fed into the MPF as compared to the LIC.

Although not a RCRA requirement, an Army goal is to measure any breakthrough of agent from the charcoal beds for the MDB filters so as to help evaluate the useful life of the charcoal. Breakthrough of agent in a filter bed is determined when the agent is detected downstream of a charcoal bed. Throughout the OVT, agent was never detected after the first of the six charcoal beds in the MDB filter. Analysis of the OVT1 ACAMS data from the MDB exhaust air, furnace room exhaust air, and the first stages of the air filters showed that the GB concentration in each of the six beds was reduced by more than 400,000 times, much better than the design reduction minimum of 10,000 times reduction (or 99.99 percent removal).

**Table C-4. Agent Destruction Removal Efficiencies
Achieved During Trial Burns at JACADS**

Furnace*	Agent	DRE (%)
LIC	GB (rockets)	>99.9999995
	VX (rockets)	>99.9999997
	HD (ton containers)	>99.99995
MPF	HD (ton containers)	>99.9996

*No DUN trial burn was performed during the OVT.

In addition to the regulatory limits on the amount of agent released from exhaust stacks, the Army and Department of Health and Human Services (DHHS) require detection of agent emissions at selected locations around Johnston Island (JI). There are 12 perimeter monitor stations, with each taking two 12 hour sample measurements per day. The amount of agent detected at the perimeter stations should not exceed 1 general population level (GPL). For VX or GB, one (1.0) GPL is a 72-hour time weighted average concentration of 3.0×10^{-6} mg/m³; for mustard, it is equivalent to 1×10^{-4} mg/m³. Although there were several occasions where positive readings were obtained from the perimeter monitoring stations, there were no instances where chemical agent was confirmed to be present. Examination of plant operations data such as whether or not agent operations were underway, furnace temperatures and pressures, and other monitor data at the time of the perimeter monitor readings supported the conclusion that the monitors did not detect agent.

With the exception of Indiana, Kentucky, and Utah, the agent DRE established by the five states is 99.99 percent, which is the same as the federal standards. Indiana and Kentucky require a 99.9999 percent DRE for all chemical agents for all furnaces, while Utah requires a 99.9999 percent DRE for the LIC and 99.99 percent for the other furnaces. In addition to trial burns using actual chemical agents, states may require trial burns using surrogate agents. For example, Utah requires trial burns to demonstrate a 99.9999 percent DRE for surrogate agents prior to an actual agent trial burn.

As noted above, the less than 99.9999 percent DRE demonstrated during the JACADS HD trial burn tests for the MPF was limited by the agent detection technology and the small amount of agent fed. The Army is already looking into ways of further improving the sensitivity of the agent monitors.

C.3 NON-AGENT AIR EMISSIONS

At JACADS, the PAS common exhaust stack and all furnace exhaust ducts are required to be continuously monitored using on-line continuous emission monitors (CEMs) for certain parameters, such as CO and O₂ concentrations. In addition, to ensure that the combustion efficiency of each furnace is maintained during the processing of hazardous waste, other furnace operating data such as furnace temperature and pressure are monitored. As noted earlier, the Toxic Substances Control Act (TSCA) DRE requirement for Polychlorinated biphenyl (PCB) must be demonstrated during the performance burns, but continuous monitoring of PCB concentration during furnace operation is not required since the operation at proper furnace conditions ensure the destruction of the PCBs.

As summarized below, non-agent air emissions from JACADS were maintained within the permitted limits:

- Particulate emissions from the DFS, LIC, and MPF were below the limit of 180 mg/dscm (0.08 gr/dscf). Preliminary BRA source emission tests indicated that particulate emissions from the BRA PAS were less than 33 percent of the 30 mg/dscm RCRA limit (see table C-5).
- The Hydrochloric Acid (HCl) emissions from the LIC HD demonstration burn and MPF HD trial burns were well below the allowable limit of 4 lb/hr. HCl is not produced during combustion of GB or VX.
- CO and O₂ concentrations of emissions from the DFS, LIC, and MPF did not violate permit requirements.
- The DFS trial burn surpassed the 99.99 percent RCRA DRE requirement for nitroglycerin.
- In three out of four performance burn runs, the DRE for PCBs was better than the required 99.9999 percent TSCA DRE. One of four burn tests resulted in a PCB DRE of slightly less than 99.9999 percent. However, the emission rate from this run was below the emission rates of three commercially-operated PCB incinerators and also below that of the U.S. Army Chemical Agent Munitions Disposal Facility (CAMDS) at Tooele, Utah.
- Stack emissions during the performance burns were analyzed for volatile and semi-volatile products of incomplete combustion (PICs), as well as for presence of dioxins and furans. There were small quantities of substances emitted that are listed

as hazardous constituents by EPA (e.g., benzene, dimethyl phthalate, toluene, and vinyl chloride). However, there are no regulatory limits with which to compare the results of the PICs analysis. The levels of dioxin and furan emissions ranged from 0 to 23.64 micrograms/hour, well under the calculated threshold of 350 micrograms/hour for no adverse effect for aquatic life. None of the dioxins found were the 2, 3, 7, 8-tetrachlorodibenzo-p- dioxin (2, 3, 7, 8 TCDD) isomer, which is regarded as the most toxic form of dioxin. The detected PICs were most likely from the fuel used for the furnaces rather than from the waste constituents.

Table C-5. Particulate Emissions

Furnace ¹	Performance Burn	Particulate Matter (mg/dscm) ²
DFS	TSCA R&D test	12-23.9
	RCRA trial and TSCA demonstration burns	1.10-4.55
LIC	GB rocket trial burn	<4.23
	VX rocket trial burn	2.69-10.4
	HD TC demonstration burn	0.54-5.06
MPF	HD TC trial burn	0.89-10.9
BRA	Capacity testing	7.1-13.8

¹No trial burns performed for the DUN during the OVT.

²Corrected to 7 percent O₂ concentration.

Regarding the CO and O₂ concentration limits, it is important to understand the basis of EPA's permitted levels. The EPA has determined that the RCRA permit conditions apply to JACADS only when hazardous materials are being fed to the furnace; and not when the furnace is on standby, or in startup or shutdown mode. The limits also do not apply if a furnace upset occurs when the hazardous material is in the furnace as long as new material feed is immediately stopped.

The JACADS RCRA permit requires that the furnace exhaust CO concentration must be kept to less than 100 ppm over a one hour average during hazardous waste operations. O₂ concentration limits vary according to furnace type. For example, the DFS afterburner outlet O₂ concentration must be kept within 6 to 14 percent while the limit from the LIC secondary

chamber outlet is 5 to 10 percent. Exceedences of the O₂ concentration limit occurred primarily from the DFS afterburner and LIC secondary chamber. Examination of the circumstances of the CO concentration exceedences that occurred during OVT indicated that most were associated with the startup and shutdown of the furnace. Although there were times when the CO concentration in the LIC exhaust gas exceeded the limit while hazardous waste was being processed, the feed was immediately stopped as required.

The majority of O₂ alarms that occurred during OVT were attributed to the plugging of O₂ sensing probes in the exhaust duct from the LIC secondary chamber. During OVT3, the primary and secondary LIC exhaust gas samples to the CEMS were scrubbed with caustic solution before entering the O₂ monitor. This modification improved the O₂ detector response and eliminated poisoning of the detector cell which may have caused the downward drift of O₂ concentrations during OVT2. The contribution of O₂ alarms to LIC downtime significantly decreased after the implementation of the caustic wash.

Although monitoring NO_x and SO_x emissions during routine operations is not required for JACADS, the Army has set a goal of acquiring such emission data to support the CAA permitting process for the U.S. facilities. Both NO_x and SO_x concentrations are monitored from the PAS common and DUN exhaust stack. There are no separate monitors in the LIC, DFS, and MPF exhaust ducts. Limited NO_x and SO_x data were collected during the OVT. The LIC exhaust gas NO_x and SO_x concentrations were not measured during OVT1. Although the RCRA trial burn for the LIC was performed during OVT1, RCRA trial burn protocol did not specify the measurement of NO_x and SO_x concentrations. However, the DFS afterburner exhaust was monitored for both NO_x and SO_x during OVT1. NO_x concentration averaged between 5 and 30 ppm, while SO_x concentration averaged between 50 and 150 ppm.

There was only one occasion (during OVT2 on 1/22/92) when the SO_x concentration detected from the LIC exceeded the maximum Process Data Acquisition and Reporting System reading of 500 ppm. On this same day, the NO_x concentration in the PAS common stack due to LIC operation was between 300 and 500 ppm. This was higher than the NO_x concentration of 200–300 ppm during the performance burns for the DFS. High concentrations of NO_x continued to be produced during agent processing throughout the rest of OVT2 (above 450 ppm during maximum VX feed rates). A possible, although unconfirmed, reason for the high concentrations of SO_x and NO_x was channeling through the small metal cylinders (pall rings) in the packed bed scrubber; these cylinders are designed to increase the available surface area for contact between the circulating caustic and gas streams to achieve acid gas removal.

During OVT2, the LIC outlet SO_x concentration was not monitored during the period of highest rate of rocket processing and agent burning (March 1992). Moreover, the SO_x analyzer was not operating during the DFS performance burns that were performed during OVT2.

During OVT3, the LIC outlet NO_x concentration was on the average less than 100 ppm, while SO_x concentration was normally under 10 ppm. During OVT4, the NO_x concentration averaged between 50 and 75 ppm when both the DFS and MPF were operating, while the SO_x averaged between 2 and 20 ppm.

Table C-6 summarizes the state-imposed air permit standards for the different air pollutants. The National Ambient Air Quality Standards determine how air pollution is to be controlled at new or existing sources. An important consideration in the enforcement of emission limitations and other controls is the location of new or modified sources of pollutants. A Prevention of Significant Deterioration (PSD) permit is needed for a new or modified source located in a PSD region, which is defined by EPA as a region where the air quality exceeds the federal ambient air standards and significant deterioration of air quality must be avoided. To obtain a PSD permit, the new source must demonstrate that it will use the best available control technology to control emissions within the allowable air quality increment levels.

All eight states where the U.S. plants will be located require permits to regulate air emissions in accordance with the CAA. Two sites—Anniston Army Depot (ANAD) in Alabama and Pine Bluff Arsenal (PBA) in Arkansas—will require a PSD permit. Non-demil operations at ANAD currently emit more than 250 tons/year of air pollutants (e.g., NO_x and particulate matter). Due to manufacturing of ordnance, PBA is currently categorized by the State of Arkansas as a "Chemical Process Plant." Thus, being a named PSD source, the emission units of the chemical demilitarization facility at PBA will emit one or both of the following PSD-regulated pollutants: NO_x and particulate matter. Two other sites—Pueblo Depot Activity (PUDA) in Colorado and Umatilla Depot Activity (UMDA) in Oregon—may also require a PSD permit. The PSD status for each of these sites has not yet been finalized. The small amounts of NO_x and SO_x emitted during the operations at JACADS should enhance the Army's ability to meet the states' emission standards.

One important limitation of the JACADS data relates to the characterization of the particulates emitted from the BRA PAS. Analysis of BRA particulates for heavy metals has been performed during the BRA capacity testing, but the results of the BRA test will be superseded by the results from the compliance test scheduled for some time in 1993.

Table C-6. State Air Emission Standards

Facility/ State	PM	Pb	NO _x	SO _x	VOCs	CO	Opacity
ANAD/AL ^(a)	Best Available Control Technology (BACT)	-- ^(b)	BACT	--	--		20%
PBA/AR ^(a)	BACT	--	BACT	--	--		20%
PUDA/CO	0.10 gr/dscf, corrected to 12% CO ₂	--	--	--	--		20%
NAAP/TN	0.5 lbs/1,000 lbs dry exhaust gas, corrected to 50% excess air	--	--	--	--		40%
LBAD/KY ^(c)	0.08 gr/dscf, corrected to 12% CO ₂	--	--	--	--		20%
APG/MD ^(d)	0.03 gr/dscf, corrected to 12% CO ₂	--	--	--	--	If CO >500 lbs/day and at concentration >12% volume, direct flame afterburner for >= 0.3 sec. at >= 1300°F	No visible emissions
UMDA/OR	0.10 gr/dscf, corrected to 7% O ₂ (Refuse burning)??	--	--	--	--		20%
TEAD/UT	0.02 gr/dscf, corrected to 7% O ₂	--	--	--	--		10% (incinerators) 0% for BRA stacks
Federal standards (for incinerators)	0.08 gr/dscf, corrected to 12% CO ₂	--	--	--	--		--
JACADS	0.0002 TO 0.04 gr/dscf, corrected to 7% O ₂		<500ppm	<500pp	--	<100 ppm@ 1hr average	not measured

- (a) Major sources are currently emitting >250 tons per year of at least one criteria pollutant.
 - (b) (--) Emission levels are emission system-specific and specified in the permit in order to meet ambient air quality standards.
 - (c) Toxic air pollutant standards are risk-based.
 - (d) Air toxics program requires that sources quantify all toxic air pollutants and use TOXIC-BACT as determined by the State.
- VOSs = Volatile Organic Compounds

DPE suits were originally planned to be destroyed in the DUN. Since this would produce HCl in the exhaust gas, controls and permit limits were applied. However, since the Army has decided not to burn DPEs in the DUN at JACADS, there is no data to indicate whether HCl emission limits will be achieved. If the Army decides to process DPEs in the DUN for the U.S. facilities, it may have to control the feed rate for DPEs so the allowable emission standard for HCl is not exceeded.

The DFS trial burns demonstrated conformance to TSCA requirements for PCB destruction in three of four test runs. Hence, there are no apparent problems that would be of concern for the U.S. plants. Moreover, the U.S. plant design for the DFS afterburner provides for a longer residence time (2 seconds as compared to 1 second for JACADS) at a higher temperature (2200°F as compared to 2000°F for JACADS).

C.4 LIQUID AND SOLID WASTES

RCRA requirements also apply to process- and nonprocess-generated liquid and solid hazardous wastes. Process-generated liquid wastes include the agent decontamination solutions and the brine solution generated in the PASs. Spent decontamination solutions are stored in tanks and eventually fed to the LIC for incineration. PAS brine is also stored in tanks and then converted to dry salt in the BRA.

Sources of hazardous solid waste* include the furnace residues and dried salt from the BRA. Bulk solid wastes are generally collected in bins at the point of generation (e.g., the Heated Discharge Conveyor (HDC) carrying the ash and solid debris from the DFS) and then packaged for offsite shipment per Department of Transportation (DOT) specification. Hazardous waste disposed of offsite is packaged in DOT-approved containers.

Hazardous waste material either processed or generated during OVT included chemical agent, M55 rockets, shipping and firing tubes, propellant, projectiles' explosives, fuzes, spent decon, scrubber brine, dried salt, and incinerator ash.

Approximately 5.9 million pounds of waste was shipped from JI for disposal during OVT. The total quantity of waste shipped during each of the four tests is shown in table C-7. Note that these are the quantities shipped, and are not necessarily those wastes generated during each test period. Additionally, approximately 125,000 pounds of waste is contaminated with agent and is being held in storage for processing at JACADS after all of the munitions and

* The term "solid waste" is used to refer to waste in solid form and is not intended to have the same meaning as solid waste defined in various EPA regulations.

bulk containers are processed. The majority of this waste is used DPE suits that are being stored for future disposal. Approximately 3.4 million pounds of brine was shipped for disposal in deep wells at an approved hazardous waste disposal site in Corpus Christi, Texas. Had the BRA operated as designed, this quantity of brine could have been reduced to 509,843 pounds of salt, thereby reducing both transportation and disposal costs.

Table C-7. Wastes Shipped During Each OVT Test Period

Test	Agent-Contaminated Waste* (lb)	DFS Residue (lb)	Brine (lb)	DPE Suits (lb)	Other Waste (lb)	Total Waste (lb)
OVT1	0	330,966	883,627	0	222,550	1,437,143
OVT2	6,677	408,331	2,024,999	26,643	422,382	2,889,032
OVT3	29,337	212,910	486,716	13,551	258,979	1,001,493
OVT4	36,187	0	3,608	10,587	515,539	565,921
Total	72,201	952,207	3,398,950	50,781	1,419,450	5,893,589

*Wastes contaminated with agent that have been decontaminated (XXX level).

Approximately 16.4 pounds of waste was produced per pound of agent destroyed. If all brine that was shipped for disposal had been dried to salt, the weight of waste generated would have been 8.3 pounds per pound of agent destroyed.

Liquid Waste

During OVT2, events involving the BRA, agent tanks, and spent decon tanks indicated that the standards to prevent spills and tank overflows were not met. For example, although brine tanks are equipped with high and high-high level alarms to ensure that they were not overfilled, tank overflow occurred on two occasions because the high-high level alarms were overridden in the control room several weeks prior to the overflow events. The high-high level alarm and interlock controls to the agent holding tank were also disabled several times in November and December 1991 to allow for additional storage capacity. However, none of the incidents involving the agent holding tank resulted in agent release to the environment. As

a corrective action, the Army has discontinued the practice of disabling hazardous waste storage tank high-high alarms during normal operations.

Numerous brine management problems also occurred during OVT3. The large amounts of acid gas generated from the incineration of the agent HD in the LIC generated large amounts of brine during the neutralization of the acid gases in the main PAS. This, combined with the high processing rates of the LIC and unavailability of the BRA during the first two weeks of the test, led to the accumulation of large quantities of brine. The brine was stored in two 26,000 gallon BRA surge tanks and fifteen 5,000 gallon portable stainless steel intermodal tanks. The main PAS secondary containment was intermittently used to store brine during OVT3. This violated 40 CFR 264.194, which requires that appropriate controls and practices be used to prevent any spills or overflows from tank or containment systems.

On another occasion, the liquid (mostly accumulated rain water) in the BRA baghouse secondary containment area was pumped to the ground instead of being transferred to one of the BRA storage tanks for processing as required by the operating permit. During OVT4, 20 gallons of liquid brine containing barely hazardous concentrations of cadmium (Cd), chromium (Cr), and lead (Pb) leaked out of the drum dryer exhaust duct onto the ground; however, no environmental damage was found.

The BRA PAS is designed to remove particulates from the BRA exhaust. However, the operation of the BRA and BRA PAS was erratic. For example, brine residue (i.e., salt) was found to accumulate in the exhaust duct before reaching the PAS baghouse. During one cleanup operation, over 8,000 pounds of salt was recovered. Although not functioning correctly, the BRA and BRA PAS did not release brine residue to the environment.

Wastewater Discharge

The JACADS National Pollutant Discharge Elimination System (NPDES) permit specified limits on the flow and discharge temperature of the cooling water used by the plant, and on the temperature rise permitted in the receiving water. The NPDES permit limits are as follows: (1) 2.6 million gallons per day of wastewater discharged; (2) temperature rise of seawater used for cooling shall not be more than 15°C; (3) the temperature rise in the receiving water should be less than 1°C; and (4) effluent pH shall not be less than 6, but not more than 9.

The wastewater discharge quantity requirement was met, as was the requirement to control temperature rise below 15°C. However, the receiving water temperature rise limit of 1°C was not met during the OVT. In addition, the Army encountered problems with the collection of temperature monitoring data, which persisted until OVT ended. The receiving

water temperature rise has been shown to fluctuate more than 1°C as a result of direct sunlight, ambient air temperature, and relatively stagnant water. This necessitated an Army request to EPA for an NPDES permit modification to raise the allowable receiving water temperature limit.

Wastewater pH was measured once a week and normally was within permitted limits. However, during OVT2 a pH of 9.08 was recorded, and during OVT3 a pH of 9.36 was recorded. Both events were attributed to an out-of-calibration pH meter.

Solid Waste

Solid process wastes include the dunnage and other materials associated with the packaging of rockets, munition metal parts, the residue from each furnace, and the dried salt resulting from evaporated brine used in the PAS of each furnace. Nonprocess solid waste include rags, papers, and used DPE suits.

A major consideration in solid waste management at JACADS is the proper segregation of waste. Material that may have been contaminated with agent can either be surface-decontaminated and designated as XXX material, or can undergo thermal treatment (1000°F for 15 minutes) and be designated as XXXXX material. The XXX items are not allowed to leave government control without written authorization. The XXXXX classification indicates that any agent present has been destroyed by the thermal treatment (1000°F for 15 minutes).

The DFS HDC residue is considered XXXXX material, while the DFS cyclone residue waste stream is considered XXX. Although the Army considers the XXXXX treatment as ensuring that the material will be agent-free, the RCRA permit requires that the residue be analyzed for agent when the DFS feed changes or annually, whichever is more frequent. Laboratory testing of the HDC residue indicated no agent was present above the level of quantification. Since the cyclone residue is not subject to the minimum 1000°F for 15 minutes treatment, it is subject to chemical analysis to demonstrate that the concentration of VX or GB present is below 20 ppb, and the concentration of HD is below 200 ppb, or it will remain classified as XXX material. The JACADS RCRA permit requires that the cyclone residue be analyzed for agent when the DFS feed changes or annually, whichever is more frequent. Analysis of cyclone ash during OVT1 and OVT2 showed that no agent was present.

A number of procedural violations related to solid waste handling occurred during the OVT. The DFS cyclone residue, classified as XXX material, was shipped to a U.S. Treatment, Storage and Disposal (TSD) facility, although the Program Manager for Chemical Demilitarization (PM Cml Demil) was not authorized to dispose of XXX material, except DPE suits, in this manner. Moreover, all 11 drums of cyclone residue were shipped as

nonregulated material under RCRA even though analysis of 3 of the 11 drums indicated presence of up to 12.5 ppm leachable Cr. However, this error was identified while the drums were in transit and the necessary changes were made to the shipping manifest prior to the final disposal of the material. No hazardous material was released to the environment.

The DFS HDC residues also contain hazardous levels of Cd and Pb. The residue bins are stored on a concrete pad and, while being cooled, emissions of fugitive dust routinely occur. Runoff of hazardous material from the pad can occur during a rain storm since there are no structures in the pad to prevent such event. As a corrective measure, the Army planned to construct a roof and berm at the pad. Quantities of Cd and Pb that may be present are quite small (0.0375 to 0.0625 pounds per bin). Their release to the environment would result in minimal impact.

A release to the environment of a hazardous substance that has been designated as a reportable hazardous substance under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) must be reported to the National Response Center. CERCLA-defined hazardous substances include hazardous substances listed under the Clean Water Act, RCRA hazardous wastes, hazardous air pollutants under the CAA, and chemicals listed under Section 7 of TSCA. The hazardous substances and reportable quantities (RQs) are listed in 40 CFR 302.4. For JACADS, the RQ requirement is one pound for each of the following JACADS process wastes: (1) DFS HDC residue, (2) DFS cyclone residue, (3) dried salt, and (4) brine. The RQ applies to any consecutive 24-hour period.

During the period between 20 July 1990 and 2 August 1991, there were at least 29 reportable releases of hazardous fugitive emissions from the handling of rocket waste residues (JACADS 1991 RCRA report). None of these releases led to soil contamination.

On 7 August 1991, about 17 pounds of particulate resulting from the incineration of GB-filled rockets was released to the atmosphere. The particulate originated from the incineration ash packaging operation in the residue handling area. Although no chemical agent was released, previous analysis of the material samples indicated that they contained up to 60 ppm Cd and 62 ppm Pb (note that the RCRA threshold values are 1 ppm for Cd and 5 ppm for Pb). This release was above the CERCLA reportable quantity for hazardous wastes containing Pb. The prevailing winds dispersed the particulate toward the Red Hat area, which is a restricted access, hazardous waste storage area. The release did not lead to public exposure or measurable ground contamination.

Corrective actions taken by the Army to prevent release of hazardous fugitive emissions have been effective. For example, during OVT3, 3.5 million pounds of hazardous wastes was handled without any reportable CERCLA release.

Hazardous waste may accumulate and be stored on site for 90 days without a RCRA permit. Violations of this RCRA 90-day storage limit occurred on several occasions. For example in 1991, 51 containers of hazardous waste were accumulated and stored beyond the 90-day period. The hazardous waste included an isotainer filled with spent decontamination solution and three flexible intermediate bulk containers (FIBCs) of ash and residues from the DFS. Corrective actions instituted by the Army, such as improvements to the Waste Inventory Database and Tracking System, significantly reduced the 90-day noncompliances.

Provisions have not been made on the final disposal of empty ton containers and projectiles. At the end of OVT, they were still being stored at JI and no decision had been made on whether the projectile bodies would have to be crushed prior to disposal.

In addition to the incidents cited above, problems were also encountered with regard to use of FIBCs for HDC residue. The FIBCs had not been tested and were not DOT-authorized packaging for shipment of HDC residue. When this problem was identified, the Army stopped shipments. To be certified by DOT, the FIBCs were modified to have cardboard liners to prevent the metal rocket parts from puncturing them. Shipments were resumed upon successful DOT certification.

Most of the non-compliance at JACADS affecting the handling of liquid and solid wastes could be avoided at the planned U.S. facilities. Meeting the 90-day storage requirement should be easier because of closer proximity of hazardous waste disposal and treatment sites to the U.S. facilities, as compared to the situation at JACADS. Incidents at JACADS, occurring as a result of the inadequate operator training with regard to permit requirements, can be reduced with improved training.

C.5 OTHER ENVIRONMENTAL REQUIREMENTS

The RCRA also imposes limits on operational parameters such as furnace temperatures, as well as procedural or administrative requirements to ensure that hazardous wastes are not released to the environment. This section discusses JACADS experience in meeting these requirements and the implications it may have for the planned U.S. facilities. Another important element of a RCRA permit concerns emergency planning requirements. Sections 264.50 through 264.55 of 40 CFR 264 establish the requirements for the development of a contingency plan and emergency procedures to ensure that hazards to human health or the environment are minimized should unplanned events such as fires and explosions occur at a TSD facility.

Noncompliance with RCRA requirements did not lead to exposure of worker and the public to chemical agent and other hazardous material. The problems experienced during the OVT as they relate to other RCRA requirements not addressed in previous sections include the following:

Inspection Requirements. An audit conducted on 27 October 1991 indicated that the facility was not being maintained in accordance with regulatory requirements. Many of the inspection requirements in the permit were based on inaccurate description of the plant process equipment. Thus, RCRA permit modifications were made to establish revised inspection schedules that are more in line with the plant equipment configuration.

Record Keeping and Reporting. Copies of waste analyses, test results, and other records used in determining hazardous waste classifications were not filed in a central location. Process and non-process wastes were not tracked in the same level of detail as the chemical agent inventory. The inadequate number of flow meters in the PASs and the BRA contributed to inaccurate records of material stored and processed in the BRA. Transfers between brine storage containers and temporary portable containers were also poorly recorded.

Personnel Training. Although the Operations and Maintenance Contractor (OMC) has full-time training staff on JI, compliance with the administrative portion of RCRA training requirements—such as maintaining job titles and duties, and detailed descriptions of individual courses—was not fully accomplished during the early part of the OVT. Record keeping problems experienced in the BRA could also be attributed to the fact that the BRA training program insufficiently prepared the operators for tracking hazardous waste properly and uniformly. The Army has revised its training requirements, which EPA approved on 14 October 1992.

Stopping Agent Feed. During the HD TC test, in one isolated instance, the agent feed to the LIC was not stopped, either manually or with the required feed interlock, when the temperature of the LIC primary chamber dropped 5°C below the permitted low temperature limit. The secondary chamber remained at the required temperature (2000°F) during this period. The problem arose from an inadvertent removal of the interlock. Data showed that no agent was emitted. On another occasion, during the HD TC test, agent feed to the LIC was not stopped after an alarm was received indicating that the Process Data Acquisition and Recording System was no longer collecting data. While the parameters were still being monitored for alarm conditions, some of the data were not recorded for about 30 minutes.

Based on the JACADS experience, the procedural and administrative noncompliances were more prevalent during the early part of the OVT. The corrective actions taken by the Army in response to the RCRA noncompliances cited above have led to a significant

reduction of these noncompliances. Thus, there is sufficient basis to believe that the U.S. facilities would not have serious difficulty in addressing similar problems.

No problems were encountered at JACADS that could raise significant question concerning any aspects of the facility's emergency response plan. However, this issue is difficult to assess since states' approaches for implementing this requirement vary. The types of munitions handled, the logistics of moving munitions from storage to the MDB, and the different organizations (including state agencies) involved in an emergency are but a few of the factors that will have to be considered in the development of emergency response and emergency control programs for each U.S. site.

C.6 EPA AUDITS

Compliance with the environmental regulations has been a top priority for the Chemical Stockpile Disposal Program. The administrative requirements for a TSD are extensive. Compliance with these requirements has improved steadily throughout OVT. There have been only two Notices of Violation (NOVs) issued to the office of the PM Cml Demil following audits by the EPA.

An NOV was received following the 1990 EPA audit that cited three deficiencies, which included storing non-permitted waste in the spent decontamination solution tanks, storing a drum of waste for more than 90 days, and failing to complete inspections specified in Attachment F of the RCRA operating permit. The first two deficiencies were easily corrected, but some of the Attachment F inspections are still not being performed.

On 21 December 1992, the Army received an NOV from the EPA that cited JACADS for accumulating waste beyond 90 days at some of the satellite accumulation areas. The Army and the EPA inspector interpreted the regulations differently and the Army has submitted justification to the EPA for its interpretation. The EPA concurred with the Army's position (EPA letter to PM Cml Demil, 22 March 1993).

APPENDIX D

THROUGHPUT CALCULATION

Different performance measures show different aspects of operation. These are derived by computing production over different time periods. The plant is in different states at different times:

- Available—The plant is available for immediate operation. Available time may be during scheduled operation or at night during standby.
- Down—The plant is not operable because of some problem. During OVT, downtimes of longer than 15 minutes were identified as documented downtimes. Shorter downtimes were not individually counted, but were shown as slowdowns during operations, and are referred to in this report as "undocumented downtimes".
- Operating—The plant was demilitarizing munitions. In general, an hour with at least one rocket destroyed was considered an operating hour.

Process data were adjusted to a 24-hour basis by assessing the operating and downtime performance for each day. The ratio of downtime associated with each hour of operating time (i.e., hours without documented downtime) was computed. The remaining hours of the 24-hour day, when the plant was available for operation (i.e., not actually operating or under repair or maintenance) were then allocated to operating and downtime with the same ratio, and a theoretical 24-hour production was computed.

A problem in this process is how to count downtimes that occur outside the scheduled hours of operation. If such a downtime is caused by munition processing, it should be counted as a downtime and will directly reduce the day's throughput. However, if it simply occurs as the result of the passage of time, it should not be counted as a downtime. In both cases, it will have the effect of removing time the plant is available for operation. Since it is often very difficult to distinguish the precise cause of a downtime, the 24-hour basis was computed assuming that the downtime outside of scheduled hours of operation was caused by the passage of time only. If the contrary assumption is made, the projected throughput will be smaller.

As with any projection technique, there are a variety of factors that affect the results, in addition to those explicitly stated. Some of these make the projection optimistic (i.e., high), while others likely make the projection pessimistic (i.e., low). These factors and assumptions include the following:

- An assumption inherent in the calculation of the 24-hour basis is that the proportion of time in operation and downtime will remain the same, even as the hours per day of operation are extended. This may be pessimistic, since a real attempt to operate on a 24-hour basis will reduce downtime associated with turning equipment on and off. In addition, the proportion of downtime associated with failures resulting from the sheer passage of time (in contrast to destroying munitions) will be reduced. On the other hand, an increased amount of operation may generate new failure modes not so far seen. More intense operation may also increase the relative rates of certain failures.
- A second set of assumptions in the 24-hour basis calculation involves how maintenance to the demilitarization equipment is performed. During OVT, preventive maintenance was performed during the night (off shift), or in some cases, in association with corrective maintenance. However, in full 24-hour U.S. plant operation, there would not be scheduled routine maintenance except for weekends. While preventive maintenance could be conducted in connection with corrective maintenance, the degree to which this will be possible is not clear. The projections performed here assumed that the time now spent in preventive maintenance will continue (and will thereby contribute to downtime).
- Some outages or downtime occurred at the end of the day's operation, or at night while no operation was being attempted. While MITRE recorded the time of the outage and its correction, it is likely that on some occasions the maintenance staff did not move as quickly as they might have to correct the problem (since processing was not being adversely affected). A review of the data indicated that this appears to have a relatively small effect, but it would make the projection pessimistic.
- Another assumption is that the selected baseline was fully representative of long-term operation. While five weeks is a substantial period and includes a variety of problems, it is likely that a longer operation would have demonstrated other problems. On the other hand, some of the problems seen would likely be corrected (lessons learned).

Beyond the specific implicit assumptions in the projections, is the basic assumption that the overall OVT period was long enough to bring forth all the operating problems and the best solutions for them. In fact, although the calendar period of OVT1 and OVT2 extended over about 84 weeks, in only about 26 weeks did actual operations take place (i.e., about six months). A substantial body of experience in industry (including the closely-related chemical

industry), shows that most prototype plants do not achieve their design goals until two to five years of operation have passed.

APPENDIX E

LIST OF REFERENCES

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GLOSSARY

ACAMS	Automatic Continuous Air Monitoring System
AQS	Agent Quantification System
ASC	Allowable Stack Concentration
ANAD	Anniston Army Depot
BDS	Bulk Drain Station
BRA	Brine Reduction Area
CAA	Clean Air Act
CAMDS	Chemical Agent Munitions Disposal System
CDTF	Chemical Demilitarization Training Facility
CEM	Continuous Emissions Monitor
CO	Carbon Monoxide
CWA	Clean Water Act
CWDA	Cases With Days Away
DAAMS	Depot Area Air Monitoring System
DFS	Deactivation Furnace System
DHHS	Department of Health and Human Services
DOT	Department of Transportation
DPE	Demilitarization Protective Ensemble
DRE	Destruction and Removal Efficiency
DUN	Dunnage Incinerator
ECR	Explosion Containment Room
ECV	Explosion Containment Vestibule
EPA	U.S. Environmental Protection Agency
FIBC	Flexible Intermediate Bulk Container
GB	Nerve Agent
GPL	General Population Limit
gr/dscf	Grains per dry standard cubic feet
H/HD	Blister Agents
HCl	Hydrochloric Acid
HDC	Heated Discharge Conveyor

HMTA	Hazardous Materials Transportation Act
HVC	Heating, Ventilation, and Cooling
JACADS	Johnston Atoll Chemical Agent Disposal System
JI	Johnston Island
LIC	Liquid Incinerator
LOQ	Limit of Quantification
MDB	Munitions Demilitarization Building
MDM	Multipurpose Demilitarization Machine
mg/dscm	milligrams per dry normal cubic meter
MPB	Munitions Processing Bay
MPF	Metal Parts Furnace
ng/m ³	nanograms per cubic meter
NPDES	National Pollutant Discharge Elimination System
NOV	Notice of Violation
NO _x	Nitrogen Oxides
OVT	Operational Verification Testing
P/hr	Projectiles per hour
PAS	Pollution Abatement System
PBA	Pine Bluff Arsenal
PCB	Polychlorinated Biphenyl
PM Cml Demil	Program Manager for Chemical Demilitarization
PMD	Projectile/Mortar Disassembly Machine
POHC	Principal Organic Hazardous Constituent
ppb	parts per billion
ppm	parts per million
PSD	Prevention of Significant Deterioration
PUDA	Pueblo Depot Activity
R/hr	Rockets per hour
RCRA	Resource Conservation and Recovery Act
RHA	Residue Handling Area
RQ	Reportable Quantity
RSM	Rocket Shear Machine

SOP	Standing Operating Procedure
SO_x	Sulfur Oxides
TAR	Temporary Authorization Request
T-BACT	Toxic Best Available Control Technology
TOCDF	Tooele Chemical Demilitarization Facility
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage, or Disposal
UMDA	Umatilla Depot Activity
VX	Nerve Agent